AMERICAN COLLEGE of SPORTS MEDICINE
LEADING THE WAY

ACSM'S Guidelines for Exercise Testing and Prescription

Eleventh Edition

Wolters Kluwer

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Guidelines for Exercise Testing and Prescription

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DISCLAIMER

This book is dedicated to the hundreds of volunteer professionals who have, since 1975, contributed thousands of hours developing these internationally adopted Guidelines. Now in its 11th edition, it is the most widely circulated set of guidelines established for exercise professionals. This edition is dedicated to the editors, the writing teams, and the reviewers of this and previous editions who have not only provided their collective expertise but also sacrificed precious time with their colleagues, friends, and families to make sure that these Guidelines meet the highest standards in both science and practice.

INTRODUCTION

The American College of Sports Medicine (ACSM) *Guidelines* origins are within the ACSM Committee on Certification and Registry Boards (CCRB, formerly known as the Certification and Education Committee and the Preventive and Rehabilitative Exercise Committee). Today, the *Guidelines* are reviewed by a combination of certified professionals and content experts to provide the most relevant information to individuals who conduct exercise testing or develop exercise programs. The *Guidelines* provide the foundation of content for its supporting companion texts produced by ACSM, which include the sixth edition of *ACSM's Certification Review*, sixth edition of *ACSM's Resources for the Personal Trainer*, third edition of *ACSM's Resources for the Exercise Physiologist*, sixth edition of *ACSM's Fitness Assessment Manual* (previously titled, *ACSM's Health-Related Physical Fitness Assessment Manual*), and several other key ACSM titles.

The first edition of the *Guidelines* was published in 1975, with updated editions published approximately every 4–6 yr. The outstanding scientists and clinicians who have served in leadership positions as chairs and editors of the *Guidelines* since 1975 are: First Edition, 1975

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Foreword

The 11th edition of the *ACSM's Guidelines for Exercise Testing and Prescription* represents nearly 50 yr since the inception of the very first *Guidelines* in 1975. In recognition of all that has evolved since, Dr. Barry Franklin, PhD, FACSM, ACSM Past President and Senior Editor of the sixth edition of the *Guidelines* (circa 2000), has prepared this "Foreword," briefly describing the evolution of the *Guidelines*.

EVOLUTION OF THE ACSM GUIDELINES: BARRY FRANKLIN, PHD, FACSM

Several early lay and professional publications played a key role in igniting worldwide interest in exercise training and prescription for promoting health and preventing and treating chronic disease. These seminal works and a special interest group meeting on cardiac rehabilitation at the Annual Meeting of the American College of Sports Medicine (ACSM) held in Philadelphia on May 2, 1972, provided the impetus for the ACSM to undertake the writing and serial publication of *ACSM Guidelines* to assist the many new disciplines who were starting exercise programs. A special subcommittee was formed, co-chaired by Karl G. Stoedefalke, PhD, FACSM and John A. Faulkner, PhD, FACSM to develop guidelines for graded exercise testing and exercise prescription for both healthy and unhealthy individuals. Additional members of the writing team for the first edition of *ACSM's Guidelines for Graded Exercise Testing and Exercise*

Prescription included Samuel M. Fox, MD, Henry S. Miller, Jr., MD, and Bruno Balke, MD.

This eleventh edition of *ACSM's Guidelines for Exercise Testing and Prescription* represents another step in the evolution of this manual first published by the ACSM in 1975. A volume that began as a concise summary of research-based and empirically derived recommendations for exercise testing and prescription, primarily in cardiac individuals, has now become one of the most single widely read and referenced texts of its kind in the world (~100,000 copies of the 10th edition have been sold), and a virtual pharmacopoeia of exercise guidelines for a broad spectrum of individuals.

Reflecting back nearly two decades to the sixth edition of the *Guidelines*, numerous subsequent scientific/clinical publications, statements, position stands, Federal guidelines, and consensus development conferences have emphasized new knowledge and insights relative to the diagnostic/prognostic role of exercise testing and moderate-to-high intensity physical activity (PA) in preventing and treating chronic diseases.

Although numerous reports have emphasized that physical inactivity represents a leading cause of death worldwide, the beneficial effects of regular exercise, increased lifestyle PA, or both, are generally underestimated by many clinicians and the public at large. Consequently, the burden of physical inactivity continues to grow with escalating technologic advances, suboptimal community landscape planning, and inadequate emphasis during most clinical encounters. The latter, that is, not considering habitual PA as a "vital sign," represents missed opportunities to counsel individuals using proven behavioral interventions to combat our increasingly hypokinetic environment. Related strategies or interventions may include recommending community, home, or clinically based exercise programs, as well as advocating antidotal technology, including pedometers, accelerometers, smartphone apps, and heart rate monitors.

Behavioral lifestyle choices are consistently reported to be the single greatest determinant of premature death, approximating genetic predisposition, social circumstances, environmental exposure, and health care access combined. Indeed, common characteristics of the world's longest living populations (*e.g.*, Sardinians, Adventists, Okinawans) include daily PA. It has been suggested that "a prescription to walk 30 min $\cdot$ d^{-1} could be one of the most important prescriptions an individual could receive." Clinicians, allied health, and exercise professionals play a trusted and influential role in providing needed care and counsel to individuals and can offer a powerful nudge in getting people more active. These efforts should be complemented by making self-responsibility (*e.g.*, meeting certain health metrics, such as regular PA) a greater priority in the evolving health care coverage environment. Perhaps, Joseph Alpert, MD, summed it up best, when asked by friends or family, "How often should I exercise?" he replied, "Only on the days you eat."

In conclusion, the 11th edition of *ACSM's Guidelines for Exercise Testing and Prescription*, the most comprehensive *Guidelines* to date, continues with an emphasis on the benefits of moderate-to-high intensity PA as well as relevant prescriptive considerations. The authors, editors, and reviewers are to be highly commended on this unique and invaluable resource which, no doubt, will have a profound and favorable impact on "helping people help themselves" in achieving better health outcomes.

Preface

The 11th edition of *ACSM's Guidelines for Exercise Testing and Prescription* will continue the efforts of the editors and contributing authors of recent editions to make it a true *Guidelines* book rather than a sole and inclusive *resource*. It was the original intent of the *Guidelines* to be user-friendly, easily accessible, and a current primary resource for exercise and other health professionals who conduct exercise testing and exercise programs. To this effect, in this edition, text descriptions have been minimized; more tables, boxes, and figures have been included; and key Web sites conclude each chapter.

The reader of this edition of *ACSM's Guidelines for Exercise Testing and Prescription* will notice several innovations. The 11th edition of the *Guidelines* presents a new chapter focused on the role of exercise in conditions that affect the brain. This chapter includes conditions previously in the *Guidelines* (*e.g.*, Parkinson) along with conditions new to the *Guidelines* (*i.e.*, Alzheimer's, autism, depression, and anxiety). Some of the book content has been reorganized to make it easier to locate information quickly. Finally, there was a substantial increase in the number of external reviewers. In addition to chapter reviewers, the 11th edition used content expert reviewers for specific sections when chapters contained subsections. We have integrated the most recent guidelines and recommendations available from ACSM position stands and other relevant professional organizations' scientific statements, including the *2018 Physical Activity Guidelines for Americans*, so that the *Guidelines* are the most current, primary resource for exercise testing and prescription. It is important for the readership to know that new themes and innovations included in the 11th edition were developed with input from the ACSM membership prior to the initiation of this project via an electronic survey and focus groups conducted at the 2018 ACSM Annual Meeting that asked respondents and individuals, respectively, for their suggestions regarding the content.

Any updates made in this edition of the *Guidelines* after their publication and prior to the publication of the next edition of the *Guidelines* can be accessed from the ACSM website (https://www.acsm.org/get-stay-certified/get-certified/prepare-for-exams/acsm-book-updates). Furthermore, the reader is referred to the ACSM Get Certified link for a listing of ACSM Certifications at https://www.acsmcertification.org/get-certified and to https://www.acsm.org/get-stay-certified/get-certified/prepare-for-exams/exam-content-outlines for detailed exam content outlines.

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First and foremost, this book could not have been completed without the patience, expertise, guidance, and friendship of Angie Chastain, ACSM Development Editor, and Katie Feltman, ACSM Chief Operating Officer. We would also like to acknowledge the extraordinary work of the ACSM Publications Committee and its Chair, Jeffrey Potteiger, and for entrusting in us with the *Guidelines*.

We are in great debt to the contributing authors of the 11th edition of the *Guidelines* for volunteering their expertise and valuable time to ensure the *Guidelines* meet the highest standards in exercise science and practice. It was my personal honor to work with each and every contributor. The *Guidelines* review process undergoes many layers of expert scrutiny to ensure the highest quality of content, and we thank the many reviewers for their careful reviews of the 11th edition.

We thank our publisher, Wolters Kluwer, and in particular Michael Nobel, Director of Publishing and Editorial; Amy Millholen, Senior Development Editor; and Phyllis Hitner, Marketing Manager.

On a personal note, I thank my three associate editors, Drs. Yuri Feito, Charles (Chuck) Fountaine, and Brad A. Roy. As much as I value their expertise and direction, it is their friendship, collaboration, and camaraderie that I will always cherish. They have embodied the essence of teamwork in our collective effort to maintain the highest standards for the *Guidelines*.

And, of course, no acknowledgment would be complete without expressing my deep and everlasting love for my wife, Heidi Bills, and our three amazing children, Noah, Autumn, and Zoe, who all inspire me each and every day. Dream big, the stars are yours to reach.

Gary Liguori, PhD, FACSM
Senior Editor

ADDITIONAL RESOURCES

ACSM's Guidelines for Exercise Testing and Prescription, Eleventh Edition, includes additional resources for instructors that are available on the book's companion Web site at http://thepoint.lww.com/.

Instructors Approved adopting instructors will be given access to the following additional resources: ■ Test bank ■ PowerPoint presentations ■ Image bank ■ Course cartridges Nota Bene The views and information contained in the 11th edition of *ACSM's Guidelines for Exercise Testing and Prescription* **are provided as guidelines — as opposed to** *standards of practice*. **This distinction is an important one because specific legal connotations may be attached to standards of practice that are not attached to guidelines. This distinction is critical inasmuch as it gives the professional in exercise testing and programmatic settings the freedom to deviate from these guidelines when necessary and appropriate in the course of using independent and prudent judgment.** *ACSM's Guidelines for Exercise Testing* *and Prescription* **presents a framework whereby the professional may certainly — and in some cases has the obligation to — tailor to individual needs while balancing institutional or legal requirements.**

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Abbreviations

AACVPR	American Association of Cardiovascular and Pulmonary Rehabilitation
ABI	ankle/brachial pressure index
ACC	American College of Cardiology
ACE-I	angiotensin-converting enzyme inhibitors
ACS	Acute coronary syndrome
ACSM	American College of Sports Medicine
ACSM-CEP	ACSM Certified Clinical Exercise Physiologist
ACSM-CPT	ACSM Certified Personal Trainer
ACSM-EP	ACSM Certified Exercise Physiologist
ACSM-GEI	ACSM Certified Group Exercise Instructor
ADL	activities of daily living
ADT	androgen deprivation therapy
AEDs	automated external defibrillators
AHA	American Heart Association
AHFS	American Hospital Formulary Service
AIDS	acquired immunodeficiency syndrome
AMI	acute myocardial infarction
AMS	acute mountain sickness
ARBs	angiotensin II receptor blockers
ART	antiretroviral therapy
AS	ankylosing spondylitis
ATP III	Adult Treatment Panel III
AV	atrioventricular
BIA	bioelectrical impedance analysis
BMD	bone mineral density
BMI	body mass index
BMT	bone marrow transplantation
BP	blood pressure

CABG(S)	coronary artery bypass graft (surgery)
CAD	coronary artery disease
CCB	calcium channel blockers
CDC	Centers for Disease Control and Prevention
CHF	congestive heart failure
CKD	chronic kidney disease
CM	cardiomyopathy
CNS	central nervous system
COPD	chronic obstructive pulmonary disease
CP	cerebral palsy
CPET	cardiopulmonary exercise test
CPR	cardiopulmonary resuscitation
CR	cardiac rehabilitation
CRF	cardiorespiratory fitness
CVD	cardiovascular disease
CWR	constant work rate
Db	body density
DBP	diastolic blood pressure
DBS	deep brain stimulation
DM	diabetes mellitus
DOMS	delayed onset muscle soreness
DS	Down syndrome
DVR	dynamic variable resistance
DXA	dual-energy X-ray absorptiometry
EAS	European Atherosclerosis Society
ECG	electrocardiogram (electrocardiographic)
EDSS	Kurtzke Expanded Disability Status Scale
EE	energy expenditure

EI	energy intake
EIB	exercise-induced bronchoconstriction
ESRD	end-stage renal disease
ETT	exercise tolerance test
Ex R_x	exercise prescription
FES-LCE	functional electrical stimulation-leg cycle ergometry
$FEV_{1.0}$	forced expiratory volume in one second
FFBd	fat-free body density
FFM	fat-free mass
FITT	Frequency, Intensity, Time, Type
FM	fat mass
FN	false negative
FP	false positive
FPG	fasting plasma glucose
FRAX	Fracture Risk Algorithm
FRIEND	Fitness Registry and the Importance of Exercise National Database
FVC	forced vital capacity
GFR	glomerular filtration rate
GOLD	Global Initiative for Chronic Obstructive Lung Disease
GXT	graded exercise test
HACE	high-altitude cerebral edema
HAPE	high-altitude pulmonary edema
HbA1C	glycolated hemoglobin
HBM	health belief model
HDL-C	high-density lipoprotein cholesterol
HFpEF	heart failure with preserved ejection fraction
HFrEF	heart failure with reduced ejection fraction

HIIT	high intensity interval training
HIPAA	Health Insurance Portability and Accountability Act
HIV	human immunodeficiency virus
HMG-CoA	hydroxymethylglutaryl-coenzyme A
HR	heart rate
HR_{max}	maximal heart rate
HR_{peak}	peak heart rate
HRR	heart rate reserve
HR_{rest}	resting heart rate
HSCT	hematopoietic stem cell transplantation
ICD	implantable cardioverter defibrillator
ID	intellectual disability
IDF	International Diabetes Federation
IFG	impaired fasting glucose
IGT	impaired glucose tolerance
IHD	ischemic heart disease
IMT	inspiratory muscle training
ISH	International Society of Hypertension
IVCD	intraventricular conduction delay
JTA	job task analysis
KSs	knowledge and skills
LABS	Longitudinal Assessment of Bariatric Surgery
LBP	low back pain
LDL-C	low-density lipoprotein cholesterol
L-G-L	Lown-Ganong-Levine
LVAD	left ventricular assist device
LVEF	left ventricular ejection fraction
LVH	left ventricular hypertrophy

MAP	mean arterial pressure
MET	metabolic equivalent
Metsyn	metabolic syndrome
MI	myocardial infarction
MS	multiple sclerosis
MSI	musculoskeletal injury
MVC	maximal voluntary contraction
6-MWT	6-min walk test
NCEP	National Cholesterol Education Program
NFCI	nonfreezing cold injuries
NHANES	National Health and Nutrition Examination Survey
NHLBI	National Heart, Lung, and Blood Institute
NOTF	National Obesity Task Force
NSAIDs	nonsteroidal anti-inflammatory drugs
NYHA	New York Heart Association
OA	osteoarthritis
OGTT	oral glucose tolerance test
OUES	oxygen uptake efficiency slope
PA	physical activity
PAD	peripheral artery disease
P_aCO_2	partial pressure of carbon dioxide
PAH	pulmonary arterial hypertension
P_aO_2	partial pressure of arterial oxygen
PAR-Q+	Physical Activity Readiness Questionnaire for Everyone
PCI	percutaneous coronary intervention
PD	Parkinson disease
PG	plasma glucose
PNF	proprioceptive neuromuscular facilitation

PR	pulmonary rehabilitation
PVC	premature ventricular contraction
$\dot{Q}$	cardiac output
QTc	QT corrected for heart rate
RA	rheumatoid arthritis
RER	respiratory exchange ratio
RHR	resting heart rate
1-RM	one repetition maximum
ROM	range of motion
RPE	rating of perceived exertion
RVH	right ventricular hypertrophy
SaO_2	percent saturation of arterial oxygen
SBP	systolic blood pressure
SCD	sudden cardiac death
SCI	spinal cord injury
SCT	social cognitive theory
SD	standard deviation
SDT	self-determination theory
SEE	standard error of the estimate
SEM	social ecological model
SIT	sprint interval training
SpO_2	percent saturation of arterial oxygen
SPPB	Short Physical Performance Battery
T1DM	Type 1 diabetes mellitus
T2DM	Type 2 diabetes mellitus
TG	triglycerides
THR	target heart rate
TN	true negative

TP	true positive
TPB	theory of planned behavior
TTM	transtheoretical model
VAT	ventilatory-derived anaerobic threshold
$\dot{V}CO_2$	**volume of carbon dioxide per minute**
$\dot{V}E$	expired ventilation per minute
VF	ventricular fibrillation
$\dot{V}O_2$	**volume of oxygen consumed per minute**
$\dot{V}O_{2max}$	maximal volume of oxygen consumed per minute (maximal oxygen uptake, maximal oxygen consumption)
$\dot{V}O_{2peak}$	peak oxygen uptake
$\dot{V}O_2R$	oxygen uptake reserve
$\%\dot{V}O_2R$	percentage of oxygen uptake reserve
VT	ventilatory threshold
WBGT	wet-bulb globe temperature
WCT	Wind Chill Temperature Index
WHR	waist-to-hip ratio
W-P-W	Wolff-Parkinson-White

Benefits and Risks Associated with Physical Activity

CHAPTER 1

INTRODUCTION

This chapter summarizes information regarding the benefits and risks of physical activity (PA) and/or exercise. Additional information related to the benefits of PA and exercise specific to a disease, disability, or health condition are explained within the respective chapters of this edition of the guidelines. PA continues to take on an increasingly important role in the prevention and treatment of multiple chronic diseases0 health conditions, and their associated risk factors. Thus, this chapter focuses on the public health perspective that forms the basis for the current PA recommendations (1–6). Additionally, this chapter concludes with recommendations for reducing the incidence and severity of exercise-related complications for primary and secondary prevention programs.

PHYSICAL ACTIVITY AND FITNESS TERMINOLOGY

PA and exercise are often used interchangeably; however, these terms are not synonymous. *PA* is defined as any bodily movement produced by the contraction of skeletal muscles that results in an increase in caloric requirements over resting energy expenditure (7). *Exercise*, on the other hand, is a type of PA consisting of planned, structured, and repetitive bodily movement done to improve and/or maintain one or more components of physical fitness (7). *Physical fitness*, although defined in several ways, has generally been described as a set of attributes or characteristics individuals have or achieve that relate to their ability to perform PA and activities of daily living (7). These attributes or characteristics are commonly separated into health- and skill-related components of physical fitness. Nonetheless, recent evidence suggests these components of physical fitness may not be mutually exclusive, as several skill-related components can be important for achieving health goals and therefore should be incorporated when designing exercise prescription programs with different populations (*e.g.*, power and balance activities with older adults) (*Box 1.1*).

Box 1.1 Health- and Skill-Related Components of Physical Fitness

Health-Related Physical Fitness Components

- Cardiorespiratory endurance: the ability of the circulatory and respiratory system to supply oxygen during sustained physical activity
- Body composition: the relative amounts of muscle, fat, bone, and other vital parts of the body
- Muscular strength: the ability of muscle to exert force
- Muscular endurance: the ability of muscle to contue to perform without fatigue
- Flexibility: the range of motion available at a joint

Skill-Related Physical Fitness Components

- Agility: the ability to change the position of the body in space with speed and accuracy
- Coordination: the ability to use the senses, such as sight and hearing, together with body parts in performing tasks smoothly and accurately
- Balance: the maintenance of equilibrium while stationary or moving
- Power: the ability or rate at which one can perform work
- Reaction time: the time elapsed between stimulation and the beginning of the reaction to it
- Speed: the ability to perform a movement within a short period of time

Adapted from (7).

In addition to defining PA, it is important to clearly define the wide range of intensities associated with PA (see *Table 5.2*) and with different methods for estimating intensities, which includes percentage of oxygen uptake reserve ($\dot{V}O_2R$), heart rate reserve (HRR), volume of oxygen consumed per minute ($\dot{V}O_2$), heart rate (HR), or metabolic equivalents (METs; see *Box 5.2* and *Appendix D*). Several chapters throughout the guidelines provide the methodology and guidance for selecting a suitable estimation method based on individual circumstances.

METs are a useful, convenient, and standardized method for quantifying the absolute intensity of various behaviors and activities. Among adults, light intensity PA is defined as 1.6–2.9 METs, moderate as 3.0–5.9 METs, and vigorous as ≥6.0 METs (6). *Table 1.1* gives specific examples of MET values for activities in each of the described intensity ranges. A comprehensive catalog of absolute intensity values for various behaviors and activities can be found in the Compendium of Physical Activities (8).

TABLE 1.1 • Metabolic Equivalents (METs) Values of Common Physical Activities Classified as Light, Moderate, or Vigorous Intensity

Light (1.6–2.9 METs)	Moderate (3.0–5.9 METs)	Vigorous (≥6.0 METs)
Walking	**Walking**	**Walking, jogging, and running**
Walking slowly around home, store, or office = 2.0[a]	Walking 3.0 mi · h^{-1} = 3.0[a]	Walking at very, very brisk pace (4.5 mi · h^{-1}) = 6.3[a]
	Walking at very brisk pace (4 mi · h^{-1}) = 5.0[a]	Walking/hiking at moderate pace and grade with no or light pack (<10 lb) = 7.0
		Hiking at steep grades and pack 10–42 lb = 7.5–9.0
		Jogging at 5 mi · h^{-1} = 8.0[a]
		Jogging at 6 mi · h^{-1} = 10.0[a]
		Running at 7 mi · h^{-1} = 11.5[a]
Household and occupation	**Household and occupation**	**Household and occupation**
Standing performing light work, such as making bed, washing dishes, ironing, preparing food, or store clerk = 2.0–2.5	Cleaning, heavy — washing windows, car, clean garage = 3.0	Shoveling sand, coal, etc. = 7.0
	Sweeping floors or carpet, vacuuming, mopping = 3.0–3.5	
	Carpentry — general = 3.6	
	Carrying and stacking wood = 5.5	
	Mowing lawn — walk power mower = 5.5	
Leisure time and sports	**Leisure time and sports**	
Billiards = 2.5		
Boating — power = 2.5		
Croquet = 2.5		
Darts = 2.5		
Fishing — sitting = 2.5		
Playing most musical instruments = 2.0–2.5		

	Badminton — recreational = 4.5 Basketball — shooting around = 4.5 Dancing — ballroom slow = 3.0; ballroom fast = 4.5 Fishing from riverbank and walking = 4.0 Golf — walking, pulling clubs = 4.3 Sailing boat, wind surfing = 3.0 Table tennis = 4.0 Tennis doubles = 5.0 Volleyball — noncompetitive = 3.0–4.0	Carrying heavy loads, such as bricks = 7.5 Heavy farming, such as bailing hay = 8.0 Shoveling, digging ditches = 8.5 **Leisure time and sports** Bicycling on flat — light effort (10–12 mi · h^{-1}) = 6.0 Basketball game = 8.0 Bicycling on flat — moderate effort (12–14 mi = h^{-1}) = 8.0; fast (14–16 mi · h^{-1}) = 10.0 Skiing cross-country — slow (2.5 mi · h^{-1}) = 7.0; fast (5.0–7.9 mi · h^{-1}) = 9.0 Soccer — casual = 7.0; competitive = 10.0 Swimming leisurely = 6.0[b]; swimming — moderate/hard = 8.0–11.0[b] Tennis singles = 8.0 Volleyball — competitive at gym or beach = 8.0

[a]On flat, hard surface.

[b]MET values can vary substantially from individual to individual during swimming as a result of different strokes and skill levels.

Adapted from (8–10).

Because of age-related declines in maximal aerobic capacity (4,11), when older and younger individuals work at the same MET level, the relative exercise intensity (*e.g.*, %$\dot{V}O_{2max}$) will usually be different (see *Chapter 5*). In other words, the older individual will be working at a greater relative percentage of maximal oxygen consumption ($\dot{V}O_{2max}$) than their younger counterparts. Nonetheless, physically active older adults may have aerobic capacities comparable to or greater than those of physically inactive younger adults. This relationship will be similar when comparing individuals with different fitness levels, where those with lower $\dot{V}O_{2max}$ will work at a higher percentage of their maximal ability compared to their more fit counterparts at the same absolute MET value.

PUBLIC HEALTH PERSPECTIVE FOR CURRENT RECOMMENDATIONS

More than 20 yr ago, the American College of Sports Medicine (ACSM), in conjunction with the Centers for Disease Control and Prevention (CDC) (12), the U.S. Surgeon General (13), and the National Institutes of Health (14), issued landmark publications on PA and health. An important goal of these reports was to clarify for exercise professionals and the public the amount and intensity of PA needed to improve health, lower susceptibility to disease (morbidity), and decrease premature mortality (12–14). In addition, these reports documented the dose-response relationship between PA and health (*i.e.*, some activity is better than none, and more activity, up to a point, is better than less).

In 1995, the CDC and ACSM recommended that "every U.S. adult should accumulate 30 minutes or more of moderate physical activity on most, preferably all, days of the week" (12). This recommendation was quickly followed in 1996 by the *Physical Activity and Health: A Report of the Surgeon General*, a landmark report detailing the myriad health benefits associated with regular PA (13). Collectively, the intent of these statements was to increase public awareness of the health-related benefits of moderate intensity PA. As a result of an increasing awareness of the adverse health effects of physical inactivity and because of some confusion and misinterpretation of the original PA recommendations, the ACSM and American Heart Association (AHA) issued updated recommendations for PA and health in 2007 (*Box 1.2*) (3).

Box 1.2 The ACSM–AHA Primary Physical Activity Recommendations (3)

- All healthy adults aged 18–65 yr should participate in moderate intensity aerobic PA for a minimum of 30 min on 5 $d \cdot wk^{-1}$ or vigorous intensity aerobic activity for a minimum of 20 min on 3 $d \cdot wk^{-1}$.
- Combinations of moderate and vigorous intensity exercise can be performed to meet this recommendation.

- Moderate intensity aerobic activity can be accumulated to total the 30 min minimum by performing bouts each lasting ≥10 min.
- Every adult should perform activities that maintain or increase muscular strength and endurance for a minimum of 2 $d \cdot wk^{-1}$.
- Because of the dose-response relationship between PA and health, individuals who wish to further improve their fitness, reduce their risk for chronic diseases and disabilities, and/or prevent unhealthy weight gain may benefit by exceeding the minimum recommended amounts of PA.

ACSM, American College of Sports Medicine; AHA, American Heart Association.

Shortly after the publication of the joint ACSM and AHA recommendations, the federal government convened an expert panel, the 2008 Physical Activity Guidelines Advisory Committee (15), to review the scientific evidence on PA and health published since the 1996 U.S. Surgeon General's Report (13). This committee found compelling evidence regarding the benefits of PA for health as well as the presence of a dose-response relationship for many diseases and health conditions. The 2008 Physical Activity Guidelines Advisory Committee provided the *Physical Activity Guidelines Advisory Committee Report* (15), which resulted in two important conclusions that influenced the development of subsequent PA recommendations:

1. Important health benefits can be obtained by performing a moderate amount of PA on most, if not all, days of the week.
2. Additional health benefits result from greater amounts of PA. Individuals who maintain a regular program of PA that is longer in duration, of greater intensity, or both are likely to derive greater benefit than those who engage in lesser amounts.

These recommendations from the *Physical Activity Guidelines Advisory Committee Report* ultimately resulted in the *2008 Physical Activity Guidelines for Americans*, which were the first comprehensive guidelines related to PA published by the Federal government (see https://health.gov/paguidelines/2008/) (5).

After a decade of research and implementation of the *Physical Activity Guidelines*, the federal government convened another expert panel, the 2018 Physical Activity Guidelines Advisory Committee (16), to further review the scientific evidence on PA and health published since the *2008 Physical Activity Guidelines for Americans* (5) were released. The committee identified further evidence supporting the beneficial effects of PA for health. Beyond attenuating chronic disease risks, additional conclusions regarding the benefits of PA for health from the *2018 Physical Activity Guidelines Advisory Committee Scientific Report* include, but are not limited to, the following:

1. For those who are inactive, PA of any intensity (light, moderate, or vigorous) can provide health benefits.
2. Health benefits can be experienced following just a single bout of moderate-to-vigorous PA (MVPA).
3. Any bout of MVPA, regardless of duration, can be included when quantifying daily or weekly volumes of PA intended to be counted toward meeting current recommendations.

The collective findings from the *2018 Physical Activity Guidelines Advisory Committee Scientific Report* (16) have been further summarized and incorporated into the most recent federal PA guidelines — the *Physical Activity Guidelines for Americans, Second Edition* (https://health.gov/paguidelines/second-edition/) (*Box 1.3*) (6).

Box 1.3 The Primary Physical Activity Recommendations for Adults from the *Physical Activity Guidelines for Americans, Second Edition* (6)

- Adults should move more and sit less throughout the day. Some physical activity is better than none. Adults who sit less and do any amount of moderate-to-vigorous physical activity gain some health benefits.
- For substantial health benefits, adults should do at least 150 min · wk^{-1} to 300 min · wk^{-1} of moderate intensity, or 75 min · wk^{-1} to 150 min · wk^{-1} of vigorous intensity aerobic physical activity, or an equivalent combination of moderate and vigorous intensity aerobic activity. Preferably, aerobic activity should be spread throughout the week.
- Additional health benefits are gained by engaging in physical activity beyond the equivalent of 300 min of moderate intensity physical activity a week.
- Adults should also do muscle strengthening activities of moderate or greater intensity and that involve all major muscle groups on 2 or more d · wk^{-1}, as these activities provide additional health benefits.

Notable among changes reflected in the 2018 guidelines is the previous requirement that aerobic activities must occur in bouts of more than 10 min in duration to elicit significant health benefits, which has been eliminated (6), as recent evidence indicates that bouts of PA of less than 10 min in duration are also associated with favorable outcomes for a variety of health-related indicators (16).

Since the release of the 1996 Surgeon General's Report (13), several reports have advocated PA levels above the minimum CDC–ACSM PA recommendations (11,17).

These recommendations primarily refer to the volume of PA required to prevent weight gain and/or obesity and should not be viewed as contradictory. In other words, PA that is sufficient to reduce chronic disease and mortality risks may be insufficient to prevent or reverse weight gain and/or obesity given the typical American lifestyle. Therefore, PA beyond the minimum recommendations combined with proper nutrition is likely needed for many individuals to manage and/or prevent weight gain and obesity (11,18).

Numerous large-scale epidemiology studies have been performed that document the inverse relationship between PA and cardiovascular disease (CVD) incidence and all-cause or CVD-related mortality (19,20). Williams (21) performed a meta-analysis of 23 sex-specific cohorts reporting varying levels of PA or cardiorespiratory fitness (CRF) representing 1,325,004 individual-years of follow-up and showed inverse dose-response relationships between PA and CRF with risks for coronary artery disease (CAD) and CVD (*Figure 1.1*). In general, findings from this study indicated that higher levels of PA or CRF provide additional health benefits (21). *Table 1.2* provides the strength of evidence for the dose-response relationships among PA and numerous health outcomes.

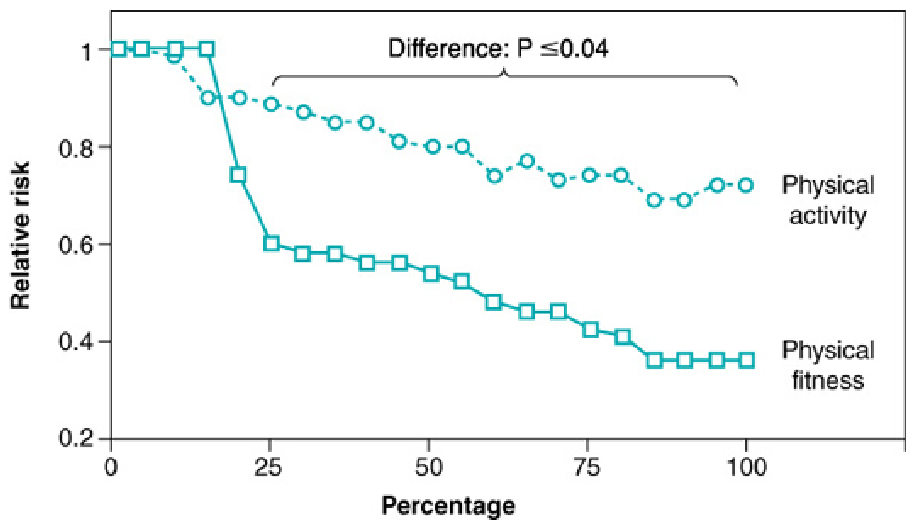

Figure 1.1 Estimated dose-response curve for the relative risk of atherosclerotic cardiovascular disease by sample percentages of fitness and physical activity. Studies weighted by individual-years of experience. Used with permission from (21).

TABLE 1.2 • Evidence for Dose-Response Relationship between Physical Activity and Health Outcomes in Adults

Variable	Evidence for a Dose-Response Relationship[a]	Strength of Evidence[b]
All-cause mortality[c]	Yes	Strong
Cardiorespiratory health[c]	Yes	Strong
Metabolic health[c]	Yes	Strong
Energy balance:		
Weight gain prevention[c]	Yes	Limited
Weight loss[d]	Yes	Strong
Weight maintenance following weight loss[d]	Yes	Moderate
Abdominal obesity[d]	Yes	Moderate
Musculoskeletal health:		
Bone[d]	Yes	Moderate
Muscular[d]	Yes	Strong
Functional health[d]	Yes	Moderate
Specific cancer risk:		
Bladder[c]	Yes	Moderate
Breast[c]	Yes	Strong
Colon[c]	Yes	Strong
Endometrial[c]	Yes	Moderate
Lung[c]	Yes	Limited
Ovarian[c]	No	Limited
Prostate[c]	Not assignable	Insufficient evidence
Mental health:		

Anxiety[c]	Yes	Limited
Cognition[c]	Not assignable	Insufficient evidence
Depression[c]	Yes	Limited
Well-being:		
Quality of life[c]	Not assignable	Insufficient evidence
Sleep[c]	Yes	Moderate

[a]Evidence for a dose-response relationship was classified as follows:

"Yes" — Evidence supports a dose-response relationship

"No" — Evidence does not support a dose-response relationship

"Not assignable" — Evidence inadequate or too disparate to generate a meaningful conclusion

[b]Strength of the evidence was classified as follows:

"Strong" — Consistent findings across many studies

"Moderate" — Some inconsistent findings across a moderate number of studies

"Limited" — Inconsistent findings across few studies

"Insufficient evidence" — Inadequate, too few, or no studies to assess strength of evidence

[c]Adapted from (16).

[d]Adapted from (15).

The ACSM and AHA have also released two publications examining the relationship between PA and public health in older adults (1,4). In general, these publications offered some recommendations that are similar to the updated guidelines for adults (2,3); however, the recommended intensity of aerobic activity reflected in these guidelines is related to the older adult's CRF level. In addition, age-specific recommendations are made concerning the importance of flexibility, neuromotor, and muscle strengthening activities (1,4). The *2008 Physical Activity Guidelines for Americans* (5) initially made three age-specific recommendations for PA targeted at children and adolescents (6–17 yr), adults (18–64 yr), and older adults (≥65 yr) that are similar to recommendations by the ACSM and AHA. However, the *Physical Activity Guidelines for Americans, Second Edition* (6) has provided further age specificity by delineating PA recommendations for preschool-aged children (3–5 yr), school-aged children and adolescents (6–17 yr), adults (18–64 yr), and older adults (≥65 yr).

SEDENTARY BEHAVIOR AND HEALTH

Despite the well-known health benefits of regular PA, physical inactivity remains a global pandemic that has been identified as one of the four leading contributors to premature mortality (22,23). Globally, 31.1% of adults are physically inactive (22). In the United States, self-report data indicate that 50.9% of adults meet aerobic activity guidelines, 30.4% meet muscle strengthening guidelines, and 20.5% meet both the aerobic and muscle strengthening guidelines (24).

Over the past 10–15 yr, the role of sedentary behavior in disease risk and progression has become an increasingly prominent public health concern (25,26). To clarify, *sedentary behavior* is defined as any behavior characterized by an energy expenditure of ≤1.5 METs while in a sitting, reclining, or lying posture (27). Despite this standardized definition, scientific efforts to measure free-living sedentary behavior have varied considerably in terms of the assessment methodologies employed.

Initial efforts to better understand contemporary sedentary behavior levels and their associated health risks largely relied on self-reported sitting and/or TV viewing time data collected using questionnaires (28–30), whereas subsequent studies have used motion sensing technologies to estimate sedentary behaviors (31–33). Due to these differing methodologies, it remains unknown exactly how much time per day Americans spend engaged in sedentary behaviors. However, published data from the National Health and Nutrition Examination Survey (NHANES) indicate that American adults self-report an average total sitting duration of 4.7 $h \cdot d^{-1}$ (34), whereas average estimates for sedentary time measured via waist-worn accelerometry have been higher, at 7.7–8.0 $h \cdot d^{-1}$ (35,36). Regardless of these discrepant measurement methodologies, the collective body of research evidence clearly indicates that high levels of sedentary behavior can be detrimental to one's health (16).

The deleterious relationships between sedentary behavior and various health indicators and outcomes have been demonstrated using a variety of research designs. Short-duration clinical experiments have demonstrated that prolonged sitting elicits unfavorable effects on glucose and insulin control (37–40), lipid metabolism (38,39), and vascular function (41,42). Numerous cross-sectional studies have indicated that sedentary behavior is positively associated with a variety of cardiometabolic risk factors (43–47). Moreover, a series of prospective longitudinal studies have demonstrated that high levels of sedentary behavior are associated with increased risks for incidence of diabetes (29,48–50), heart disease (51), and cancer (52,53) as well as increased risks for mortality from all causes (30,54–57), CVD (30,54,58–60), and cancer (61–63). Follow-up systematic reviews and meta-analyses have largely confirmed findings from previous longitudinal studies and further indicate that high levels of sedentary behavior pose significant health risks (64–68). Initially, it was believed that the relationship between sedentary behavior and various health outcomes, including mortality, was independent of time spent in higher intensity activities (*i.e.*, MVPA) (64). However, a recent meta-analysis demonstrated that high levels of MVPA (≥4.3 times the minimum recommended amount — about 60–75 $\text{min} \cdot \text{d}^{-1}$ of moderate intensity PA) appear to eliminate the mortality risk associated with high levels of sedentary behavior (65).

HEALTH BENEFITS OF REGULAR PHYSICAL ACTIVITY AND EXERCISE

Evidence supporting the inverse relationship between regular PA and/or exercise and premature mortality, CVD/CAD, hypertension, stroke, osteoporosis, Type 2 diabetes mellitus, metabolic syndrome, obesity, 13 cancers (breast, bladder, rectal, head and neck, colon, myeloma, myeloid leukemia, endometrial, gastric cardia, kidney, lung, liver, esophageal adenocarcinoma), depression, functional health, falls, and cognitive function continues to accumulate (6). For many of these diseases and health conditions, there is also strong evidence of a dose-response relationship with PA (see *Table 1.2*).

Several large-scale epidemiological studies have clearly documented a dose-response relationship between PA and risk of CVD and premature mortality in men and women and in ethnically diverse samples (69–74). It is also important to note that aerobic capacity (*i.e.*, CRF) has an inverse relationship with many negative health outcomes including risk of premature death from all causes and specifically from CVD (75–79), and higher levels of habitual PA are associated with higher levels of CRF (80–84), which in turn are associated with many health benefits (6). *Box 1.4* summarizes the benefits of regular PA and/or exercise.

Box 1.4 Benefits of Regular Physical Activity and/or Exercise

Improvement in Cardiovascular and Respiratory Function

- Increased maximal oxygen uptake resulting from both central and peripheral adaptations
- Decreased minute ventilation at a given absolute submaximal intensity
- Decreased myocardial oxygen cost for a given absolute submaximal intensity
- Decreased heart rate and blood pressure at a given submaximal intensity
- Increased capillary density in skeletal muscle
- Increased exercise threshold for the accumulation of lactate in the blood

- Increased exercise threshold for the onset of disease signs or symptoms (*e.g.*, angina pectoris, ischemic ST-segment depression, claudication)

Reduction in Cardiovascular Disease Risk Factors

- Reduced resting systolic/diastolic pressure
- Increased serum high-density lipoprotein cholesterol and decreased serum triglycerides
- Reduced total body fat and intraabdominal fat
- Reduced insulin needs; improved glucose tolerance
- Reduced blood platelet adhesiveness and aggregation
- Reduced inflammation

Decreased Morbidity and Mortality

- Primary prevention (*i.e.*, interventions to prevent the initial occurrence)
- Higher activity and/or fitness levels are associated with lower death rates from CAD.
- Higher activity and/or fitness levels are associated with lower incidence rates for CVD; CAD; stroke; Type 2 diabetes mellitus; metabolic syndrome; osteoporotic fractures; cancer of the bladder, breast, colon, endometrium, and lung; and gallbladder disease.
- Secondary prevention (*i.e.*, interventions after a cardiac event to prevent another)
- Based on meta-analyses (*i.e.*, pooled data across studies), cardiovascular and all-cause mortality are reduced in patients with post-myocardial infarction (MI) who participate in cardiac rehabilitation exercise training, especially as a component of multifactorial risk factor reduction. (Note: Randomized controlled trials of cardiac rehabilitation exercise training involving patients with post-MI do not support a reduction in the rate of nonfatal reinfarction.)

Other Benefits

- Decreased anxiety and depression
- Improved cognitive function
- Enhanced physical function and independent living in older individuals
- Enhanced feelings of well-being
- Enhanced quality of life
- Improved sleep quality and efficiency
- Enhanced performance of work, recreational, and sport activities
- Reduced risk of falls and injuries from falls in older individuals
- Prevention or mitigation of functional limitations in older adults
- Effective therapy for many chronic diseases in older adults

CAD, coronary artery disease; CVD, cardiovascular disease.

Adapted from (4,13,15,16,85).

HEALTH BENEFITS OF IMPROVING MUSCULAR FITNESS

The health benefits of enhancing muscular fitness (*i.e.*, the functional parameters of muscle strength, endurance, and power) are well established (16). Higher levels of muscular strength are associated with significantly better cardiometabolic risk profiles, lower risk of all-cause mortality, fewer CVD events, lower risk of developing physical function limitations, and lower risk for nonfatal disease (2). Significant beneficial changes in health-related biomarkers can be realized as a result of regular participation in resistance training, including improvements in body composition, blood glucose levels, insulin sensitivity, and blood pressure in individuals with mild or moderate hypertension (2,86,87). Recent evidence suggests that resistance training is as effective as aerobic training in the management and treatment of Type 2 diabetes mellitus (88,89) and in improving the blood lipid profiles of individuals who are overweight or obese (90). Resistance training positively affects walking distance and velocity in those with peripheral artery disease (89,91). Further health benefits attributed to resistance training were confirmed by a recent meta-analysis of published reports, which revealed that regimens featuring mild-to-moderate intensity isometric muscle actions were more effective in reducing blood pressure in both normotensive and hypertensive people than aerobic training or dynamic resistance training (92). Accordingly, resistance training may be effective for preventing and treating the dangerous constellation of conditions referred to as metabolic syndrome (2) (see *Chapter 9*).

Exercise that enhances muscle strength and mass also increases bone mass (*i.e.*, bone mineral density and content) and bone strength of the specific bones stressed, and may serve as a valuable measure to prevent, slow, or reverse the loss of bone mass in individuals with osteoporosis (15,16) (see *Chapter 10*). Resistance training can reduce pain and disability in individuals with osteoarthritis (2,93) and has been shown to be effective in the treatment of chronic back pain (94,95). Additionally, preliminary work suggests that resistance exercise may prevent and improve depression and anxiety, increase vigor, and reduce fatigue (2,96).

RISKS ASSOCIATED WITH PHYSICAL ACTIVITY AND EXERCISE

In general, the benefits of regular PA far outweigh the risks (15,16,97). However, participation in PA or exercise is associated with an increased risk for musculoskeletal injury (MSI) (98) and potential cardiovascular complications (2). MSI is the most common exercise-related complication and is often associated with exercise intensity, the nature of the activity, preexisting conditions, and musculoskeletal anomalies. Adverse cardiovascular events such as sudden cardiac death (SCD) and acute myocardial infarction (AMI) are usually associated with vigorous intensity exercise (99,100). SCD and AMI are much less common than MSI but may lead to long-term morbidity and mortality (97).

EXERCISE-RELATED MUSCULOSKELETAL INJURY

Walking and moderate intensity PAs are associated with a very low risk of MSI, whereas jogging, running, and competitive sports are associated with an increased risk of injury (101,102). The risk of MSI is higher in activities where there is direct contact between participants or with the ground (*e.g.*, football, wrestling) versus activities where the contact between participants or with the ground is minimal or nonexistent (*i.e.*, baseball, running, walking) (103). In 2014, over 6.3 million Americans received medical attention for sport-related injuries, with the highest rates found in children between the ages of 12 and 17 yr (83.41 injury episodes per 1,000 population) and adults between the ages of 18 and 44 yr (21.94 injury episodes per 1,000 population) (104). The most common anatomical sites for MSI are the lower extremities, with higher rates in the knees, followed by the foot and ankle (101,102).

The literature on injury consequences of PA participation often focuses on men from nonrepresentative populations (*e.g.*, military personnel, athletes) (105). A prospective study of community-dwelling women found that meeting the national PA guidelines of $\geq$150 min · wk^{-1} of MVPA resulted in a modest increase in PA-related MSI compared to women not meeting the guidelines (106). However, the risk for developing MSI is inversely related to physical fitness level (15). For any given dose of PA, individuals who are physically inactive are more likely to experience MSI when compared to their more active counterparts (15).

Commonly used methods to reduce MSI (*e.g.*, stretching, warm-up, cool-down, and gradual progression of exercise intensity and volume) may be helpful in some situations; however, there are a lack of controlled studies confirming the effectiveness of these methods (2). A comprehensive list of strategies that may assist in preventing MSI can be found elsewhere (107,108).

SUDDEN CARDIAC DEATH AMONG YOUNG INDIVIDUALS

The cardiovascular causes of exercise-related sudden death in young athletes are shown in *Table 1.3* (97). These data clearly indicate that the most common causes of SCD in young individuals are congenital and hereditary abnormalities including hypertrophic cardiomyopathy, coronary artery abnormalities, and aortic stenosis. An early report evaluating sudden death among younger individuals indicated the absolute annual risk of exercise-related death among high school and college athletes at 1 per 133,000 men and 1 per 769,000 women (109). It should be noted that these rates, although low, included all sports-related nontraumatic deaths. Of the 136 total identifiable causes of death, 100 were caused by CVD. More recent data among young competitive U.S. athletes (age: 19 ± 6 yr) from 1980 to 2011 have indicated somewhat higher annual incidence rates for all-cause sudden death at 1 per 62,439 men and 1 per 523,093 women (112). Additionally, Maron and colleagues (112) reported that 40% of recorded sudden deaths were attributable to SCD with annualized incidence rates of 1 in 121,691 men and 1 in 787,392 women. Some evidence, however, suggests that the incidence of SCD in young sports participants may be higher, ranging from 1 per 40,000 to 1 per 80,000 athletes annually (113). Furthermore, death rates seem to be higher in African American male athletes and basketball players specifically (112–114). There remains some debate regarding the between-study variability of incidence rates for exercise-related sudden death. These variances are likely due to differences in (a) the populations studied, (b) estimation of the number of sport participants, and (c) subject and/or incident case assignment. In an effort to reduce the risk of SCD incidence in young individuals, well-recognized organizations such as the International Olympic Committee and AHA have endorsed the practice of preparticipation cardiovascular screening (115–117). The recent position stand by the American Medical Society for Sports Medicine presents the latest evidence-based research on cardiovascular preparticipation screening in athletes (118).

TABLE 1.3 • Cardiovascular Causes of Exercise-Related Sudden Death in Young Athletes[a]

	Van Camp et al. (n = 100)[b] (109)	Maron et al. (n = 134) (110)	Corrado et al. (n = 55)[c] (111)	Maron et al. (n = 842)[b] (112)

Hypertrophic CM	51	36	1	302
Probable hypertrophic CM	5	10	0	77
Coronary anomalies	18	23	9	158
Valvular and subvalvular aortic stenosis	8	4	0	20
Possible myocarditis	7	3	5	57
Dilated and nonspecific CM	7	3	1	18
Atherosclerotic CVD	3	2	10	38
Aortic dissection/rupture	2	5	1	23
Arrhythmogenic right ventricular CM	1	3	11	43
Myocardial scarring	0	3	0	0
Mitral valve prolapse	1	2	6	31
Other congenital abnormalities	0	**1.5**	0	8
Long QT syndrome	0	**0.5**	0	18
Wolff-Parkinson-White syndrome	1	0	1	8
Cardiac conduction disease	0	0	3	2
Cardiac sarcoidosis	0	**0.5**	0	4
Coronary artery aneurysm	1	0	0	0
Normal heart at necropsy	7	2	1	18
Pulmonary thromboembolism	0	0	1	15

[a]Ages ranged from 13 to 24 yr (109), 12 to 40 yr (110), 12 to 35 yr (1), and 15 to 24 yr (112). References (109) and (110) used the same database and include many of the same athletes. All (109), 90% (110), and 89% (111) had symptom onset during or within an hour of training or competition.

[b] Total exceeds 100% because several athletes had multiple abnormalities.

[c] Includes some athletes whose deaths were not associated with recent exertion. Includes aberrant artery origin and course, tunneled arteries, and other abnormalities.

CM, cardiomyopathy; CVD, cardiovascular disease.

Used with permission from (97).

EXERCISE-RELATED CARDIAC EVENTS IN ADULTS

In general, exercise does not elicit cardiovascular events in healthy individuals with normal cardiovascular systems (119). The risk of SCD and AMI is very low in apparently healthy individuals performing moderate intensity PA (120,121). There is an acute and transient increase in the risk of SCD and AMI in individuals performing vigorous intensity exercise, particularly in sedentary men and women with diagnosed or occult CVD (97,122). However, this risk decreases with long-term compliance to an exercise regimen and increasing volumes of regular exercise (97,119). *Chapter 2* includes an exercise preparticipation health screening algorithm to help identify individuals who may be at risk for exercise-related cardiovascular events.

It is well established that the transient risks of SCD and AMI are substantially higher during acute vigorous physical exertion as compared with rest (97,99,123,124). A meta-analysis of published studies reported a fivefold increased risk of SCD and 3.5-fold increased risk of AMI during or shortly after vigorous intensity PA (122). The risk of SCD or AMI is higher in middle-aged and older adults than in younger individuals due to the higher prevalence of CVD in the older population. The rates of SCD and AMI are disproportionately higher in the most inactive individuals when they perform unaccustomed or infrequent exercise (97,99). As an example, the Myocardial Infarction Onset Study (100) showed that the risk of AMI during or immediately following vigorous intensity exercise was 50 times higher for the habitually inactive compared to individuals who exercised vigorously for 1-h sessions ≥5 $d \cdot wk^{-1}$ (*Figure 1.2*).

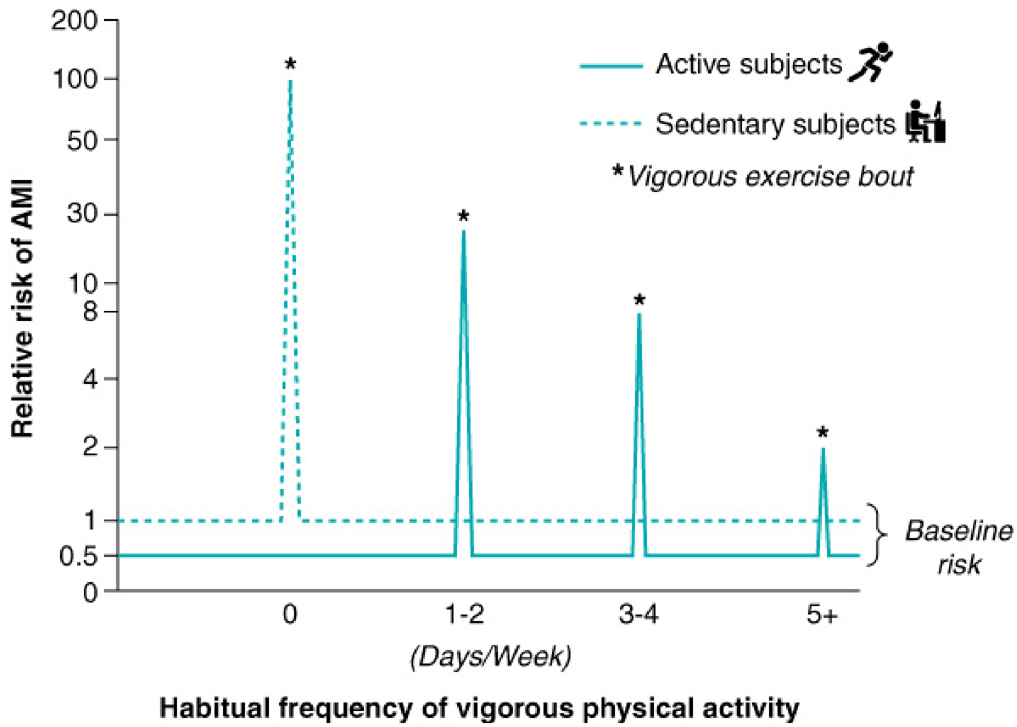

Figure 1.2 The relationship between habitual frequency of vigorous physical activity and the relative risk of acute myocardial infarction (AMI). Used with permission from (125).

Although the *relative* risks of SCD and AMI are higher during sudden vigorous physical exertion versus rest, the *absolute* risk of these events is very low (97,119). Prospective evidence from the Physicians' Health Study and Nurses' Health Study suggests that SCD occurs every 1.5 million episodes of vigorous physical exertion in men (99) and every 36.5 million h of moderate-to-vigorous exertion in women (121). Retrospective analyses also support the rarity of these events. Thompson and colleagues (126) reported 1 death per 396,000 h of jogging. An analysis of exercise-related cardiovascular events among participants at YMCA sports centers found 1 death per 2,897,057 person-hours, although exercise intensity was not documented (127). Kim et al. (128) studied over 10 million marathon and half-marathon runners and identified an overall cardiac arrest incidence rate of 1 per 184,000 runners and an SCD incidence rate of 1 per 256,000 runners, which translates to 0.20 cardiac arrests and 0.14 SCDs per 100,000 estimated runner-hours.

Although the risk is extremely low, vigorous intensity exercise has a small but measurable acute risk of CVD complications; therefore, mitigating this risk in susceptible individuals is important (see *Chapter 2*). The exact mechanisms of SCD and AMI during vigorous intensity exercise are not completely understood. Among those 30–35 yr and older, exercise-related SCD can most often be attributed to acute complications of atherosclerosis (97,119). Specifically, atherosclerosis-related complications are associated with exercise-related SCD in more than 80% of cases among those older than 35 yr of age and greater than 95% of cases among those older than 40 yr of age (129–133). Generally, exercise-related stress is believed to be a risk factor for vulnerable atherosclerotic plaque (119). Secondary to mechanisms that remain unclear, this exercise-related stress may accelerate fissuring of fragile and nonocclusive plaque. Subsequent geometric and hemodynamic changes of the epicardial arteries may then lead to plaque disruption (119). Moreover, plaque rupture may be induced somewhat spontaneously via increased fibrinolytic activity subsequent to heightened thrombogenicity in response to vigorous exercise (119,134).

EXERCISE TESTING AND THE RISK OF CARDIAC EVENTS

As with vigorous intensity exercise, the risk of cardiac events during exercise testing varies directly with the prevalence of diagnosed or occult CVD in the study population. Numerous studies spanning more than four decades have documented these risks during exercise testing (135–146). *Table 1.4* summarizes the risks of various cardiac events including AMI, ventricular fibrillation, hospitalization, and death. These data indicate in a mixed population the risk of exercise testing is low, with approximately 6 cardiac events per 10,000 tests. One of these studies includes data for which the exercise testing was supervised by nonphysicians (141). In addition, the majority of these studies used symptom-limited maximal exercise tests. Therefore, it would be expected that the risk of submaximal testing in a similar population would be lower.

TABLE 1.4 • Cardiac Complications during Exercise Testing[a]

Reference	Year	Site	No. of Tests	MI	VF	Death	Hospitalization	Comment
Rochmis and Blackburn (144)	1971	73 U.S. centers	170,000	NA	NA	1	3	34% of tests were symptom limited; 50% of deaths in 8 h; 50% over the next 4 d
Irving et al. (138)	1977	15 Seattle facilities	10,700	NA	4.67	0	NR	
McHenry (142)	1977	Hospital	12,000	0	0	0	0	
Atterhög et	1979	20 Swedish	50,000					

al. (135)		centers		0.8	0.8	0.4	5.2	
Stuart and Ellestad (146)	1980	1,375 U.S. centers	518,448	3.58	4.78	0.5	NR	VF includes other dysrhythmias requiring treatment.
Gibbons et al. (2,14)	1989	Cooper Clinic	71,914	0.56	0.29	0	NR	Only 4% of men and 2% of women had CVD.
Knight et al. (141)	1995	Geisinger Cardiology Service	28,133	1.42	1.77	0	NR	25% were inpatient tests supervised by non-MDs.
Myers et al. (143)	2000	72 Veterans Affairs medical centers in the United States	75,828	0.40	0.13	0	NR	VF includes other dysrhythmias requiring treatment.
Kane et al. (139)	2008	Mayo Clinic	8,592	0	4.66	0	5.82	Tests were supervised by registered nurses. VF includes other dysrhythmias requiring treatment.
Keteyian et al. (140)	2009	82 clinical sites in the United States, Canada, and France	4,411	0	0	0	0	All patients were diagnosed with heart failure.
Skalski et al. (145)	2012	Mayo Clinic	5,060	0	7.91	0	11.9	All patients were diagnosed with CVD prior to testing. VF includes other dysrhythmias resulting in hospitalization.

[a]Events are per 10,000 tests.

CVD, cardiovascular disease; MD, medical doctor; MI, myocardial infarction; NA, not applicable; NR, not reported; VF, ventricular fibrillation.

RISKS OF CARDIAC EVENTS DURING CARDIAC REHABILITATION

The highest risk of cardiovascular events occurs in those individuals with diagnosed CAD. Older but still relevant research found 1 nonfatal complication per 34,673 patient-hours and 1 fatal cardiovascular complication per 116,402 patient-hours of cardiac rehabilitation (147). Collectively, average rates from other studies have been lower: 1 cardiac arrest per 116,906 patient-hours, 1 AMI per 219,970 patient-hours, 1 fatality per 752,365 patient-hours, and 1 major complication per 81,670 patient-hours (148–151). Summary statistics from these studies are presented in *Table 1.5* (97). More recent studies have demonstrated an even lower rate of cardiovascular complications during cardiac rehabilitation with ≤1 cardiac arrests per 169,344–743,471 patient-hours, ≤1 AMIs per 338,638–743,471 patient-hours, and ≤1 fatality per 338,638–743,471 patient-hours (152–154). Although these complication rates are low, it should be noted that patients were screened and exercised in medically supervised settings equipped to handle cardiac emergencies. The mortality rate appears to be 6 times higher when patients exercise in facilities without the ability to successfully manage cardiac arrest (97). Interestingly, however, a review of home-based cardiac rehabilitation programs found no increase in cardiovascular complications versus formal center-based exercise programs (155).

TABLE 1.5 • Summary of Exercise-Based Cardiac Rehabilitation Program Complication Rates

Investigator	Year	Patient Exercise Hours	Cardiac Arrest	Myocardial Infarction	Fatal Events	Major Complications[a]
Van Camp and Peterson (150)	1980–1984	2,351,916	1/111,996[b]	1/293,990	1/783,972	1/81,101
Digenio et al. (148)	1982–1988	480,000	1/120,000[c]		1/160,000	1/120,000
Vongvanich et al. (151)	1986–1995	268,503	1/89,501[d]	1/268,503[d]	0/268,503	1/67,126
Franklin et al. (149)	1982–1998	292,254	1/146,127[d]	1/97,418[d]	0/292,254	1/58,451
Average			1/116,906	1/219,970	1/752,365	1/81,670

[a]Myocardial infarction and cardiac arrest.

[b]Fatal 14%.

[c]Fatal 75%.

[d]Fatal 0%.

Used with permission from (97).

PREVENTION OF EXERCISE-RELATED CARDIAC EVENTS

Because of the low incidence of cardiac events related to vigorous intensity exercise, it is very difficult to test the effectiveness of strategies to reduce the occurrence of these events. Therefore, in a 2007 joint report by the ACSM and AHA, authors suggested that "physicians should not overestimate the risks of exercise because the benefits of habitual physical activity substantially outweigh the risks" (97, p. 2363). This report also recommends several strategies to reduce these cardiac events during vigorous intensity exercise (97):

- Health care professionals should know the pathologic conditions associated with exercise-related events so that physically active children and adults can be appropriately evaluated.
- Physically active individuals should know the nature of cardiac prodromal symptoms (*e.g.*, excessive, unusual fatigue and pain in the chest and/or upper back) and seek

prompt medical care if such symptoms develop (see *Table 2.1*).

- High school and college athletes should undergo preparticipation screening by qualified health care professionals.
- Athletes with known cardiac conditions or a family history should be evaluated by members of the health care team prior to competition using established guidelines.
- Health care facilities should ensure their staff are trained in managing cardiac emergencies and have a specified plan and appropriate resuscitation equipment.
- Physically active individuals should modify their exercise program in response to variations in their exercise capacity, habitual activity level, and the environment (see *Chapters 5* and *7*).

Although strategies for reducing the number of cardiovascular events during vigorous intensity exercise have not been systematically studied, it is incumbent on the exercise professional to take reasonable precautions when working with individuals who wish to become more physically active/fit and/or increase their PA/fitness levels. These precautions are particularly true when the exercise program will be of vigorous intensity. Although many sedentary individuals can safely begin a light-to-moderate intensity exercise program, all individuals should participate in the exercise preparticipation screening process to determine the need for medical clearance (see *Chapter 2*).

Exercise professionals who supervise exercise and fitness programs should have current training in basic and/or advanced cardiac life support and emergency procedures. These emergency procedures should be reviewed and practiced at regular intervals. Finally, individuals should be educated on the signs and symptoms of CVD and should be referred to a physician for further evaluation should these symptoms occur.

ONLINE RESOURCES

American College of Sports Medicine position stand on the quantity and quality of exercise: http://www.acsm.org

Physical Activity Guidelines for Americans, Second Edition: https://health.gov/paguidelines/second-edition/

2008 Physical Activity Guidelines for Americans: https://health.gov/paguidelines/2008/

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Preexercise Evaluation

CHAPTER 2

INTRODUCTION

This chapter contains the recommended steps that should be taken by an exercise professional prior to someone engaging in physical activity (PA) and/or taking part in a structured exercise program. Specific components of the preexercise evaluation and the American College of Sports Medicine (ACSM) recommended in order to conduct the screenings are: (a) informed consent process, (b) exercise preparticipation health screening, (c) health history, (d) and cardiovascular (CV) risk factor analysis. This chapter provides details of these components, and where available, based on the most current evidence.

The ACSM exercise preparticipation health screening recommendations described in this chapter are designed to identify individuals who are at risk for adverse exercise-related CV events and to provide guidance about which individuals should be referred for medical clearance (*i.e.*, approval from a health care provider to engage in exercise). These recommendations emphasize the public health message of PA for all, while at the same time acknowledge that vigorous exercise is associated with a small but measurable acute risk of CV disease (CVD) complications, as described in *Chapter 1*. These recommendations also decrease the need to see a physician prior to initiating exercise, thereby reducing or removing unnecessary barriers to adopting and maintaining habitual PA, a structured exercise program, or both (1).

The medical history and CV risk factor analysis are not part of the preparticipation health screening procedures for the purpose of reducing acute risk, but can and do provide the exercise professional with valuable information about each individual. Therefore, soliciting information on CV risk factors and medical history should still be an important aspect of preparticipation intake, as that information should be used to design appropriate and individualized exercise programs to lower or reduce known health risks. The information may also uncover uncertainties about an individual's ability to safely participate in an exercise program, thereby necessitating the exercise professional to refer the individual for medical evaluation and or medical clearance.

INFORMED CONSENT

The informed consent process is the first step when working with each new individual. Obtaining adequate informed consent from participants is an important ethical and legal consideration and should be completed prior to (a) the collection of any personal and confidential information, (b) any form of fitness testing, or (c) exercise participation. Although the content and extent of consent forms may vary, enough information must be present in the informed consent process to ensure that the participant knows and understands the purpose(s) and risks associated with screening, assessment, and the exercise program. The consent form should be verbally explained to the participant and should include a statement indicating the individual has been given an opportunity to ask questions about the exercise preparticipation health screening, exercise testing or fitness assessment, or the exercise program, and has been given sufficient information to provide an informed consent. It is important to document specific questions from the participant on the form along with the responses provided. The consent form must indicate the participant is free to withdraw at any time. Also, all reasonable efforts must be made to protect the privacy of individual's health information (*e.g.*, medical history, test results) as described in the Health Insurance Portability and Accountability Act (HIPAA) (2,3). A sample consent form for exercise testing is provided in *Figure 2.1*. However, it is advisable to check with authoritative bodies (*e.g.*, hospital risk management, institutional review boards, facility legal counsel) to determine what is appropriate for an acceptable informed consent process. No sample form should be adopted for a specific test or program unless approved by legal counsel and/or the appropriate institutional review board.

Informed Consent for an Exercise Test

1. **Purpose and Explanation of the Test**
You will perform an exercise test on a cycle ergometer or a motor-driven treadmill. The exercise intensity will begin at a low level and will be advanced in stages depending on your fitness level. We may stop the test at any time because of signs of fatigue or changes in your heart rate, electrocardiogram, or blood pressure, or symptoms you may experience. It is important for you to realize that you may stop when you wish because of feelings of fatigue or any other discomfort.

2. **Attendant Risks and Discomforts**
There exists the possibility of certain changes occurring during the test that increase risk. These include abnormal blood pressure; fainting; irregular, fast, or slow heart rhythm; and, in rare instances, heart attack, stroke, or death. Every effort will be made to minimize these risks by evaluation of preliminary information relating to your health and fitness and by careful observations during testing. Emergency equipment and trained personnel are available to deal with unusual situations that may arise.

3. **Responsibilities of the Participant**
Information you possess about your health status or previous experiences of heart-related symptoms (*e.g.*, shortness of breath with low-level activity; pain; pressure; tightness; heaviness in the chest, neck, jaw, back and/or arms) with physical effort may affect the safety of your exercise test. Your prompt reporting of these and any other unusual feelings with effort during the exercise test itself is very important. You are responsible for fully disclosing your medical history as well as symptoms that may occur during the test. You are also expected to report all medications (including nonprescription) taken recently and, in particular, those taken today to the testing staff.

4. **Benefits to be Expected**
The results obtained from the exercise test may assist in the diagnosis of your illness, in evaluating the effect of your medications, or in evaluating what type of physical activities you might do with low risk.

5. **Inquiries**
Any questions about the procedures used in the exercise test or the results of your test are encouraged. If you have any concerns or questions, please ask us for further explanations.

6. **Use of Medical Records**
The information that is obtained during exercise testing will be treated as privileged and confidential as described in the Health Insurance Portability and Accountability Act of 1996. It is not to be released or revealed to any individual except your referring physician without your written consent. However, the information obtained may be used for statistical analysis or scientific purposes with your right to privacy retained.

7. **Freedom of Consent**
I hereby consent to voluntarily engage in an exercise test to determine my exercise capacity and state of cardiovascular health. My permission to perform this exercise test is given voluntarily. I understand that I am free to stop the test at any point if I so desire.

I have read this form, and I understand the test procedures that I will perform and the attendant risks and discomforts. Knowing these risks and discomforts, and having had an opportunity to ask questions that have been answered to my satisfaction, I consent to participate in this test.

Date	Signature of Patient
Date	Signature of Witness
Date	Signature of Physician or Authorized Delegate

Figure 2.1 Sample of informed consent form for a symptom-limited exercise test.

When an informed consent is being used in a research setting, this should be indicated during the consent process and reflected on the *informed consent form*, and applicable policies for the testing of human subjects must be implemented. Health care professionals and research scientists should obtain approval from their institutional review board when conducting an exercise test for research purposes.

Because most consent forms include the statement “emergency procedures and equipment are available,” the program must ensure available personnel are properly trained and authorized to carry out emergency procedures that use such equipment. Written emergency policies and procedures should be in place, and emergency drills should be practiced at least once every 3 mo, or more frequently, when there is a change in staff (4).

EXERCISE PREPARTICIPATION HEALTH SCREENING

The overarching purpose of the ACSM exercise preparticipation health screening process is to identify individuals who are at risk for adverse exercise-related CV events. More specifically, the goals are to identify individuals (a) who should receive medical clearance before initiating a moderate to vigorous intensity exercise program or increasing the intensity of their current program, (b) with clinically significant disease(s) who may benefit from participating in a medically supervised exercise program, and (c) with medical conditions that may require exclusion from exercise programs until those conditions are abated or better controlled. It is important to highlight that exercise preparticipation health screening recommendations are not a replacement for sound clinical judgment and decisions about referral to a health care provider for medical clearance prior to the initiation of an exercise program, or adjustments to an exercise program to include vigorous exercise, should continue to be made on an individual basis.

The ACSM exercise preparticipation health screening process is a screening algorithm with recommendations for medical clearance based on an individual's current level of exercise participation, presence of signs or symptoms and/or known CV, metabolic, or renal disease, and the anticipated or desired exercise intensity (1). These factors are included because the risk for activity-associated sudden cardiac death (SCD) and acute myocardial infarction (AMI) is known to be highest among those with underlying CVD who perform unaccustomed vigorous PA (5–8). The relative risk of SCD and AMI during vigorous-to-near maximal intensity exercise is directly related to the presence of CVD and/or exertional symptoms (8) and is inversely related to the habitual level of PA (6,9–12). The relative risk of a CV event is transiently increased during vigorous intensity exercise as compared with rest, but the absolute risk of an exercise-related acute cardiac event is low in healthy asymptomatic individuals (see *Figure 1.2*) (8,13–15).

Exercise testing is often a useful tool for the development of an individualized exercise program; however, ACSM no longer recommends the inclusion of exercise testing or any other type of medical examination as part of medical clearance; rather, those decisions are left to the clinical judgment of qualified health care providers. This is intended to better align with relevant evidence that exercise testing is not a uniformly recommended screening procedure, as it is a poor predictor of acute cardiac events in asymptomatic individuals (16). Even though exercise testing may detect flow-limiting coronary lesions via the provocation of ischemic ST-segment depression, angina pectoris, or both, SCD and AMI are usually triggered by the rapid progression of a previously nonobstructive lesion (8). Furthermore, there is a lack of consensus regarding the extent of the medical evaluation (*i.e.*, physical exam; peak or symptom-limited exercise testing) needed as part of the preparticipation health screening process prior to initiating an exercise program, even when the program will be of vigorous intensity. The American College of Cardiology Foundation (ACCF)/American Heart Association (AHA) recommends that exercise testing may be considered in intermediate-risk asymptomatic adults. This includes sedentary adults starting a vigorous intensity exercise program if non-electrocardiogram (ECG) markers such as exercise capacity, chronotropic incompetence, and heart rate recovery are considered; however, it is acknowledged that the efficacy of this recommendation is not well established (17). The U.S. Preventive Services Task Force (USPSTF) recommends against the use of routine diagnostic testing or exercise electrocardiography as a screening tool in asymptomatic individuals who are at low risk for CVD events. The USPSTF concluded there is insufficient evidence to evaluate the benefits and harm of exercise testing before initiating a PA program. Furthermore, the USPSTF does not make specific recommendations regarding the need for exercise testing for individuals at intermediate and high risk for CVD events (18). Similarly, randomized trial data on the clinical value of exercise testing for screening purposes are absent; it is not known if exercise testing in asymptomatic adults reduces the risk of premature mortality or major cardiac morbidity

(19). There also is evidence from decision analysis modeling that routine screening using exercise testing prior to initiating an exercise program is not warranted regardless of baseline individual risk (20).

Insufficient evidence is available to suggest that the presence of CVD risk factors *without* underlying disease confers substantial risk of adverse exercise-related CV events. The high prevalence of CVD risk factors among adults (21), combined with the rarity of exercise-related SCD and AMI (8,11), suggest that the ability to predict these rare events by assessing risk factors is low, especially among otherwise healthy adults (8). Furthermore, conventional CVD risk factor–based exercise preparticipation health screening may be overly conservative due to the high prevalence of risk factors among the population. This may generate excessive physician referrals, particularly in adults older than 40 yr (21). Therefore, elimination of CVD risk factors from the prescreening procedure substantially lowers the proportion of individuals referred for medical clearance (22). Nonetheless, it is recommended that CVD risk factor assessment be conducted and shared with the participant and health care provider. Therefore, clearance to engage in a moderate to vigorous exercise program among those with sign/symptoms of CVD should not be solely based on CVD risk factor assessment, but in a complete medical evaluation as determined by the medical professional.

Overall, there is a low risk of SCD and AMI associated with participation in a light-to-moderate intensity exercise program (23). Vigorous exercise is associated with the greatest risk, and much of that risk is mitigated by adopting a "progressive transitional phase" (~2–3 mo) during which the duration and intensity of exercise are gradually increased (1,24). When previously sedentary individuals initiate an exercise program, such individuals are strongly recommended to begin with light-to-moderate intensity (*e.g.*, 2–3 metabolic equivalents [METs]) and gradually increase the intensity (*e.g.*, 3–5 METs) over time, provided that the individual remains symptom free. Such a gradual progression appears prudent because these intensities are below the vigorous intensity threshold (≥6 METs) that is commonly associated with the triggering of acute CV events in susceptible individuals (8,25). This progressive transitional phase will help to minimize the risk of musculoskeletal injury and allow sedentary individuals to improve their cardiorespiratory fitness without going through a period during which each session of vigorous exercise is associated with spikes in relative CV risk (26).

American College of Sports Medicine Preparticipation Screening Process

The following section provides guidance for preparticipation screening for exercise professionals working with the general, nonclinical population. Recommendations for those individuals who are working in a clinical or medical fitness setting are presented separately in *Chapter 4*.

Preparticipation health screening before initiating a moderate-to-vigorous exercise program is a two-stage process:

- The need for medical clearance before initiating or progressing exercise programming is determined using the ACSM screening algorithm and the help of a qualified exercise or health care professional. In the absence of professional assistance, interested individuals may use the Physical Activity Readiness Questionnaire Plus (PAR-Q+).
- If indicated during screening, medical clearance from a physician or other qualified health care provider should be recommended. The manner of clearance, however, should be determined by the clinical judgment and discretion of said health care provider.

The following section provides guidance for using the preparticipation health screening algorithm with respect to:

- Determining current PA levels
- Identifying signs and symptoms of underlying CV, metabolic, and renal disease (*Table 2.1*)
- Identifying individuals with diagnosed CV and metabolic disease
- Using signs and symptoms, disease history, current exercise participation, and desired exercise intensity to guide recommendations for preparticipation medical clearance

Preparticipation health screening before initiating an exercise program should be distinguished from a periodic medical examination, which should be encouraged as part of routine health maintenance.

TABLE 2.1 • Major Signs or Symptoms Suggestive of Cardiovascular, Metabolic, and Renal Disease[a]

Signs or Symptoms	Clarification/Significance
Pain; discomfort (or other anginal equivalent) in the chest, neck, jaw, arms, or other areas that may result from myocardial ischemia; or other recent onset pain of unknown origin	One of the cardinal manifestations of cardiac disease; in particular, coronary artery disease Key features *favoring an ischemic origin* include the following: • *Character*: constricting, squeezing, burning, "heaviness," or "heavy feeling" • *Location*: substernal, across midthorax, anteriorly; in one or both arms, shoulders; in neck, cheeks, teeth; in forearms, fingers in interscapular region • *Provoking factors*: exercise or exertion, excitement, other forms of stress, cold weather, occurrence after meals. Key features against an ischemic origin include the following: • *Character*: dull ache; "knifelike," sharp, stabbing; "jabs" aggravated by respiration • *Location*: in left submammary area; in left hemithorax • *Provoking factors*: after completion of exercise, provoked by a specific body motion
Shortness of breath at rest or with mild exertion	Dyspnea (defined as an abnormally uncomfortable awareness of breathing) is one of the principal symptoms of cardiac and pulmonary disease. It commonly occurs during strenuous exertion in healthy, well-trained individuals and during moderate exertion in healthy, untrained individuals. However, it should be regarded as abnormal when it occurs at a level of exertion that is not expected to evoke this symptom in a given individual. Abnormal exertional dyspnea suggests the presence of cardiopulmonary disorders; in particular, left ventricular dysfunction or chronic obstructive pulmonary disease.
Dizziness or syncope	Syncope (defined as a loss of consciousness) is most commonly caused by a reduced perfusion of the brain. Dizziness and, in particular, syncope *during* exercise may result from cardiac disorders that prevent the normal rise (or an actual fall) in cardiac output. Such cardiac disorders are potentially life-threatening and include severe coronary artery disease, hypertrophic cardiomyopathy, aortic stenosis, and malignant ventricular dysrhythmias. Although dizziness or syncope shortly *after* cessation of exercise should not be ignored, these symptoms may occur even in healthy individuals as a result of a reduction in venous return to the heart.
Orthopnea or paroxysmal	Orthopnea refers to dyspnea occurring at rest in the recumbent

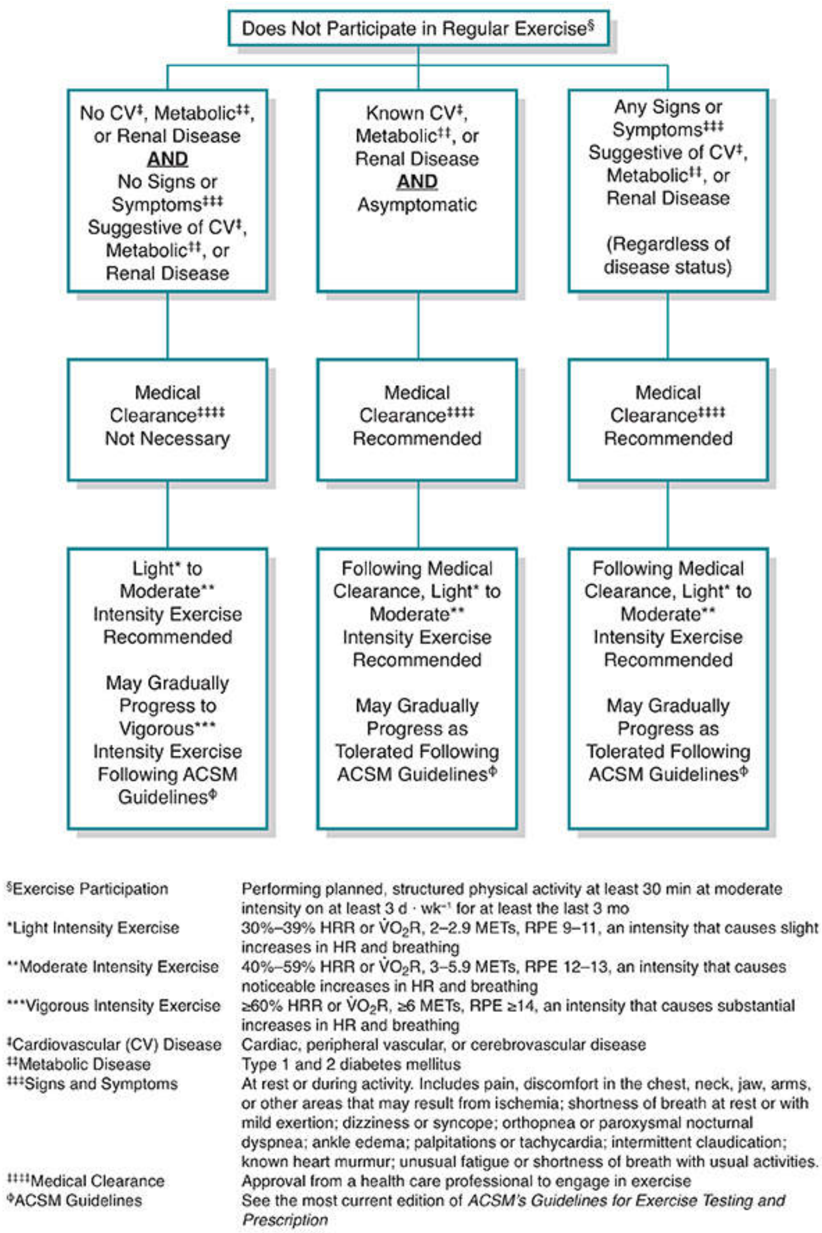
nocturnal dyspnea	position that is relieved promptly by sitting upright or standing. Paroxysmal nocturnal dyspnea refers to dyspnea, beginning usually 2–5 h after the onset of sleep, which may be relieved by sitting on the side of the bed or getting out of bed. Both are symptoms of left ventricular dysfunction. Although nocturnal dyspnea may occur in individuals with chronic obstructive pulmonary disease, it differs in that it is usually relieved following a bowel movement rather than specifically by sitting up.
Ankle edema	Bilateral ankle edema that is most evident at night is a characteristic sign of heart failure or bilateral chronic venous insufficiency. Unilateral edema of a limb often results from venous thrombosis or lymphatic blockage in the limb. Generalized edema (known as anasarca) occurs in individuals with the nephrotic syndrome, severe heart failure, or hepatic cirrhosis.
Palpitations or tachycardia	Palpitations (defined as an unpleasant awareness of the forceful or rapid beating of the heart) may be induced by various disorders of cardiac rhythm. These include tachycardia, bradycardia of sudden onset, ectopic beats, compensatory pauses, and accentuated stroke volume resulting from valvular regurgitation. Palpitations also often result from anxiety states and high cardiac output (or hyperkinetic) states, such as anemia, fever, thyrotoxicosis, arteriovenous fistula, and the so-called idiopathic hyperkinetic heart syndrome.
Intermittent claudication	Intermittent claudication refers to the pain that occurs in the lower extremities with an inadequate blood supply (usually as a result of atherosclerosis) that is brought on by exercise. The pain does not occur with standing or sitting, is reproducible from day to day, is more severe when walking upstairs or up a hill, and is often described as a cramp, which disappears within 1–2 min after stopping exercise. Coronary artery disease is more prevalent in individuals with intermittent claudication. Patients with diabetes are at increased risk for this condition.
Known heart murmur	Although some may be innocent, heart murmurs may indicate valvular or other cardiovascular disease. From an exercise safety standpoint, it is especially important to exclude hypertrophic cardiomyopathy and aortic stenosis as underlying causes because these are among the more common causes of exertion-related sudden cardiac death.
Unusual fatigue or shortness of breath with usual activities	Although there may be benign origins for these symptoms, they also may signal the onset of or change in the status of cardiovascular disease or metabolic disease.

[a]These signs or symptoms must be interpreted within the clinical context in which they appear because they are not all specific for cardiovascular, metabolic, or renal diseases.

Modified from (27).

American College of Sports Medicine Preparticipation Screening Algorithm

The ACSM preparticipation screening algorithm (*Figure 2.2*) is designed to identify individuals at risk for CV complications as a direct result of a bout of aerobic exercise. Although preparticipation screening is recommended before participation with any type of exercise program, current evidence regarding prescreening for CV complications during resistance training is limited, thus the inherent risk cannot currently be determined, but appears to be low (23).



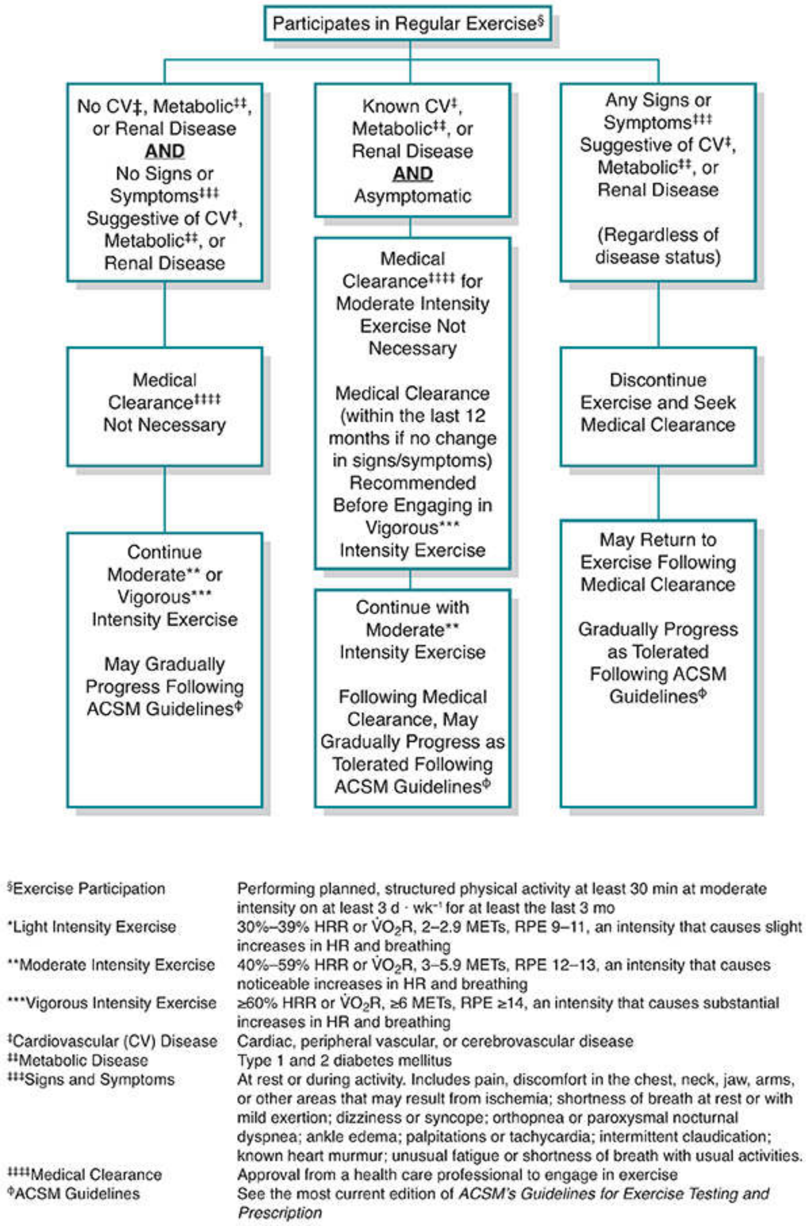


Figure 2.2 The American College of Sports Medicine (ACSM) preparticipation screening algorithm. HR, heart rate; HRR, heart rate reserve; METs, metabolic equivalents; RPE, rating of perceived exertion; $\dot{V}O_2R$, oxygen uptake reserve. Used with permission from (1).

Algorithm Components

The screening algorithm (see *Figure 2.2*) begins by classifying individuals who do or do not currently participate in regular PA. The intent is to better identify those individuals unaccustomed to regular physical exertion for whom exercise may place disproportionate demands on the CV system and increase the risk of complications. As designated, participants classified as current exercisers should have a history of performing planned, structured PA of at least moderate intensity for at least 30 min on 3 or more d · wk^{-1} during the past 3 mo.

The next level of classification involves identifying individuals with known CV, metabolic, or renal diseases or those with signs or symptoms suggestive of cardiac, peripheral vascular, renal, or cerebrovascular diseases, Types 1 and 2 diabetes mellitus (DM). During the preparticipation screening process, participants should be asked if a physician or other qualified health care provider has ever diagnosed them with any of these conditions. It is noteworthy to mention that during the preparticipation health screening, hypertension should be considered as a CVD risk factor and not a cardiac disease (28). Once an individual's disease status has been ascertained, attention should shift toward signs and symptoms suggestive of CV, metabolic, or renal disease. To better identify those who may have undiagnosed disease, individuals should be screened for the presence or absence of signs and symptoms suggestive of these diseases, as described in *Table 2.1*. Care should be taken to interpret the signs and symptoms within the context of the individual's recent history, and additional information should be sought to clarify vague or ambiguous responses. For example, an individual may describe recent periods of noticeable breathlessness; however, this occurrence is a nonspecific symptom of CVD, as many factors can cause shortness of breath. Pertinent follow-up questions may include the following:

- What were you doing during these periods?
- Were you more breathless than you would have expected for this activity?
- Compared to recent similar activities, were you more fatigued following the activity?

These questions may provide clarification to better distinguish expected signs and symptoms from potentially pathological signs and symptoms. An exercise preparticipation health screening checklist is included to guide the exercise professional through the prescreening process (*Figure 2.3*).

Exercise Preparticipation Health Screening Questionnaire for Exercise Professionals

Assess your client's health needs by marking all *true* statements.

Step 1

SIGNS AND SYMPTOMS

Does your client experience:

___ chest discomfort with exertion
___ unreasonable breathlessness
___ dizziness, fainting, blackouts
___ ankle swelling
___ unpleasant awareness of a forceful, rapid or irregular heart rate
___ burning or cramping sensations in your lower legs when walking short distance
___ known heart murmur

If you **did** mark any of these statements under the symptoms, **STOP**, your client should seek medical clearance before engaging in or resuming exercise. Your client may need to use a facility with a **medically qualified staff**.

If you **did not** mark any symptoms, continue to steps 2 and 3.

Step 2

CURRENT ACTIVITY

Has your client performed planned, structured physical activity for at least 30 min at moderate intensity on at least 3 days per week for at least the last 3 months?

Yes ☐ No ☐

Continue to Step 3.

Step 3

MEDICAL CONDITIONS

Has your client had or do they currently have:

___ a heart attack
___ heart surgery, cardiac catheterization, or coronary angioplasty
___ pacemaker/implantable cardiac defibrillator/rhythm disturbance
___ heart valve disease
___ heart failure
___ heart transplantation
___ congenital heart disease
___ diabetes
___ renal disease

Evaluating Steps 2 and 3:

- If you **did not mark any of the statements in Step 3**, medical clearance is not necessary.
- If you marked Step 2 "**yes**" and **marked any of the statements in Step 3**, your client may continue to exercise at light to moderate intensity without medical clearance. However, medical clearance is recommended before engaging in vigorous exercise.
- If you marked Step 2 "**no**" and **marked any of the statements in Step 3**, medical clearance is recommended. Your client may need to use a facility with a **medically qualified staff**.

Figure 2.3 Exercise preparticipation health screening questionnaire for exercise professionals. Used with permission (29).

In the prescreening process, individuals with pulmonary disease are not automatically referred for medical clearance because pulmonary disease does not increase the risks of nonfatal or fatal CV complications during or immediately after exercise; in fact, it is the associated inactive and sedentary lifestyle of many individuals with pulmonary disease that may increase the risk of these events (30). However, chronic obstructive pulmonary disease (COPD) and CVD are often comorbid due to the common risk factor of smoking, and the presence of COPD in current or former smokers is an independent predictor of overall CV events (31). Thus, careful attention to the presence of signs and symptoms of CV and metabolic disease is warranted in individuals with COPD during the exercise preparticipation health screening process. Nevertheless, despite this change, the presence of pulmonary or other diseases remains an important consideration for determining the safest and most effective exercise program (1).

Desired exercise intensity is the final component in the preparticipation screening algorithm. Because vigorous intensity exercise is more likely to trigger acute CV events, versus light-to-moderate intensity exercise (8), identifying the intensity at which a participant intends to exercise is important. Guidance is offered in the footnotes of the algorithm on the aforementioned designations as well as what constitutes light, moderate, and vigorous intensity exercise (for additional information regarding exercise intensity please see *Chapter 5*).

Using the Algorithm

According to the preparticipation screening algorithm, participants are grouped into one of six categories (see *Figure 2.2*). Importantly, exercise professionals using this algorithm should monitor individuals for changes that may alter their categorization and recommendations. For example, an individual who initially declares no signs or symptoms of disease may develop signs or symptoms only after beginning an exercise program; this would necessitate more aggressive screening recommendations.

When medical clearance is warranted for individuals, they should be referred to a physician or health care provider. Importantly, the type of medical evaluation is left to the discretion and clinical judgment of the provider to whom the participant is referred because there is no single, universally recommended screening test. The type of procedures conducted during clearance may vary widely from provider to provider and may include verbal consultations, resting or stress ECG/echocardiogram, computed tomography for the assessment of coronary artery calcium, or even nuclear medicine imaging studies or coronary angiography. Exercise professionals may request written clearance along with special instructions or restrictions (*e.g.*, exercise intensity) for the individual in question, and continued communication between health care providers and exercise professionals is strongly encouraged. To better understand the preparticipation screening algorithm, case studies are presented in *Box 2.1*

Box 2.1 Preparticipation Screening Case Studies

The following case studies are presented as an example how to utilize the American College of Sports Medicine (ACSM) preparticipation screening algorithm.

CASE STUDY I

A 50-yr-old nonsmoking male was recently invited by colleagues to participate in a 10-km trail run. Currently, he walks at a moderate intensity for 40 min every Monday, Wednesday, and Friday — something he has done "for years." His goal is to run the entire race without stopping, and he is seeking training services. He reports having what he describes as a "mild heart attack" at 45 yr old, completed cardiac rehabilitation, and has had no problems since. He takes a statin, an angiotensin-converting enzyme (ACE) inhibitor, and aspirin daily. During the last visit with his cardiologist, which took place 2 yr ago, the cardiologist noted no changes in his medical condition.

CASE STUDY II

A 22-yr-old recent college graduate is joining a gym. Since becoming an accountant 6 mo ago, she no longer walks across campus or plays intramural soccer and has concerns about her now sedentary lifestyle. Although her body mass index (BMI) is slightly above normal, she reports no significant medical history and no symptoms of any diseases, even when walking up three flights of stairs to her apartment. She would like to begin playing golf.

CASE STUDY III

A 45-yr-old former collegiate swimmer turned avid lifelong triathlete who trains at least 60 min $\cdot$ d^{-1}, 6 d $\cdot$ wk^{-1} requests assistance with run training. His only significant medical history is a series of overuse injuries to his shoulders and Achilles tendon. In recent weeks, he notes his vigorous intensity workouts are unusually difficult and reports feeling constriction in his chest with exertion — something he attributes to deficiencies in core strength. Upon further questioning, he explains that the chest constriction is improved with rest and that he often feels dizzy during recovery.

CASE STUDY IV

A 60-yr-old woman is beginning a professionally led walking program. Two years ago, she had a drug-eluting stent placed in her left anterior descending coronary artery after a routine exercise stress test revealed significant ST-segment depression. She completed a brief cardiac rehabilitation program in the 2 mo following the procedure but has been inactive since. She reports no signs or symptoms and takes a cholesterol-lowering statin and antiplatelet medications as directed by her cardiologist.

CASE STUDY V

A 35-yr-old business consultant is in town for 2 wk and seeking a temporary membership at a fitness club. She and her friends have been training at a moderate-to-vigorous intensity for a long-distance charity bike ride for the past 16 wk; she is unable to travel with her bike and she does not want to lose her fitness. She reports no current symptoms of cardiovascular (CV) or metabolic disease and has no medical history except hyperlipidemia, for which she takes a cholesterol-lowering statin daily.

	Case Study I	Case Study II	Case Study III	Case Study IV	Case Study V
Currently participates in regular exercise?	Yes	No	Yes	No	Yes
Known CV, metabolic, or renal disease?	Yes	No	No	Yes	No
Signs or symptoms suggestive of disease?	No	No	Yes	No	No
Desired intensity?	Vigorous	Moderate	Vigorous	Moderate	Vigorous
Medical clearance needed?	Yes	No	Yes	Yes	No

Alternative Self-Guided Method

In the absence of a qualified exercise or health care professional, preparticipation health screening using a self-screening tool should be completed by any individual wishing to initiate an exercise program. The PAR-Q+ (*Figure 2.4*), includes seven questions followed by several additional follow-up questions to guide preparticipation recommendations (33). The PAR-Q+ is an evidence-based tool and was developed in part to reduce barriers for exercise and false positive screenings (34). The tool uses follow-up questions to better tailor preexercise recommendations based on relevant medical history and symptomatology. The PAR-Q+ may be used as a self-guided exercise preparticipation health screening tool or as a supplemental tool for professionals that may want additional screening resources beyond the ACSM algorithm. Considering the cognitive ability required to fully answer the PAR-Q+, some individuals may require assistance completing the assessment. Fitness professionals should follow up with the individual to make sure all questions are answered accurately or ask follow-up questions if needed.

2020 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor **OR a qualified exercise professional before becoming more physically active.**

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1) Has your doctor ever said that you have a heart condition ☐ **OR** high blood pressure ☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** ______	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** ______	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it **does not limit your current ability** to be physically active. **PLEASE LIST CONDITION(S) HERE:** ______	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.
Please sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow Global Physical Activity Guidelines for your age (https://apps.who.int/iris/handle/10665/44399).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and NOT accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

PARTICIPANT DECLARATION

If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for its records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME ______ DATE ______

SIGNATURE ______ WITNESS ______

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at www.eparmedx.com before becoming more physically active.
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

2020 PAR-Q+

FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

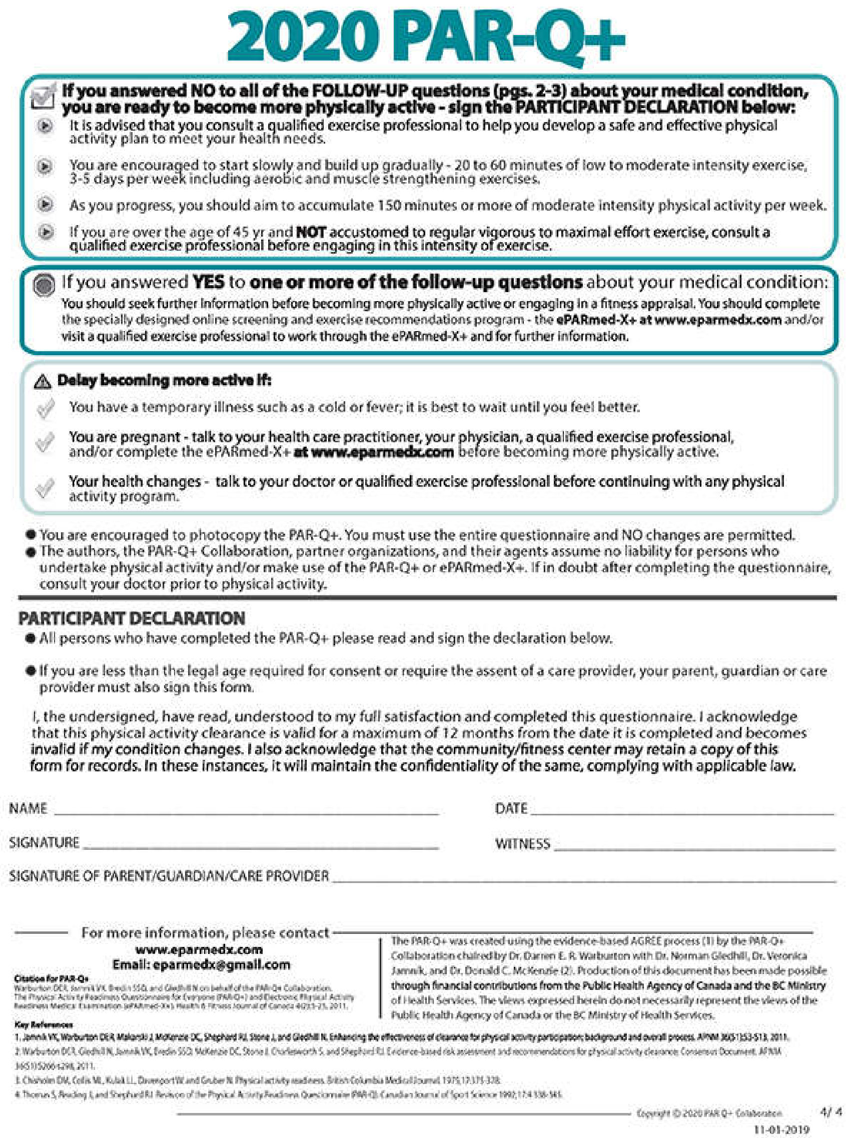
1.	**Do you have Arthritis, Osteoporosis, or Back Problems?** If the above condition(s) is/are present, answer questions 1a-1c	If **NO** ☐ go to question 2
1a.	**Do you have difficulty controlling your condition with medications or other physician-prescribed therapies?** (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	YES ☐ NO ☐
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	YES ☐ NO ☐
2.	**Do you currently have Cancer of any kind?** If the above condition(s) is/are present, answer questions 2a-2b	If **NO** ☐ go to question 3
2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and/or neck?	YES ☐ NO ☐
2b.	Are you currently receiving cancer therapy (such as chemotheraphy or radiotherapy)?	YES ☐ NO ☐
3.	**Do you have a Heart or Cardiovascular Condition? This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm** If the above condition(s) is/are present, answer questions 3a-3d	If **NO** ☐ go to question 4
3a.	**Do you have difficulty controlling your condition with medications or other physician-prescribed therapies?** (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
3b.	Do you have an irregular heart beat that requires medical management? **(e.g., atrial fibrillation, premature ventricular contraction)**	YES ☐ NO ☐
3c.	Do you have chronic heart failure?	YES ☐ NO ☐
3d.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	YES ☐ NO ☐
4.	**Do you currently have High Blood Pressure?** If the above condition(s) is/are present, answer questions 4a-4b	If **NO** ☐ go to question 5
4a.	**Do you have difficulty controlling your condition with medications or other physician-prescribed therapies?** (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
4b.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure)	YES ☐ NO ☐
5.	**Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes** If the above condition(s) is/are present, answer questions 5a-5e	If **NO** ☐ go to question 6
5a.	**Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies?**	YES ☐ NO ☐
5b.	**Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living?** Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, **abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness.**	YES ☐ NO ☐
5c.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or **complications affecting your eyes, kidneys, OR** the sensation in your toes and feet?	YES ☐ NO ☐
5d.	Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?	YES ☐ NO ☐
5e.	Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?	YES ☐ NO ☐

2020 PAR-Q+

6.	**Do you have any Mental Health Problems or Learning Difficulties?** This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome If the above condition(s) is/are present, answer questions 6a-6b	If **NO** ☐ go to question 7
6a.	**Do you have difficulty controlling your condition with medications or other physician-prescribed therapies?** (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
6b.	Do you have Down Syndrome **AND** back problems affecting nerves or muscles?	YES ☐ NO ☐
7.	**Do you have a Respiratory Disease?** This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure If the above condition(s) is/are present, answer questions 7a-7d	If **NO** ☐ go to question 8
7a.	**Do you have difficulty controlling your condition with medications or other physician-prescribed therapies?** (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
7b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	YES ☐ NO ☐
7c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	YES ☐ NO ☐
7d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	YES ☐ NO ☐
8.	**Do you have a Spinal Cord Injury?** This includes Tetraplegia and Paraplegia If the above condition(s) is/are present, answer questions 8a-8c	If **NO** ☐ go to question 9
8a.	**Do you have difficulty controlling your condition with medications or other physician-prescribed therapies?** (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
8b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	YES ☐ NO ☐
8c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	YES ☐ NO ☐
9.	**Have you had a Stroke?** This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event If the above condition(s) is/are present, answer questions 9a-9c	If **NO** ☐ go to question 10
9a.	**Do you have difficulty controlling your condition with medications or other physician-prescribed therapies?** (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
9b.	Do you have any impairment in walking or mobility?	YES ☐ NO ☐
9c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	YES ☐ NO ☐
10.	**Do you have any other medical condition not listed above or do you have two or more medical conditions?** If you have other medical conditions, answer questions 10a-10c	If **NO** ☐ read the Page 4 recommendations
10a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months?	YES ☐ NO ☐
10b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	YES ☐ NO ☐
10c.	Do you currently live with two or more medical conditions?	YES ☐ NO ☐

PLEASE LIST YOUR MEDICAL CONDITION(S) AND ANY RELATED MEDICATIONS HERE: ____________________

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.



2020 PAR-Q+

If you answered NO to all of the FOLLOW-UP questions (pgs. 2-3) about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered **YES** to **one or more of the follow-up questions** about your medical condition:
You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+ at www.eparmedx.com** and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ **at www.eparmedx.com** before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

- All persons who have completed the PAR-Q+ please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME ____________________ DATE ____________________

SIGNATURE ____________________ WITNESS ____________________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ____________________

For more information, please contact
www.eparmedx.com
Email: eparmedx@gmail.com

Citation for PAR-Q+
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The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+ Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or the BC Ministry of Health Services.

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11-01-2019

Figure 2.4 The Physical Activity Readiness Questionnaire for Everyone (PAR-Q+). Reprinted with permission from the PAR-Q+ Collaboration and the authors of the PAR-Q+ (32). See http://eparmedx.com/wp-content/uploads/2013/03/January2020PARQPlusFillable.pdf for the most current annual update of the PAR-Q+.

Exercise Testing

The ACSM preparticipation algorithm provides guidance regarding the need for a medical evaluation and for determining exercise intensity for individuals starting or progressing an exercise program. However, this procedure is not intended as a sole screening tool prior to conducting exercise testing and should accompany other screening tools (Health History Questionnaire [HHQ], PAR-Q+, etc.), particularly when conducting maximal exercise tests, which are commonly done in research, clinical, fitness, and performance-based settings. A review of 51 studies found the risks of fatal (0.2–0.8 per 10,000 tests) and nonfatal (1.4 per 10,000 tests) events during maximal exercise testing in apparently healthy individuals are rare (7). Submaximal exercise testing (see *Chapter 3*), which is commonly used in health fitness settings with nonclinical populations, likely confers an even lower risk of untoward events; however, there are no data that specifically describe this risk (7). As such, individuals conducting maximal exercise testing should follow suggested guidelines as outlined in *Chapter 4*, which outlines issues such as indications and contraindications for testing (see *Box 4.1*), pretest likelihood of ischemic heart disease, utility of testing, how to best conduct the test, staffing and monitoring the test, testing protocols, terminating the test, and interpreting the test. In addition, clinical and research facilities, in coordination with their respective ethical review boards, typically have their own set of testing guidelines, or protocol specific guidelines, to conduct maximal exercise testing, and these should be followed at all times.

Risk Stratification for Individuals with Clinical Conditions and Medical Fitness Facilities

Previous sections in this chapter presented the ACSM preparticipation screening algorithm for the general public. Exercise professionals working with individuals with known CVD or any other clinical condition in exercise-based cardiac rehabilitation or medical fitness settings are advised to use more in-depth risk stratification procedures, such as those defined by the American Association of Cardiovascular and Pulmonary Rehabilitation (AACVPR) and presented in *Box 2.2* (35).

Box 2.2 **American Association of Cardiovascular and Pulmonary Rehabilitation Risk Stratification Algorithm for Risk of Event**

Patient is at **HIGH RISK** if ANY ONE OR MORE of the following factors are present:

- Left ventricular ejection fraction <40%
- Survivor of cardiac arrest or sudden death
- Complex ventricular dysrhythmias (ventricular tachycardia, frequent [>6 beats · min^{-1}] multiform PVCs) at rest or with exercise
- MI or cardiac surgery complicated by cardiogenic shock, CHF, and/or signs/symptoms of postprocedure ischemia
- Abnormal hemodynamics with exercise, especially flat or decreasing systolic blood pressure or chronotropic incompetence with increasing workload
- Significant silent ischemia (ST depression 2 mm or greater without symptoms) with exercise or in recovery
- Signs/symptoms including angina pectoris, dizziness, light-headedness or dyspnea at low levels of exercise (<5.0 METs) or in recovery
- Maximal functional capacity of less than 5.0 METs
  - If measured functional capacity is not available, this factor can be excluded.
- Clinically significant depression or depressive symptoms

Patient is at **MODERATE RISK** if they meet neither high-risk nor low-risk standards:

- Left ventricular ejection fraction = 40%–50%
- Signs/symptoms including angina at "moderate" levels of exercise (60%–75% of maximal functional capacity) or in recovery
- Mild to moderate silent ischemia (ST depression less than 2 mm) with exercise or in recovery

Patient is at **LOW RISK** if ALL of the following factors are present:

- Left ventricular ejection fraction >50%
- No resting or exercise-induced complex dysrhythmias
- Uncomplicated MI, CABG, angioplasty, atherectomy, or stent:
  - Absence of CHF or signs/symptoms indicating postevent ischemia
- Normal hemodynamic and ECG responses with exercise and in recovery
- Asymptomatic with exercise or in recovery, including absence of angina
- Maximal functional capacity at least 7.0 METs
  - If measured functional capacity is not available, this factor can be excluded.
- Absence of clinical depression or depressive symptoms

CABG, coronary artery bypass graft; CHF, congestive heart failure; ECG, electrocardiogram; METs, metabolic equivalents; MI, myocardial infarction; PVCs, premature ventricular contractions.

Reprinted with permission from (35).

PREEXERCISE EVALUATION

Regardless of the extent of the preexercise evaluation, the findings should guide the decision about the need for medical clearance, exercise testing, and exercise prescription (Ex R_x).

MEDICAL HISTORY AND CARDIOVASCULAR DISEASE RISK FACTOR ASSESSMENT

The medical history and CVD risk factor assessment (*Table 2.2*) are used to provide exercise professionals with more in-depth information regarding the health and well-being of each individual. This information can guide decisions about exercise testing and program design. On occasion, the preexercise evaluation will identify individuals who should be referred for medical clearance due to health challenges not included in the preparticipation health screening procedure. Individuals with chronic disease and other health challenges may be encountered in health fitness settings, so the exercise professional is urged to be prudent in identifying those who need a specialized Ex R_x or medical clearance. In clinical settings, or medical fitness centers, a more comprehensive medical history may be warranted.

TABLE 2.2 • Cardiovascular Disease (CVD) Risk Factors and Defining Criteria

Positive Risk Factors[a]	Defining Criteria
Age	Men ≥45 yr; women ≥55 yr (36)
Family history	Myocardial infarction, coronary revascularization, or sudden death before 55 yr in father or other male first-degree relative or before 65 yr in mother or other female first-degree relative (37)
Cigarette smoking	Current cigarette smoker or those who quit within the previous 6 mo or exposure to environmental tobacco smoke (37,38)
Physical inactivity	Not meeting the minimum threshold of 500–1,000 MET-min of moderate-to-vigorous physical activity or 75–150 min $\cdot$ wk^{-1} of moderate-to-vigorous intensity physical activity (23)
Body mass index/waist circumference	Body mass index ≥30 kg $\cdot$ m^{-2} or waist girth >102 cm (40 in) for men and >88 cm (38 in) for women (39)
Blood pressure	Systolic blood pressure ≥130 mm Hg and/or diastolic ≥80 mm Hg, based on an average of ≥2 readings obtained on ≥2 occasions, or on antihypertensive medication (40)
Lipids	Low-density lipoprotein cholesterol (LDL-C) ≥130 mg $\cdot$ dL^{-1} (3.37 mmol $\cdot$ L^{-1}) or high-density lipoprotein cholesterol (HDL-C) <40 mg $\cdot$ dL^{-1} (1.04 mmol $\cdot$ L^{-1}) in men and <50 mg $\cdot$ dL^{-1} (1.30 mmol $\cdot$ L^{-1}) in women or non-HDL-C <130 (3.37 mmol $\cdot$ L^{-1}) or on lipid-lowering medication. If total serum cholesterol is all that is available, use ≥200 mg $\cdot$ dL^{-1} (5.18 mmol $\cdot$ L^{-1}) (41).
Blood glucose	Fasting plasma glucose ≥100 mg $\cdot$ dL^{-1} (5.5 mmol $\cdot$ L^{-1}); or 2 h plasma glucose values in oral glucose tolerance test (OGTT) ≥140 mg $\cdot$ dL^{-1} (7.77 mmol $\cdot$ L^{-1}); or HbA1C ≥5.7% (42)
Negative Risk Factors	**Defining Criteria**
HDL-C[b]	≥60 mg $\cdot$ dL^{-1} (1.55 mmol $\cdot$ L^{-1}) (41)

[a]If the presence or absence of a CVD risk factor is not disclosed or is not available, that CVD risk factor should be counted as a risk factor.

[b]High HDL-C is considered a negative risk factor. For individuals having high HDL ≥60 mg $\cdot$ dL^{-1} (1.55 mmol $\cdot$ L^{-1}), one positive risk factor is subtracted from the sum of positive risk factors.

HbA1C, glycated hemoglobin; MET, metabolic equivalent; non-HDL-C, total cholesterol minus HDL-C.

The preexercise medical history should be thorough and include past and current information. Appropriate components of the medical history are presented in *Box 2.3*. Identifying and controlling CVD risk factors continues to be an important objective of overall CV and metabolic disease prevention and management (43,44). CVD risk factor assessment provides important information for the development of an individual's Ex R_x, as well as for lifestyle modification, and is an important opportunity for one-to-one education about CVD risk reduction. Criteria for hypertension (*Table 2.3*) and dyslipidemia (*Tables 2.4 and 2.5*) are essential parts of developing an appropriate Ex R_x. Therefore, exercise professionals are encouraged to complete a CVD risk factor assessment with each individual to determine if the individual meets any of the criteria for CVD risk factors (see *Table 2.2*). If the presence of a CVD risk factor is uncertain or is not available, that CVD risk factor should be counted as a risk factor. Because of the cardioprotective effect of high-density lipoprotein cholesterol (HDL-C), high levels [≥60 mg · dL^{-1} (1.55 mmol · L^{-1})] of this lipoprotein are considered a negative CVD risk factor (41). Therefore, for individuals with HDL-C levels greater than 60 mg · dL^{-1} (1.55 mmol · L^{-1}), one positive CVD risk factor is subtracted from the sum of positive CVD risk factors. *Box 2.4* provides a framework for conducting CVD risk factor assessment.

Box 2.3 Components of the Medical History

Appropriate components of the medical history may include the following:

- Medical diagnoses and history of medical procedures: cardiovascular disease risk factors including hypertension, obesity, dyslipidemia, and diabetes; cardiovascular disease including heart failure, valvular dysfunction (*e.g.*, aortic stenosis/mitral valve disease), myocardial infarction, and other acute coronary syndromes; percutaneous coronary interventions including angioplasty and coronary stent(s), coronary artery bypass surgery, and other cardiac surgeries such as valvular surgeries; cardiac transplantation; pacemaker and/or implantable cardioverter defibrillator; ablation procedures for dysrhythmias; peripheral vascular disease; pulmonary disease including asthma, emphysema, and bronchitis; cerebrovascular disease including stroke and transient ischemic attacks; anemia and other blood dyscrasias (*e.g.*, lupus erythematosus); phlebitis, deep vein thrombosis, or emboli; cancer; pregnancy; osteoporosis; musculoskeletal disorders; emotional disorders; and eating disorders
- Previous physical examination findings: murmurs, clicks, gallop rhythms, other abnormal heart sounds, and other unusual cardiac and vascular findings; abnormal pulmonary findings (*e.g.*, wheezes, rales, crackles), high blood pressure, and edema
- Laboratory findings (*i.e.*, plasma glucose, HbA1C, hs-CRP, serum lipids and lipoproteins)
- History of symptoms: discomfort (*e.g.*, pressure, tingling sensation, pain, heaviness, burning, tightness, squeezing, numbness) in the chest, jaw, neck, back, or arms; light-headedness, dizziness, or fainting; temporary loss of visual acuity or speech; transient unilateral numbness or weakness; shortness of breath; rapid heartbeat or palpitations, especially if associated with physical activity, eating a large meal, emotional upset, or exposure to cold (or any combination of these activities)
- Recent illness, hospitalization, new medical diagnoses, or surgical procedures
- Orthopedic problems including arthritis, joint swelling, and any condition that would make ambulation or use of certain test modalities difficult
- Medication use (including dietary/nutritional supplements) and drug allergies
- Other habits including caffeine, alcohol, tobacco, or recreational (illicit) drug use
- Exercise history: information on readiness for change and habitual level of activity: frequency, duration or time, type, and intensity or FITT of exercise
- Work history with emphasis on current or expected physical demands, noting upper and lower extremity requirements
- Family history of cardiac, pulmonary, or metabolic disease, stroke, or sudden death

FITT, Frequency, Intensity, Time, and Type; HbA1C, glycosylated hemoglobin; hs-CRP, high-sensitivity C-reactive protein.

TABLE 2.3 • Classification and Management of Blood Pressure (BP) for Adults[a,b]

ACC/AHA criteria[c]				
BP classification	**Normal**	**Elevated**	**Stage 1 hypertension**	**Stage 2 hypertension**
SBP (mm Hg)	<120	120–129	130–139	**≥140**
DBP (mm Hg)	<80	<80	80–89	**≥90**
Treatment recommendations	Promote optimal lifestyle habits; reassess yearly.	Nonpharmacological therapy; reassess in 3–6 mo.	Estimate 10-yr CVD risk. If <10% risk, start with healthy lifestyle recommendation; reassess in 3–6 mo. If ≥10% risk or ASCVD, DM, kidney disease, recommend lifestyle change and pharmacological treatment; reassess within 1 mo.	Nonpharmacological treatment and BP-lowering medication; follow-up monthly until BP is controlled

JNC criteria[d]				
BP classification	**Normal**	**Prehypertension**	**Hypertension, stage 1**	**Hypertension, stage 2**
SBP (mm Hg)	<120	120–139	140–159	**≥160**
DBP (mm Hg)	<80	80–89	90–99	**≥100**
Treatment recommendations	Promote optimal	Lifestyle modifications	Lifestyle modifications	Lifestyle modifications and

	lifestyle habits; reassess yearly.		and BP-lowering medication	BP-lowering medication

[a]Individuals are classified in any given category by meeting either of SBP or DBP thresholds.

[b]Individuals with SBP and DBP in two classifications should be designated to the higher BP classification.

[c]Whelton PK, Carey RM, Aronow WS, et al. Systematic review for the 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA guideline for the prevention, detection, evaluation, and management of high blood pressure in adults: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Hypertension*. 2018;71:1269–1324. doi:10.1161/HYP.0000000000000066

[d]Chobanian AV, Bakris GL, Black HR, et al. Seventh report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. *Hypertension*. 2003;42(6):1206–52.

ASCVD, atherosclerotic cardiovascular disease; DBP, diastolic BP; SBP, systolic BP.

TABLE 2.4 • Classifications of Cholesterol and Triglycerides Levels (mg · dL^{-1}) (45)

Non-HDL-C	
<130	Desirable
130–159	Above desirable
160–189	Borderline high
190–219	High
≥220	Very high
LDL-C	
<100	Desirable
100–129	Above desirable
130–159	Borderline high
160–189	High
≥190	Very high
HDL-C	
<40 (men)	Low
<50 (women)	Low
Triglycerides	
<150	Normal
150–199	Borderline high
200–499	High
≥500	Very high[a]

[a]Severe hypertriglyceridemia is another term used for very high triglycerides in pharmaceutical product labeling.
HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; non-HDL-C, total cholesterol minus HDL-C.

TABLE 2.5 • Atherosclerotic Cardiovascular Disease Risk Categories and LDL-C Treatment Goals (29)

	Risk category	Risk factors[a]/10-yr risk[b]	Treatment Goals LDL-C ($mg \cdot dL^{-1}$)	Non-HDL-C ($mg \cdot dL^{-1}$)	apoB ($mg \cdot dL^{-1}$)
Extreme risk	AACE	• Progressive ASCVD after achieving an LDL-C <70 $mg \cdot dL^{-1}$ • Established clinical cardiovascular disease in patients with DM, CKD stage 3 or 4, or HeFH • History of premature ASCVD (<55 male, <65 female)	<55	<80	<70
	EAS	No recommendations made	—	—	—
Very high risk	AACE	• Established or recent hospitalization for ACS; coronary, carotid, or peripheral vascular disease; 10-yr risk >20% • Diabetes or CKD stage 3 or 4 with one or more risk factor(s) • HeFH	<70	<100	<80
	EAS	• Established ASCVD • Severe CKD (GFR <30) • DM with target organ damage or major risk factor	<70	<100	<80
High risk	AACE	• >2 risk factors and 10-yr risk 10%–20% • Diabetes or CKD stage 3 or 4 with no other risk factors	<100	<130	<90
	EAS	• Diabetes, moderate CKD (GFR 30–50), 10-yr risk 5%–10%, familial hypercholesterolemia	<100	<130	<100
Moderate risk	AACE	<2 risk factors and 10-yr risk <10%	<100	<130	<90
	EAS	10-yr risk 1%–5%	<115	—	—

AACE	No risk factors	<130	<160	NR
EAS	10-yr risk <1%	<115	—	—

[a]Major independent risk factors are high LDL-C, polycystic ovary syndrome, cigarette smoking, hypertension (blood pressure ≥140/90 mm Hg or on hypertensive medication), low HDL-C (<40 mg · dL^{-1}), family history of coronary artery disease (in male, first-degree relative younger than 55 yr; in female, first-degree relative younger than 65 yr), chronic renal disease (CKD) stage 3 or 4, evidence of coronary artery calcification and age (men ≥45 yr; women ≥55 yr). Subtract 1 risk factor if the person has high HDL-C.

[b]Framingham risk scoring is applied to determine 10-yr risk.

AACE, American Association of Clinical Endocrinologists and American College of Endocrinology; ACS, acute coronary syndrome; apoB, apolipoprotein B; ASCVD, atherosclerotic cardiovascular disease; CKD, chronic kidney disease; DM, diabetes mellitus; EAS, European Atherosclerotic Society; GFR, glomerular filtration rate; HDL-C, high-density lipoprotein cholesterol; HeFH, heterozygous familial hypercholesterolemia; LDL-C, low-density lipoprotein cholesterol; NR, not recommended.

Box 2.4 Case Studies to Conduct Cardiovascular Disease Risk Factor Assessment

CASE STUDY I

Female, age 21 yr, smokes socially on weekends (~10–20 cigarettes). Drinks alcohol one or two nights a week, usually on weekends. Height = 63 in (160 cm), weight = 124 lb (56.4 kg), BMI = 22.0 kg · m^{-2}. RHR = 76 beats · min^{-1}, resting BP = 118/72 mm Hg. Total cholesterol = 178 mg · dL^{-1} (4.61 mmol · L^{-1}), LDL-C = 98 mg · dL^{-1} (2.54 mmol · L^{-1}), HDL-C = 62 mg · dL^{-1} (1.60 mmol · L^{-1}), FBG = 96 mg · dL^{-1} (5.33 mmol · L^{-1}). Currently taking oral contraceptives. Attends 45 min moderate intensity group exercise class two to three times a week; both parents living and in good health.

CASE STUDY II

Man, age 45 yr, nonsmoker. Height = 72 in (182.9 cm), weight = 168 lb (76.4 kg), BMI = 22.8 kg · m^{-2}. RHR = 64 beats · min^{-1}, resting BP = 124/78 mm Hg. Total cholesterol = 187 mg · dL^{-1} (4.84 mmol · L^{-1}), LDL-C = 103 mg · L^{-1} (2.67 mmol · L^{-1}), HDL-C = 39 mg · dL^{-1} (1.01 mmol · L^{-1}), FBG = 88 mg · dL^{-1} (4.84 mmol · L^{-1}). Recreationally competitive runner, runs 4–7 d · wk^{-1}, completes one to two marathons and numerous other road races every year. No medications other than over-the-counter ibuprofen as needed. Father died at age 51 yr of a heart attack; mother died at age 81 yr of cancer.

CASE STUDY III

Man, age 44 yr, nonsmoker. Height = 70 in (177.8 cm), weight = 216 lb (98.2 kg), BMI = 31.0 kg · m^{-2}. RHR = 62 beats · min^{-1}, resting BP = 128/84 mm Hg. Total serum cholesterol = 184 mg · dL^{-1} (4.77 mmol · L^{-1}), LDL-C = 106 mg · dL^{-1} (2.75 mmol · L^{-1}), HDL-C = 44 mg · dL^{-1} (1.14 mmol · L^{-1}), FBG = 130 mg · dL^{-1} (7.22 mmol · L^{-1}). Reports that he does not have time to exercise. Father had Type 2 diabetes and died at age 67 yr of a heart attack; mother living, no CVD; no medications.

CASE STUDY IV

Woman, age 36 yr, nonsmoker. Height = 64 in (162.6 cm), weight = 108 lb (49.1 kg), BMI = 18.5 kg · m^{-2}. RHR = 61 beats · min^{-1}, resting BP = 142/86 mm Hg. Total cholesterol = 174 mg · dL^{-1} (4.51 mmol · L^{-1}), blood glucose normal with insulin injections. Type 1 diabetes mellitus diagnosed at age 7 yr. She teaches high intensity cardio kickboxing classes three times per week and walks at a moderate intensity for approximately 45 min four times a week; both parents in good health with no history of CVD.

	Case Study I	Case Study II	Case Study III	Case Study IV
CVD risk factors:				
Age?	No	Yes	No	No
Family history?	No	Yes	No	No
Cigarette smoking?	Yes	No	No	No
Physical inactivity?	No	No	Yes	No
Obesity?	No	No	Yes	No
Hypertension?	No	No	Yes	Yes
Dyslipidemia?	No	Yes	No	No
Diabetes?	No	No	Yes	Yes
Negative risk factor:				
HDL-C ≥60 mg · dL^{-1}	Yes	No	No	No

Number of CVD risk factors	Zero	Three	Four	Two

BMI, body mass index; BP, blood pressure; CVD, cardiovascular disease; FBG, fasting blood glucose; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; RHR, resting heart rate.

Additional Recommendations

If warranted, a preliminary physical examination should be performed by a physician or other qualified health care provider. Appropriate components of the physical examination specific to subsequent exercise testing are presented in *Box 2.5*. Recommended laboratory tests, depending on individual risk factors, signs, and symptoms, could include fasting serum total cholesterol, fasting plasma glucose, 12-lead ECG, Holter monitoring, cardiac echocardiography, chest radiography, pulmonary function, and oximetry. Although detailed descriptions of all the physical examination procedures and the recommended laboratory tests are beyond the scope of the *Guidelines*, additional basic information related to assessment of CVD risk factors are provided in subsequent chapters of the *Guidelines*. The reader is encouraged to read the sections pertinent to the risk factor of interest and information related to exercise testing and prescription related to that condition. Additionally, for more detailed descriptions of these assessments, the reader is referred to the work of Bickley and Szilagyi (45,46).

Box 2.5 Components of the Preparticipation Physical Examination*

Appropriate components of the physical examination may include the following:

- Body weight; in many instances, determination of body mass index, waist girth, and/or body composition (body fat percentage) is desirable.
- Apical pulse rate and rhythm
- Resting blood pressure: seated, supine, and standing
- Auscultation of the lungs with specific attention to uniformity of breath sounds in all areas (absence of rales, wheezes, and other breathing sounds)
- Palpation of the cardiac apical impulse and point of maximal impulse
- Auscultation of the heart with specific attention to murmurs, gallops, clicks, and rubs
- Palpation and auscultation of carotid, abdominal, and femoral arteries
- Evaluation of the abdomen for bowel sounds, masses, visceromegaly, and tenderness
- Palpation and inspection of lower extremities for edema and presence of arterial pulses
- Absence or presence of tendon xanthoma and skin xanthelasma
- Follow-up examination related to orthopedic or other medical conditions that would limit exercise testing
- Tests of neurologic function including reflexes and cognition (as indicated)
- Inspection of the skin, especially of the lower extremities in known patients with diabetes mellitus

*For more detailed information see (46).

ONLINE RESOURCES

American College of Cardiology: http://tools.acc.org/ASCVD-Risk-Estimator-Plus/#!/calculate/estimate/
American College of Sports Medicine Exercise is Medicine: http://www.exerciseismedicine.org

American Diabetes Association: http://www.diabetes.org
American Heart Association: http://www.americanheart.org
European Society of Cardiology: http://www.escardio.org
National Heart, Lung, and Blood Institute Health Information for Professionals:
http://www.nhlbi.nih.gov/health/indexpro.htm

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CHAPTER 3

Health-Related Physical Fitness Testing and Interpretation

INTRODUCTION

Current evidence clearly supports the numerous health benefits resulting from regular participation in physical activity (PA) and structured exercise programs (1). Health-related components of physical fitness have a strong relationship with overall health, are characterized by an ability to perform activities of daily living with vigor, and are associated with a lower prevalence of chronic disease and health conditions and their associated risk factors (2). Measures of health-related physical fitness are closely aligned with both disease prevention and health promotion. Skill-related components typically associated with sport performance (*i.e.*, power and agility) are also important, particularly in supporting an independent living status as one ages (3–5). A fundamental goal of primary and secondary prevention and rehabilitation programs should be the promotion of health; hence, exercise programs should focus on enhancement of the health-related components of physical fitness. This chapter therefore focuses on the health-related components of physical fitness testing and interpretation.

PURPOSES OF HEALTH-RELATED PHYSICAL FITNESS TESTING

Measurement of physical fitness is a common and appropriate practice in preventive and rehabilitative exercise programs. Minimally, a health-related physical fitness test must be both reliable and valid, and ideally, it should be relatively inexpensive. The information obtained from health-related physical fitness testing, in combination with the individual's medical and exercise history, is used for the following:

- Collecting baseline data and educating individuals about their present health/fitness status relative to health-related standards and age- and sex-matched norms
- Providing data that are helpful in the development of individualized exercise programs to address all health/fitness components
- Collecting follow-up data that allow evaluation of short- and long-term progress following an exercise prescription (Ex R_x)
- Motivating individuals by establishing reasonable and attainable health/fitness goals (see *Chapter 12*)

BASIC PRINCIPLES AND GUIDELINES

Pretest Instructions for Fitness Testing

All pretest instructions should be provided and adhered to prior to arrival at the testing facility. The following steps should be taken to ensure individual safety and comfort before administering any physical fitness tests:

- Make the informed consent document available and allow ample time for the individual undergoing assessment to have all questions adequately addressed (see *Figure 2.1*).
- Perform a preparticipation screening evaluation to determine the need for medical evaluation based on sign/symptoms of cardiovascular, metabolic and/or renal disease. A minimal recommendation is that individuals complete a self-guided questionnaire such as the Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) (see *Figure 2.4*). Other more detailed medical history forms may also be used.
- Follow the list of preliminary testing instructions for all individuals highlighted in *Chapter 2*. These instructions may be modified to meet specific needs and circumstances.

The reader is encouraged to review the detailed instructions related to preexercise assessment protocols provided in *Chapter 2*.

Organizing the Fitness Test

The following should be accomplished before the individual begins a fitness test:

- Ensure all consent and screening forms, data recording sheets, and any related testing documents are available in the individual's file prior to test administration.
- Ensure that selected testing equipment (*e.g.*, cycle ergometer, treadmill, sphygmomanometer, skinfold caliper) has been calibrated according to manufacturer's recommendation, or more frequently, based on use (*e.g.*, ventilatory expired gas analysis systems, blood pressure [BP] sphygmomanometer), and document all equipment calibration. Skinfold calipers should be regularly checked for accuracy and sent to the manufacturer for calibration when needed.
- Ensure a room temperature between 68° F and 72° F (20° C and 22° C) and humidity of less than 60% with adequate airflow (6).

When multiple tests are to be administered during the same appointment, the sequencing of the testing session can be important, depending on which physical fitness components are to be evaluated. Resting measurements such as heart rate (HR), BP, height, weight, and body composition should be obtained first. An optimal testing order for exertional fitness components (*i.e.*, cardiorespiratory fitness [CRF], muscular fitness, and flexibility) has not been established, but sufficient time should be allowed for HR and BP to return to baseline between tests conducted serially. Additionally, tests should be arranged in an order that does not result in stressing the same muscle group repeatedly. To ensure reliability, the chosen order should be followed on subsequent testing sessions. Because certain medications (*e.g.*, β-blockers) will affect some physical fitness test results, use of these medications should be noted (see *Appendix A*).

Test Environment

The environment is important for test validity and reliability. Test anxiety, emotions, room temperature, and ventilation should be controlled as much as possible. To minimize individual anxiety, the test procedures should be explained adequately and should not be rushed, and the test environment should be quiet and private. The room should be equipped with a comfortable seat and/or examination table to be used for resting HR and BP. The demeanor of personnel should be one of relaxed confidence to put the individual at ease. Finally, the exercise professional should be familiar with the facility's emergency response plan (7).

A COMPREHENSIVE HEALTH FITNESS EVALUATION

A comprehensive health/fitness assessment can usually be completed in a single session and includes the following: (a) informed consent, exercise preparticipation health screening, and preexercise evaluation (see *Chapter 2*); (b) resting measurements; (c) circumference measurements and body composition analysis; (d) measurement of CRF; (e) measurement of muscular fitness; and (f) measurement of flexibility. Additional evaluations, such as static and dynamic balance measurements, may be administered. The data accrued from the evaluation should be interpreted by a competent exercise professional and conveyed to the individual in terms he or she can understand. This information is central to educate the individual about his or her current physical fitness status and to the development of the individual's short- and long-term goals as well as forming the basis for the individualized Ex R_x and subsequent evaluations to monitor progress.

The number of visible transgender individuals is increasing, and they are therefore more likely to be encountered by fitness and exercise professionals in their daily work. The current estimated number of adults reported as transgender in the United States is approximately 1.4 million (8). In regard to fitness testing and health risk status, many norms and criteria are based on sex recorded at birth, along with age and other discriminating factors. Herein lies the challenge to the exercise professional, as currently, there is little evidence to guide the decision as to which sex-based criteria and norms to use for transgender individuals undergoing medical treatment. Additionally, although it may seem intuitive to use the current gender identification to align with health and fitness norms, there is little current evidence to support this as of yet. Therefore, because there are few data and few norms for individuals in the midst of a medical treatment for gender incongruence, it may be best to use collected data only on an intrapersonal basis while norms are being developed.

For certain individuals, the risks of health-related physical fitness testing may outweigh the potential benefits. Some assessments pose little risk (*e.g.*, body composition), whereas others may have higher risks (*e.g.*, CRF and one repetition maximum [1-RM]) for some individuals. It is important to carefully assess risk versus benefit when deciding on whether a fitness test should be performed. Performing the preexercise evaluation with a careful review of current and prior medical history will help to identify the possible need for referral to a medical provider, potential contraindications, and also increases the safety of the health-related physical fitness assessment. *Box 4.1* provides a list of conditions that preclude exercise testing (absolute contraindication) or permit exercise testing if the benefits outweigh the risks (relative contraindications).

MEASUREMENT OF RESTING HEART RATE AND BLOOD PRESSURE

A comprehensive physical fitness assessment includes the measurement of resting HR and BP. HR can be determined using several techniques including pulse palpation, auscultation with a stethoscope, or the use of an HR monitor. Although more commonly used in clinical assessments, electrocardiogram (ECG) monitoring is also an option for monitoring HR. Upon arrival to the testing facility, it is important to allow each person time to relax and remain seated or assume a supine position on a nonconductive surface for at least 5 min before assessing HR and BP, to allow these measures to stabilize (9). The pulse palpation technique involves “feeling” the pulse by placing the index and middle fingers over the radial artery, located near the thumb side of the wrist. The pulse is counted for 30 or 60 s. The 30-s count is multiplied by 2 to determine the 1-min resting HR (beats per minute). For the auscultation method, the bell of the stethoscope should be placed to the left of the sternum just above the level of the nipple. The auscultation method is most accurate when the heart sounds are clearly audible, and the individual’s torso is stable. If an HR monitor (*i.e.*, chest strap or wristwatch) is used, it should fit snugly, be in direct contact with the skin, and positioned on the body as recommended by the manufacturer. The measurement of resting BP is described in *Box 3.1*. Potential sources of error in BP measurement are listed in *Box 3.2*.

Box 3.1 Procedures for Assessment of Resting Blood Pressure

1. Those being tested should be seated quietly for at least 5 min in a chair with back support (rather than on an examination table) with their feet on the floor and their arms supported at heart level. Individuals should refrain from smoking cigarettes or ingesting caffeine for at least 30 min preceding the measurement.
2. Measuring supine and standing values may be indicated under special circumstances.
3. Wrap cuff firmly around upper arm at heart level; align cuff with brachial artery.
4. The appropriate cuff size must be used to ensure accurate measurement. The bladder within the cuff should encircle at least 80% of the upper arm. Many adults require a large adult cuff.
5. Place stethoscope chest piece below the antecubital space over the brachial artery. Bell and diaphragm side of chest piece appear equally effective in assessing BP (10).
6. Quickly inflate cuff pressure to 20 mm Hg above the first Korotkoff sound.
7. Slowly release pressure at rate equal to 2–3 mm Hg · s^{-1}.
8. SBP is the point at which the first of two or more Korotkoff sounds is heard (phase 1), and DBP is the point before the disappearance of Korotkoff sounds (phase 5).

9. At least two measurements should be made (minimum of 1 min apart), and the average should be taken.
10. BP should be measured in both arms during the first examination. Higher pressure should be used when there is consistent interarm difference.
11. Provide to individuals, verbally and in writing, their specific BP numbers and BP goals.

BP, blood pressure; DBP, diastolic blood pressure; SBP, systolic blood pressure. Modified from (9). For additional, more detailed recommendations, see (11).

Box 3.2 Potential Sources of Error in Blood Pressure Assessment

- Inaccurate sphygmomanometer
- Improper cuff size
- Auditory acuity of technician
- Rate of inflation or deflation of cuff pressure
- Experience of technician
- Faulty equipment
- Improper stethoscope placement or pressure
- Not having the cuff at heart level
- Certain physiologic abnormalities (*e.g.*, damaged brachial artery, subclavian steal syndrome, arteriovenous fistula)
- Reaction time of technician[a]
- Background noise
- Allowing individuals to hold treadmill handrails or flex elbow[a]

[a]Applies specifically during exercise testing.

BODY COMPOSITION

It is well established that excess body fat, particularly when located centrally around the abdomen, is associated with many chronic conditions including hypertension, metabolic syndrome, Type 2 diabetes mellitus (T2DM), stroke, cardiovascular disease (CVD), and dyslipidemia (12,13). More than two-thirds (70.2%) of American adults are classified as either overweight or obese (body mass index [BMI] ≥25 kg · m^{-2}), and more than a third (37.7%) are classified as obese (BMI ≥30 kg · m^{-2}) (14). Nearly one-third (31.8%) of American children and adolescents are overweight or obese (15) (see *Chapter 9*). The data on overweight/obesity prevalence among the adult and pediatric populations and its health implications have precipitated an increased awareness in the value of identifying and treating individuals with excess body weight (16). Indeed in 2013, the American Medical Association labeled obesity as a disease (17).

It is important to recognize the health-related changes in body composition that accompany aging. Such changes may include increasing body fat, decreasing bone mineral density, and loss of muscle mass. Sarcopenia, the degenerative loss of muscle mass and strength as a result of aging and reduced PA, is associated with a reduced ability to perform activities of daily living and increases the fear of falling and risk of musculoskeletal injury (18). Thus, body composition measurement can be used to monitor changes in lean body mass, particularly among older adults.

Basic body composition can be expressed as the relative percentage of body mass that is fat and fat-free tissue using a two-component model. Body composition can be estimated with methods that vary in terms of complexity, cost, and accuracy (19). Different assessment techniques are briefly reviewed in this section, but details associated with obtaining measurements and calculating estimates of body fat for all of these techniques are beyond the scope of the *Guidelines*. Additional detailed information is available (20–22). Before collecting data for body composition assessment, the technician must be trained, experienced in the techniques, and already have demonstrated reliability in obtaining measurements, independent of the technique being used.

Anthropometric Methods

Height, Weight, and Body Mass Index

Body weight should be measured using a calibrated balance beam or electronic scale with the individual wearing minimal clothing and having empty pockets. Shoes should be removed prior to these assessments (21).

BMI, or the Quetelet index, is used to assess weight relative to height and is calculated by dividing body weight in kilograms by height in meters squared ($kg \cdot m^{-2}$). Common practice is to define a BMI of $<18.5\ kg \cdot m^{-2}$ as underweight, $18.5–24.9\ kg \cdot m^{-2}$ as normal, $25.0–29.9\ kg \cdot m^{-2}$ as overweight, and $\geq 30.0\ kg \cdot m^{-2}$ as obese (23). Because Asian populations develop health problems at lower BMI values in comparison to other population subgroups, using lower cut points for defining overweight and obesity for Asian populations ($\geq 23.0\ kg \cdot m^{-2}$ and $\geq 25.0\ kg \cdot m^{-2}$, respectively) is recommended (24). Moreover, the distribution of body weight and composition proportions are known to vary across different population subgroups (25), thereby raising questions about the suitability of BMI as a proxy for adiposity. Although BMI fails to distinguish between body fat, muscle mass, or bone, it is well accepted that with the exception of individuals with large amounts of muscle mass, those with a BMI $\geq 30\ kg \cdot m^{-2}$ have excess body fat. An increased risk of obesity-related diseases, health conditions, and mortality are associated with a BMI $\geq 30.0\ kg \cdot m^{-2}$ (*Table 3.1*) (27,28). This association is not perfect, as there is compelling evidence to indicate individuals diagnosed with congestive heart failure (CHF) actually have improved survival when BMI is ≥30.0 kg · m^{-2}, a phenomenon known as the “obesity paradox” (29).

TABLE 3.1 • Classification of Disease Risk Based on Body Mass Index (BMI) and Waist Circumference

		Disease Risk[a] Relative to Normal Weight and Waist Circumference	
	BMI (kg · m^{-2})	Men, ≤102 cm Women, ≤88 cm	Men, >102 cm Women, >88 cm
Underweight	<18.5	—	—
Normal	18.5–24.9	—	—
Overweight	25.0–29.9	Increased	High
Obesity, class			
I	30.0–34.9	High	Very high
II	35.0–39.9	Very high	Very high
III	≥40.0	Extremely high	Extremely high

[a]Disease risk for Type 2 diabetes, hypertension, and cardiovascular disease.
Dashes (—) indicate that no additional risk at these levels of BMI was assigned. Increased waist circumference can also be a marker for increased risk even in individuals of normal weight.
Modified from (26).

Compared to individuals classified as obese, the link between BMI in the overweight range (25.0–29.9 kg · m^{-2}) and higher mortality risk is less clear. However, a BMI of 25.0−29.9 kg · m^{-2} is convincingly linked to an increased risk for other health issues such as T2DM, dyslipidemia, hypertension, and certain cancers (30). A BMI of <18.5 kg · m^{-2} also increases mortality risk from causes other than cancer and CVD (31) and may be indicative of malnutrition, disordered eating, osteoporosis, and metabolic abnormalities (32). Despite the relationship between BMI and health risks, other methods of body composition assessment should be used to estimate percent body fat during a physical fitness assessment (33).

Circumferences

The measurement of regional body circumference can be important to quantify body fat distribution, especially of the waist and hip. The pattern of body fat distribution is recognized as an important indicator of health and prognosis (34). Android obesity that is characterized by more fat on the trunk (*i.e.*, abdominal fat) increases the risk of hypertension, metabolic syndrome, T2DM, dyslipidemia, CVD, and premature death compared with individuals who demonstrate gynoid or gynecoid obesity (*i.e.*, fat distributed in the hip and thigh) (35). Moreover, increased visceral fat (*i.e.*, fat within and surrounding thoracic and abdominal cavities) confers a higher risk for development of metabolic syndrome compared to distribution of fat within the subcutaneous compartment (36). Because of this, circumference (or girth) measurements may be used to provide a general representation of body fat distribution and subsequent risk. Equations are also available for both sexes and a range of age groups to predict body fat percentage from circumference measurements (standard error of estimate [SEE] = 2.5%–4.0%) (21,37,38). A cloth tape measure with a spring-loaded handle (*e.g.*, Gulick tape measure), which allows for the standardization of the tension of the tape on the skin is recommended, as it improves consistency of measurement; however, other types of tape measures can be used. Duplicate measurements are recommended at each site and should be obtained in a rotational instead of a consecutive order (*i.e.*, take one measurement at all sites being assessed and then repeat the sequence). An average of the two measures is used provided they do not differ by more than 5 mm. *Box 3.3* contains a description of the common measurement sites.

Box 3.3 Standardized Description of Circumference Sites and Procedures

Abdomen:	With the individual standing, a horizontal measure is taken at the height of the iliac crest, usually at the level of the umbilicus.
Arm:	With the individual standing and arms hanging freely at the sides with hands facing the thigh, a horizontal measure is taken midway between the acromion and olecranon processes.
Buttocks/hips:	With the individual standing and feet together, a horizontal measure is taken at the maximal circumference of the buttocks. This measure is used for the hip measure in the waist-to-hip ratio.
Calf:	With the individual standing (feet apart ~20 cm), a horizontal measure is taken at the level of the maximum circumference between the knee and the ankle, perpendicular to the long axis.
Forearm:	With the individual standing, arms hanging downward but slightly away from the trunk and palms facing anteriorly, a measure is taken perpendicular to the long axis at the maximal circumference.
Hips/thigh:	With the individual standing, legs slightly apart (~10 cm), a horizontal measure is taken at the maximal circumference of the hip/proximal thigh, just below the gluteal fold.
Midthigh:	With the individual standing and one foot on a bench so the knee is flexed at 90 degrees, a measure is taken midway between the inguinal crease and

the proximal border of the patella, perpendicular to the long axis.

Waist: With the individual standing, arms at the sides, feet together, and abdomen relaxed, a horizontal measure is taken at the narrowest part of the torso (above the umbilicus and below the xiphoid process). The National Obesity Task Force (NOTF) suggests obtaining a horizontal measure directly above the iliac crest as a method to enhance standardization (26). Unfortunately, current formulas are not predicated on the NOTF suggested site.

Procedures

- All measurements should be made with a flexible yet inelastic tape measure.
- The tape should be placed on the skin surface without compressing the subcutaneous adipose tissue.
- If a Gulick-type spring-loaded tape measure is used, the handle should be extended to the same marking with each trial.
- Take duplicate measures at each site and retest if duplicate measurements are not within 5 mm.
- Rotate through measurement sites or allow time for skin to regain normal texture.

Modified from (39).

The waist-to-hip ratio (WHR) is the circumference of the waist divided by the circumference of the hips (see *Box 3.3* for waist and buttocks/hips measures) and has traditionally been used as a simple method for assessing body fat distribution patterns and identifying individuals with higher amounts of abdominal fat or central adiposity (40). Health risk increases as WHR increases, and the standards for risk vary with age and sex. For example, for those younger than 60 yr of age, health risk is *very high* for men when WHR is >0.95 and for women when WHR is >0.86. For individuals aged 60–69 yr, the WHR cutoff values are >1.03 for men and >0.90 for women for the same high-risk classification as young adults (21).

The waist circumference alone may be used as an indicator of obesity-related health risk because central obesity is the primary health issue (41,42); waist circumference and WHR are reported to be superior to BMI for this purpose (43). Although BMI and waist circumference are correlated, the correlation between BMI and WHR is weak and implies the information provided by the two measures is different (40). Waist circumference is a proxy for the combination of visceral fat and abdominal fat. Because visceral adiposity increases the risk for obesity-related diseases, waist circumference is an important measure for health risk assessments (44). The Expert Panel on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults provides a classification of disease risk based on both BMI and waist circumference as shown in *Table 3.1* (26). Previous research demonstrated that the waist circumference thresholds shown in *Table 3.1* effectively identify individuals at increased health risk across the different BMI categories (45). Furthermore, risk criteria for adults based on more specific waist circumferences have been developed (*Table 3.2*) (46). It is important to note that these risk criteria are based on data derived from Caucasian men and women and may be different for other racial/ethnic groups. For example, South Asian (47) and African American men and women may have different cut points for specific BMI and waist circumferences (48,49). The Pennington Center Longitudinal Study found that BMI, along with other measure of obesity (*i.e.*, body adiposity index, waist-to-height ratio, and WHR) all correlated with mortality in Caucasians but not in African Americans. However, the risk of mortality associated with waist circumference was almost identical between races (50). Furthermore, the optimal BMI and waist circumference thresholds to identify cardiometabolic health risk differ between Caucasian and African American men and women (47).

TABLE 3.2 • Risk Criteria for Waist Circumference in Adults

	Waist Circumference cm (in)	
Risk category	**Women**	**Men**
Very low	<70 cm (<27.5 in)	<80 cm (31.5 in)
Low	70–89 (27.5–35.0)	80–99 (31.5–39.0)
High	90–110 (35.5–43.0)	100–120 (39.5–47.0)
Very high	>110 (>43.5)	>120 (>47.0)

Reprinted with permission from (46).

Several methods for waist circumference measurement involving different anatomical sites are available. Practitioners should be aware of which anatomical location the waist circumference is measured in order to be consistent with certain disease risk stratification and for follow-up assessments. For example, *Table 3.2* is based on data where the waist circumference was taken at the level of the iliac crest (46,51), whereas the Pennington Longitudinal Studies take waist circumference at the midpoint between the inferior border of the ribcage and the superior aspect of the iliac crest (48–50). Evidence indicates that waist circumference taken just inferior to the lowest rib is preferred over waist circumference at the midpoint as a predictor of T2DM and cardiometabolic risk in adults between 46 and 73 yr of age (52).

Skinfold Measurements

Although BMI and circumferences are anthropometric measures that may be used to assess health risk, they are not true measures of body composition. The skinfold technique is a body composition method that estimates body fat percentage by determining the thickness of several folds of skin across the body. Body fat percentage determined from skinfold thickness measurements correlates well ($r = 0.70-0.93$) with hydrodensitometry (53), air displacement plethysmography (54), and dual-energy X-ray absorptiometry (DXA) (55). The principle behind the skinfold technique is that the amount of subcutaneous fat is proportional to the total amount of body fat. It is assumed that approximately one-third of the total fat in the body is located subcutaneously (56), but there is considerable variation in intramuscular, intermuscular, and internal organ fat deposits among individuals (56,57). The exact proportion of subcutaneous to total fat also varies with sex, age, and race (13,56). Therefore, regression equations used to convert sum of skinfolds to body density and to convert body density to percent body fat should consider these variables for reducing prediction error. *Box 3.4* presents a standardized description of skinfold sites and procedures. Additional detail of skinfold technique is described elsewhere (20,21). Skinfold assessment of body composition is dependent on the expertise of the technician, so proper training (*i.e.*, knowledge of anatomical landmarks) and ample practice of the technique is necessary to obtain accurate measurements. The accuracy of predicting percent body fat from skinfolds is approximately ±3.5%, assuming appropriate techniques and equations have been used (21).

Box 3.4 Standardized Description of Skinfold Sites and Procedures

Skinfold Site	
Abdominal	Vertical fold; 2 cm to the right side of the umbilicus
Triceps	Vertical fold; on the posterior midline of the upper arm, halfway between the acromion and olecranon processes, with the arm held freely to the side of the body
Biceps	Vertical fold; on the anterior aspect of the arm over the belly of the biceps muscle, 1 cm above the level used to mark the triceps site
Chest/pectoral	Diagonal fold; one-half the distance between the anterior axillary line and the nipple (men) or one-third of the distance between the anterior axillary line and the nipple (women)
Medial calf	Vertical fold; at the maximum circumference of the calf on the midline of its medial border
Midaxillary	Vertical fold; on the midaxillary line at the level of the xiphoid process of the sternum. An alternate method is a horizontal fold taken at the level of the xiphoid/sternal border on the midaxillary line.
Subscapular	Diagonal fold (45-degree angle); 1–2 cm below the inferior angle of the scapula

Suprailiac	Diagonal fold; in line with the natural angle of the iliac crest taken in the anterior axillary line immediately superior to the iliac crest
Thigh	Vertical fold; on the anterior midline of the thigh, midway between the proximal border of the patella and the inguinal crease (hip)

Procedures

- All measurements should be made on the right side of the body with the individual standing upright.
- Caliper should be placed directly on the skin surface, 1 cm away from the thumb and finger, perpendicular to the skinfold, and halfway between the crest and the base of the fold.
- Pinch should be maintained while reading the caliper.
- Wait 1–2 s before reading caliper.
- Take duplicate measures at each site and retest if duplicate measurements are not within 1–2 mm.
- Rotate through measurement sites or allow time for skin to regain normal texture and thickness.

Factors that may contribute to measurement error within skinfold assessment include poor anatomical landmark identification, poor measurement technique, an inexperienced evaluator, an extremely obese or extremely lean individual, and an improperly calibrated caliper (58,59). Various regression equations have been developed to predict body density or percent body fat from skinfold measurements. *Box 3.5* lists generalized equations that allow calculation of body density for a wide range of individuals (59,60). Other equations have been published that are sex, age, race, fat, and sport specific (21,62). A useful alternative to using skinfolds to predict body fat is to track change in measurements at individual skinfold sites or use the sum of skinfolds.

Box 3.5 Generalized Skinfold Equations

Men

- **Seven-site formula** (chest, midaxillary, triceps, subscapular, abdomen, suprailiac, thigh)

  Body density = 1.112 − 0.00043499 (sum of seven skinfolds)

  + 0.00000055 (sum of seven skinfolds)^2

  − 0.00028826 (age) *[SEE 0.008 or ~3.5% fat]*

- **Three-site formula** (chest, abdomen, thigh)

  Body density = 1.10938 − 0.0008267 (sum of three skinfolds)

$+ 0.0000016$ (sum of three skinfolds)^2
$- 0.0002574$ (age) *[SEE 0.008 or ~3.4% fat]*

- **Three-site formula** (chest, triceps, subscapular)

  Body density = 1.1125025 − 0.0013125 (sum of three skinfolds)

  $+ 0.0000055$ (sum of three skinfolds)^2
  $- 0.000244$ (age) *[SEE 0.008 or ~3.6% fat]*

Women

- **Seven-site formula** (chest, midaxillary, triceps, subscapular, abdomen, suprailiac, thigh)

  Body density = 1.097 − 0.00046971 (sum of seven skinfolds)

  $+ 0.00000056$ (sum of seven skinfolds)^2
  $- 0.00012828$ (age) *[SEE 0.008 or ~3.8% fat]*

- **Three-site formula** (triceps, suprailiac, thigh)

  Body density = 1.0994921 − 0.0009929 (sum of three skinfolds)

  $+ 0.0000023$ (sum of three skinfolds)^2
  $- 0.0001392$ (age) *[SEE 0.009 or ~3.9% fat]*

- **Three-site formula** (triceps, suprailiac, abdominal)

  Body density = 1.089733 − 0.0009245 (sum of three skinfolds)

  $+ 0.0000025$ (sum of three skinfolds)^2
  $- 0.0000979$ (age) *[SEE 0.009 or ~3.9% fat]*

SEE, standard error of estimate.
Adapted from (60,61).

Densitometry

The estimate of total body fat percentage can be derived from a measurement of whole-body density using the ratio of body mass to body volume. Densitometry has been used as a reference or criterion standard for assessing body composition for many years; although, DXA and multicomponent modeling have recently gained popularity as a criterion measure. The limiting factor in the measurement of body density is the accuracy of the body volume measurement because the measurement of body mass (weight) is considered to be highly accurate. Body volume can be measured by hydrodensitometry (underwater weighing), plethysmography, or calculated using DXA algorithms (63). However, the DXA method of body volume determination requires additional development and validation (53,64).

Hydrodensitometry (underwater) weighing is based on Archimedes principle that states when a body is immersed in water, it is buoyed by a counterforce equal to the weight of the water displaced. This loss of weight in water allows for calculation of body volume. Bone and muscle tissues are denser than water, whereas fat tissue is less dense. Therefore, when two individuals have the same total body mass, the person with more fat-free mass (FFM) weighs more in water and has a higher body density and lower percentage of body fat compared to the person with less FFM (FFM = body mass − fat mass [FM]). Although hydrostatic weighing is a standard method for measuring body volume and, hence, body composition, it requires special equipment, the accurate measurement of residual volume, body density conversion formulas, and significant cooperation by the individual (65). Body volume also can be measured by plethysmography (*i.e.*, air displacement in a closed chamber). Albeit expensive, plethysmography is well established and is thought to reduce the challenges associated with submersion in water during hydrodensitometry in some individuals (65). For a more detailed explanation of these densitometric techniques, see (62).

Conversion of Body Density to Body Composition

Percent body fat can be estimated once body density has been determined. The most commonly used prediction equation to estimate percent body fat from body density was derived from the two-component model of body composition (66):

$$[(4.95 / Db) - 4.50] \times 100$$

The prediction of body fat from body density assumes the density of FM and FFM are consistent for the studied population. However, age, sex, race, training status, and certain disease states may affect the density of FFM, with much of this variance related to the bone mineral density component of FFM. Because of this variance, population-specific, two-component model conversion formulas are also available for specific age, sex, race, training status, and disease condition (*Table 3.3*). Because of the significant effect of these factors on the validity of the conversion of body density to body fat, exercise professionals are encouraged to select the most specific formula possible for each individual (62).

TABLE 3.3 • Population-Specific Formulas for Conversion of Body Density to Percent Body Fat

Population	Age	Gender	%BF[a]	FFBd[b] ($g \cdot cm^{-3}$)
		Ethnicity		
African American	9–17	Women	(5.24 / Db) − 4.82	1.088
	19–45	Men	(4.85 / Db) − 4.39	1.106

	24–79	Women	(4.86 / Db) − 4.39	1.106
American Indian	18–62	Men	(4.97 / Db) − 4.52	1.099
	18–60	Women	(4.81 / Db) − 4.34	1.108
Asian Japanese Native	18–48	Men	(4.97 / Db) − 4.52	1.099
		Women	(4.76 / Db) − 4.28	1.111
	61–78	Men	(4.87 / Db) − 4.41	1.105
		Women	(4.95 / Db) − 4.50	1.1
Singaporean (Chinese, Indian, Malay)		Men	(4.94 / Db) − 4.48	1.102
		Women	(4.84 / Db) − 4.37	1.107
Caucasian	8–12	Men	(5.27 / Db) − 4.85	1.086
		Women	(5.27 / Db) − 4.85	1.086
	13–17	Men	(5.12 / Db) − 4.69	1.092
		Women	(5.19 / Db) − 4.76	1.09
	18–59	Men	(4.95 / Db) − 4.50	1.1
		Women	(4.96 / Db) − 4.51	1.101
	60–90	Men	(4.97 / Db) − 4.52	1.099
		Women	(5.02 / Db) − 4.57	1.098
Hispanic		Men	NA	NA
	20–40	Women	(4.87 / Db) − 4.41	1.105

Athletes				
Resistance trained	24 ± 4	Men	(5.21 / Db) − 4.78	1.089
	35 ± 6	Women	(4.97 / Db) − 4.52	1.099
Endurance trained	21 ± 2	Men	(5.03 / Db) − 4.59	1.097
	21 ± 4	Women	(4.95 / Db) − 4.50	1.1
All sports	18–22	Men	(5.12 / Db) − 4.68	1.093
	18–22	Women	(4.97 / Db) − 4.52	1.099
Clinical populations[c]				
Anorexia nervosa	15–44	Women	(4.96 / Db) − 4.51	1.101
Cirrhosis				
Childs A			(5.33 / Db) − 4.91	1.084
Childs B			(5.48 / Db) − 5.08	1.078
Childs C			(5.69 / Db) − 5.32	1.07
Obesity	17–62	Women	(4.95 / Db) − 4.50	1.1
Spinal cord injury (paraplegic/quadriplegic)	18–73	Men	(4.67 / Db) − 4.18	1.116
	18–73	Women	(4.70 / Db)− 4.22	1.114

[a]Multiply by 100 for percentage of body fat.

[b]FFBd, fat-free body density based on average values reported in selected research articles.

[c]There are insufficient multicomponent model data to estimate the average FFBd of the following clinical populations: coronary artery disease, heart/lung transplants, chronic obstructive pulmonary disease, cystic fibrosis, diabetes mellitus, thyroid disease, human immunodeficiency virus (HIV)/acquired immunodeficiency syndrome (AIDS), cancer, kidney failure (dialysis), multiple sclerosis, and muscular dystrophy.

%BF, percentage of body fat; Db, body density; NA, no data available for this population subgroup.

Adapted with permission from (21).

Other Techniques

DXA is a common body composition method in clinical research settings but has limited applicability in routine health/fitness testing because of cost, specialized equipment, and the need for highly trained personnel (20). Prediction of the deleterious visceral adipose tissue volume, as correlated with a computed tomography criterion, is reported to be similar for anthropometric (*e.g.*, waist circumference and BMI) and standard DXA abdominal fat measurements (67). However, software revisions improved the ability of DXA-based visceral adipose tissue measurements to accurately predict computed tomography results for South African women (67).

Bioelectrical impedance analysis (BIA) is occasionally used as an assessment technique in routine health/fitness testing. Generally, the accuracy of BIA is similar to skinfolds, as long as stringent protocol adherence (*e.g.*, assurance of normal hydration status) is followed, and the equations programmed into the analyzer are valid for the populations being tested. For example, differences in BIA accuracy between obese and normal weight individuals may be due to how body water is distributed in these groups. Reliance on the results from empirical linear regression models is a limitation of both single-frequency and multifrequency BIA (28,68).

Ultrasound uses sound waves to provide a noninvasive, direct measure of subcutaneous fat thickness, as opposed to skinfold calipers that yield an indirect estimate of fat thickness from a compressed fold of fat and skin. Ultrasound devices vary in cost and complexity, but proprietary prediction equations from inexpensive devices have been validated against skinfolds, DXA, and air displacement plethysmography (15,69). Intertester reliability is higher for ultrasound compared to skinfolds (70). Smartphone applications that provide estimates of body fat percentage from photos are also available, but they lack rigorous independent validation at this point.

Body Composition Norms

There are no universally accepted norms for body composition; however, *Tables 3.4* and *3.5*, which were developed using skinfold measurements, provide percentile values for percent body fat in men and women, respectively. A consensus opinion for an exact percent body fat value associated with optimal health risk has yet to be defined. However, based on these skinfold reference values, the range of 12%–23% and 17%–26% for men and women, respectively, spans the "good" category of body fat values across a wide age spectrum (see *Tables 3.4* and *3.5*). Other research supports this range, although age, sex, race, and athletic level impact what may be construed as a healthy percent body fat. Method of assessment also influences results and further complicates the definition of healthy body fat percentages. DXA percent body fat ranges for a Caucasian adult sample from the United States (71) are higher (19%–26% and 28%–36%, respectively, for men and women) compared to the same "good" category percentiles in *Tables 3.4* and *3.5*. Sex- and age-specific lean mass data derived from DXA scans (72) are also available.

TABLE 3.4 • Fitness Categories for Body Composition (% Body Fat) for Men by Age

		Age (yr)					
%		20–29	30–39	40–49	50–59	60–69	70–79
99	Very lean[a]	4.2	7.3	9.5	11.1	12.0	13.6
95		6.4	10.3	13.0	14.9	16.1	15.5
90	Excellent	7.9	12.5	15.0	17.0	18.1	17.5
85		9.1	13.8	16.4	18.3	19.2	19.0
80		10.5	14.9	17.5	19.4	20.2	20.2
75	Good	11.5	15.9	18.5	20.2	21.0	21.1
70		12.6	16.8	19.3	21.0	21.7	21.6
65		13.8	17.7	20.1	21.7	22.4	22.3
60		14.8	18.4	20.8	22.3	23.0	22.9
55	Fair	15.8	19.2	21.4	23.0	23.6	23.6
50		16.7	20.0	22.1	23.6	24.2	24.1
45		17.5	20.7	22.8	24.2	24.9	24.5
40		18.6	21.6	23.5	24.9	25.6	25.2
35	Poor	19.8	22.4	24.2	25.6	26.4	25.7

30		20.7	23.2	24.9	26.3	27.0	26.3
25		22.1	24.1	25.7	27.1	27.9	27.1
20		23.3	25.1	26.6	28.1	28.8	28.0
15	Very poor	25.1	26.4	27.7	29.2	29.8	29.3
10		26.6	27.8	29.1	30.6	31.2	30.6
5		29.3	30.2	31.2	32.7	33.5	32.9
1		33.7	34.4	35.2	36.4	37.2	37.3
n		1,938	10,457	16,032	9,976	3,097	571

[a]Very lean, no less than 3% body fat is recommended for men.
Total n = 42,071.
Adapted with permission from *Physical Fitness Assessments and Norms for Adults and Law Enforcement*. The Cooper Institute, Dallas, Texas. 2013. For more information: http://www.cooperinstitute.org.

TABLE 3.5 • Fitness Categories for Body Composition (% Body Fat) for Women by Age

		Age (yr)					
%		**20–29**	**30–39**	**40–49**	**50–59**	**60–69**	**70–79**
99	Very lean[a]	11.4	11.0	11.7	13.8	13.8	13.7
95		14.1	13.8	15.2	16.9	17.7	16.4
90	Excellent	15.2	15.5	16.8	19.1	20.1	18.8
85		16.1	16.5	18.2	20.8	22.0	21.2
80	Good	16.8	17.5	19.5	22.3	23.2	22.6
75		17.7	18.3	20.5	23.5	24.5	23.7
70		18.6	19.2	21.6	24.7	25.5	24.5
65		19.2	20.1	22.6	25.7	26.6	25.4
60		20.0	21.0	23.6	26.6	27.5	26.3
55	Fair	20.7	22.0	24.6	27.4	28.3	27.1
50		21.8	22.9	25.5	28.3	29.2	27.8
45		22.6	23.7	26.4	29.2	30.1	28.6
40		23.5	24.8	27.4	30.0	30.8	30.0
35	Poor	24.4	25.8	28.3	30.7	31.5	30.9
30		25.7	26.9	29.5	31.7	32.5	31.6
25		26.9	28.1	30.7	32.8	33.3	32.6
20		28.6	29.6	31.9	33.8	34.4	33.6
15	Very poor	30.9	31.4	33.4	34.9	35.4	35.0

10	33.8	33.6	35.0	36.0	36.6	36.1
5	36.6	36.2	37.0	37.4	38.1	37.5
1	38.4	39.0	39.0	39.8	40.3	40.0
n	1,342	4,376	6,392	4,496	1,576	325

[a]Very lean, no less than 10%–13% body fat is recommended for women.
Total *n* = 18,507.

Adapted with permission from *Physical Fitness Assessments and Norms for Adults and Law Enforcement*. The Cooper Institute, Dallas, Texas. 2013. For more information: http://www.cooperinstitute.org.

CARDIORESPIRATORY FITNESS

CRF is related to the ability to perform large muscle, dynamic, moderate-to-vigorous intensity exercise for prolonged periods of time. Performance of exercise at this level of physical exertion depends on the integrated physiologic and functional state of the respiratory, cardiovascular, and musculoskeletal systems. CRF is considered a health-related component of physical fitness because (a) low levels of CRF have been associated with a markedly increased risk of premature death from all causes and specifically from CVD; (b) increases in CRF are associated with a reduction in death from all causes; and (c) high levels of CRF are associated with higher levels of habitual PA, which in turn are associated with many health benefits (73,74). The American Heart Association recognizes CRF as a clinical vital sign and potentially a stronger predictor of mortality than other established risk factors (74). As such, the assessment of CRF is an important part of any primary or secondary prevention and rehabilitation program, and the knowledge and skills to complete the assessment and interpret the subsequent results are an important responsibility of the exercise professional.

The Concept of Maximal Oxygen Uptake

Maximal volume of oxygen consumed per unit time ($\dot{V}O_{2max}$) is accepted as the criterion measure of CRF. This variable is typically expressed clinically in relative ($mL \cdot kg^{-1} \cdot min^{-1}$) as opposed to absolute ($mL \cdot min^{-1}$) terms, allowing for meaningful comparisons between/among individuals with differing body weight. $\dot{V}O_{2max}$ is the product of the maximal cardiac output ($\dot{Q}$; $L\ blood \cdot min^{-1}$) and arterial-venous oxygen difference ($mL\ O_2 \cdot L\ blood^{-1}$). Significant variation in $\dot{V}O_{2max}$ across populations and fitness levels results primarily from differences in $\dot{Q}$; therefore, $\dot{V}O_{2max}$ is closely related to the functional capacity of the heart. The designation of $\dot{V}O_{2max}$ implies an individual's true physiologic limit has been reached, and a plateau in volume of oxygen consumed per minute ($\dot{V}O_2$) may be observed between the final two work rates of a progressive exercise test. This plateau is not consistently observed during maximal exercise testing, and the endpoint criteria chosen to designate maximal exertion impacts the ultimate $\dot{V}O_{2max}$ value (75). A verification bout of exercise at a workload at 105%–110% of the highest workload attained in the maximal exertion exercise test is an alternative to the reliance on secondary criteria historically used to verify achievement of $\dot{V}O_{2max}$ (76,77). The plateau is rarely observed in individuals with CVD or pulmonary disease. Peak $\dot{V}O_2$ ($\dot{V}O_{2peak}$) is used when leveling off of $\dot{V}O_2$ does not occur, or maximum performance appears limited by local muscular factors rather than central circulatory dynamics (78). $\dot{V}O_{2peak}$ is commonly used to describe CRF in these and other populations with chronic diseases and health conditions (79), although acceptance of the $\dot{V}O_{2peak}$ term as a descriptor of CRF is equivocal (77,80). A plateau in HR ($\leq$2 beats · min^{-1}) in the final minute of data collection is reported to hold promise as a singular method for confirming $\dot{V}O_{2max}$ without need for a verification trial (81).

Open circuit spirometry is used to measure $\dot{V}O_{2max}$ during a graded incremental or ramp exercise test to exhaustion, also called *indirect calorimetry*. In this procedure, the individual breathes through a low-resistance valve with his or her nose occluded (or through a nonlatex mask) while pulmonary ventilation and expired fractions of oxygen (O_2) and carbon dioxide (CO_2) are measured. In addition, the use of open circuit spirometry during maximal exercise testing may allow for the accurate assessment of an anaerobic/ventilatory threshold and direct measurement of $\dot{V}O_{2max}$/$\dot{V}O_{2peak}$. Automated systems are typically used to collect these data; however, system calibration is essential to obtain accurate results (82,83). The mode selected (*i.e.*, leg ergometer vs. treadmill) for the exercise test can impact the result, as performance is related to familiarity with the exercise modality as well as the amount of muscle mass involved (see *Chapter 4*). Administration of the test and interpretation of results should be reserved for trained professional personnel with a thorough understanding of exercise physiology. Because of costs associated with the equipment, space, and personnel needed to carry out these tests, direct measurement of $\dot{V}O_{2max}$ may not always be possible. Several equations predict $\dot{V}O_{2max}$ from submaximal $\dot{V}O_2$ values acquired via direct measurements and produce results that do not differ significantly from the measured $\dot{V}O_{2max}$ (84). Although these prediction protocols may reduce the time and risk of a maximal exertion exercise test, they still require direct measurement of O_2 consumption.

When direct measurement of $\dot{V}O_{2max}$ is not feasible, a variety of maximal and submaximal exercise tests can be used to estimate $\dot{V}O_{2max}$. These tests have been validated by examining (a) the correlation between directly measured $\dot{V}O_{2max}$ and the $\dot{V}O_{2max}$ estimated from physiologic responses to submaximal exercise (*e.g.*, HR at a specified power output) or (b) the correlation between directly measured $\dot{V}O_{2max}$ and field test performance (*e.g.*, time to run 1 or 1.5 mi [1.6 or 2.4 km]) or time to volitional fatigue using a standard graded exercise test (GXT) protocol. It should be noted that there is the potential for a significant underestimation or overestimation of $\dot{V}O_{2max}$ by these types of indirect measurement techniques. Overestimation is more likely to occur when the exercise protocol (see *Chapter 4*) chosen for testing is too aggressive for a given individual (*i.e.*, Bruce treadmill protocol in individuals with CHF) or when treadmill testing is employed and the individual heavily relies on handrail support (79). Every effort should be taken to choose the appropriate exercise protocol given an individual's characteristics, and handrail use should be minimized during testing on a treadmill (85).

Maximal versus Submaximal Exercise Testing

The decision to use a maximal or submaximal exercise test depends largely on the reasons for the test, risk level of the individual, and availability of appropriate equipment and personnel (see *Chapter 4*). Maximal tests require an individual to exercise to the point of volitional fatigue, which may be inappropriate for some individuals and may require the need for emergency equipment to be available (7). The American Heart Association identified competencies, roles, and responsibilities of GXT team members that may prevent adverse events from happening during exercise test administration (86).

Exercise professionals often rely on submaximal exercise tests to assess CRF because maximal exercise testing is not always feasible in the health/fitness setting. The basic aim of submaximal exercise testing is to determine the HR response to one or more submaximal work rates and use the results to predict $\dot{V}O_{2max}$. Although the primary purpose of the test has traditionally been to predict $\dot{V}O_{2max}$ from the HR workload relationship, it is important to obtain additional indices of the individual's response to exercise. The exercise professional should use the various submaximal measures of HR, BP, workload, rating of perceived exertion (RPE), and other individual indices as valuable information regarding one's functional response to exercise. This information can be used to evaluate submaximal exercise responses over time, in a controlled environment, and make modifications to the Ex R_x as needed.

The most accurate estimate of $\dot{V}O_{2max}$ is achieved from the HR response to submaximal exercise tests if all of the following are achieved (62):

- A steady state HR is obtained for each exercise work rate.
- A linear relationship exists between HR and work rate.

- The difference between actual and predicted maximal HR is minimal.
- Mechanical efficiency (*i.e.*, $\dot{V}O_2$ at a given work rate) is the same for everyone.
- The individual is not on any HR altering medications (see *Appendix A*).
- The individual is not using high quantities of caffeine, ill, or in a high-temperature environment, all of which may alter the HR response.

Cardiorespiratory Test Sequence and Measures

After the initial screening process, baseline measurements of HR and BP should be obtained prior to the start of the exercise test. A minimum of HR, BP, and RPE should be measured during exercise tests. Monitoring exercise HR via ECG or HR monitor is most common. In situations where an HR monitor or ECG is unavailable, it may be necessary to palpate or auscultate HR using 10-s, 15-s, or 30-s intervals with conversion to beats per minute. Most protocols that use postexercise HR to assess CRF also use these shorter time intervals due to the rapid and immediate decline in HR following the cessation of exercise. HR telemetry monitors with chest electrodes or radio telemetry have proven to be accurate and reliable, provided there is no outside electrical interference (87). Light-based technology based on photoplethysmography is now integrated into wearable devices and monitors pulsatile blood flow at the nail bed or wrist. Proprietary algorithms convert the blood flow to HR with varying degrees of accuracy (88–90).

BP should be measured at heart level with the individual in the exercise position (*i.e.*, standing or seated) and individual's arm relaxed and not grasping a handrail (treadmill) or handlebar (cycle ergometer). Automated brachial cuffs typically allow for auditory confirmation of the BP measurement, which may improve confidence in the resting BP value obtained. Use of automated brachial or finger cuffs during exercise is discouraged, as they are susceptible to erroneous results attributable to artifacts (91). To obtain accurate BP measures during exercise, follow the stethoscope placement and cuff inflation and deflation guidelines in *Box 3.1*. If an automated BP system is used during exercise testing, calibration checks with manual BP measurements must be routinely performed to confirm accuracy of the automated readings (91). Systolic (SBP) and diastolic BP (DBP) measurements can be used as indicators for stopping an exercise test (*Box 3.6*).

Box 3.6 General Indications for Stopping an Exercise Test[a]

- Onset of angina or angina-like symptoms
- Drop in SBP ≥10 mm Hg with an increase in work rate or if SBP decreases below the value obtained in the same position prior to testing
- Excessive rise in BP: systolic pressure >250 mm Hg and/or diastolic pressure >115 mm Hg
- Shortness of breath, wheezing, leg cramps, or claudication
- Signs of poor perfusion: light-headedness, confusion, ataxia, pallor, cyanosis, nausea, or cold and clammy skin
- Failure of HR to increase with increased exercise intensity
- Noticeable change in heart rhythm by palpation or auscultation
- Individual requests to stop
- Physical or verbal manifestations of severe fatigue
- Failure of the testing equipment

[a]Assumes that testing is nondiagnostic and is being performed without electrocardiogram monitoring. For clinical testing, *Box 4.3* provides more definitive and specific termination criteria.
BP, blood pressure; HR, heart rate; SBP, systolic blood pressure.

RPE can be a valuable indicator for monitoring an individual's exercise tolerance. The RPE scale was developed to allow the exerciser to individually rate their physical strain during exercise (92). An individual's perception of exertion can be influenced by a multitude of factors such as personal health and exercise history, demographics, and testing environment. Therefore, exercise professionals should control as many exercise-related variables as possible and refrain from comparing RPE responses across modalities and individuals. The correlation between RPE and indicators of exercise intensity is strong, but interindividual variability of HR and blood lactate at specific RPEs is high (93). The relationship between RPE and objective measures of exercise intensity (HR and blood lactate) is reported as being independent of PA level, exercise modality, age, sex, and medical history of coronary artery disease (93). The exercise professional's explanation of how to use the RPE scale is of utmost importance in helping an individual convey his or her own assessment of the level of exertion (92,94). Two RPE scales are widely used: (a) the original Borg or category scale, which rates exercise intensity from 6 to 20 (*Table 3.6*), and (b) the category-ratio scale of 0–10 (see *Figure 4.2*). OMNI 0–10 scales with pictorial representations of exertion are also available and appropriate for various age groups, exercise modalities, and exercise intensities between 50% and 70% $\dot{V}O_2$ reserve [% × ($\dot{V}O_{2max}$ − $\dot{V}O_2$ at rest) + $\dot{V}O_2$ at rest] (96–99).

TABLE 3.6 • The Borg Rating of Perceived Exertion Scale	
6	No exertion at all
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

 The scale with correct instructions can be obtained from Borg Perception, Radisvagen 124, 16573 Hasselby, Sweden. See also the home page: http://www.borgperception.se/index.html.

During exercise testing, the RPE can be used as an indication of impending fatigue. Most apparently healthy individuals reach their limit of fatigue at an RPE of 18–19 (very, very hard) on the category Borg scale, or 9–10 (very, very strong) on the category-ratio scale; therefore, RPE can be used to monitor progress toward maximal exertion during exercise testing (95).

Test Termination Criteria

GXT, whether maximal or submaximal, is a safe procedure when individual prescreening and testing guidelines are adhered to and when the GXT is administrated by trained exercise professionals (86). Occasionally, for safety reasons, the test may have to be terminated prior to the individual reaching a measured or estimated $\dot{V}O_{2max}$, volitional fatigue, or a predetermined endpoint (*i.e.*, 50%–70% heart rate reserve [HRR] or 70%–85% age-predicted maximal heart rate [HR_{max}]). Because of the individual variation in HR_{max}, the upper limit of 85% of an estimated HR_{max} may result in a maximal effort for some individuals and submaximal effort in others. General indications for stopping an exercise test are outlined in *Box 3.6*.

Modes of Testing

Commonly used modes for exercise testing include treadmills, cycle ergometers, and field tests. The mode of exercise testing used is dependent on the setting, equipment available, and training of personnel. There are advantages and disadvantages of each exercise testing mode:

- ***Treadmills*** can be used for submaximal and maximal testing and are often employed for diagnostic testing. Treadmills provide a familiar form of exercise to many and, if the correct protocol is chosen (*i.e.*, aggressive vs. conservative adjustments in workload), can accommodate individuals across the fitness continuum of walking to running speeds. Nevertheless, a familiarization session might be necessary in some cases to permit habituation and reduce anxiety. On the other hand, treadmills usually are expensive, not easily transportable, and some measurements (*e.g.*, BP, ECG) become more difficult at higher speeds, particularly while running. Treadmills must also be calibrated periodically to ensure the accuracy of the test when estimating $\dot{V}O_{2max}$. In addition, holding on to the support rail(s) should be discouraged to ensure accuracy of metabolic work output. Lack of calibration and extensive handrail use are among factors leading to errors in predictions of $\dot{V}O_{2max}$ (100).
- ***Mechanically braked cycle ergometers*** are also a viable test modality for submaximal and maximal testing and are frequently used for diagnostic testing (85). Advantages of this testing mode include lower equipment expense, some transportability, and greater ease in obtaining BP and ECG (if appropriate) measurements. Cycle ergometers also provide a non–weight-bearing test modality in which work rates are easily adjusted in small increments. The main disadvantage is cycling may be a less familiar mode of exercise to some individuals, often resulting in localized muscle fatigue and an underestimation of $\dot{V}O_{2max}$. The cycle ergometer must be calibrated, and the individual must maintain the proper pedal rate because most tests require HR to be measured at specific work rates (85). Electronic cycle ergometers can deliver the same work rate across a range of pedal rates (*i.e.*, revolutions per minute [rpm]), but calibration might require special equipment not available in some laboratories. If a cycle ergometer cannot be calibrated for any reason or if it does not provide a reasonable estimate of workload, it should not be used for fitness testing to predict CRF.
- ***Field tests*** are those that are conducted outside of a laboratory to predict CRF by measuring HR response. These tests may consist of walking, running, and/or stepping, following predetermined protocols. Ease of administration to large numbers of individuals at one time, the relatively low skill needed to complete the tests, low cost, and little equipment

need (*e.g.*, a stopwatch) are the main advantages. Additionally, these tests can be implemented in rehabilitation settings as well as with general populations. However, there are several disadvantages, including the inability to control individual effort, identify test termination criteria (see *Box 3.6*), and monitor BP and HR responses during the test. Additionally, an individual may not be able to complete the test, as some tests can be near-maximal or maximal intensity for some, particularly in individuals with low CRF. Therefore, these tests may be inappropriate for sedentary individuals or those at increased risk for cardiovascular and/or musculoskeletal complications. Many factors can have a profound impact on test results, including an individual's sex, training status, age, test procedures, and required distance (101).

Treadmill Tests

The primary exercise modality for submaximal exercise testing traditionally has been the cycle ergometer, although treadmills are used in many settings. Similar to submaximal cycling protocols, submaximal treadmill tests use the same submaximal definition (70% HRR or 85% of age-predicted HR_{max}) as the HR-based test termination criterion, and the stages of the test should be 3 min or longer to ensure a steady state HR response at each stage. The HR values are extrapolated to age-predicted HR_{max}, and $\dot{V}O_{2max}$ is estimated using the formula in *Appendix D* from the highest speed and/or grade that would have been achieved if the individual had worked to maximum. Most common treadmill protocols presented in *Figure 4.1* can be used, but the duration of each stage should be at least 3 min.

Cycle Ergometer Tests

The Åstrand-Ryhming cycle ergometer test is a single-stage test lasting 6 min (102). The pedal rate is set at 50 rpm. The goal is to obtain HR values between 125 and 170 beats · min^{-1}, with HR measured during the fifth and sixth minute of work. The average of the two HRs is then used to estimate $\dot{V}O_{2max}$ from a nomogram (*Figure 3.1*). The suggested work rate is based on sex and an individual's fitness status as follows:

- Men, unconditioned: 300 or 600 kg · m · min^{-1} (50 or 100 W)
- Men, conditioned: 600 or 900 kg · m · min^{-1} (100 or 150 W)
- Women, unconditioned: 300 or 450 kg · m · min^{-1} (50 or 75 W)
- Women, conditioned: 450 or 600 kg · m · min^{-1} (75 or 100 W)

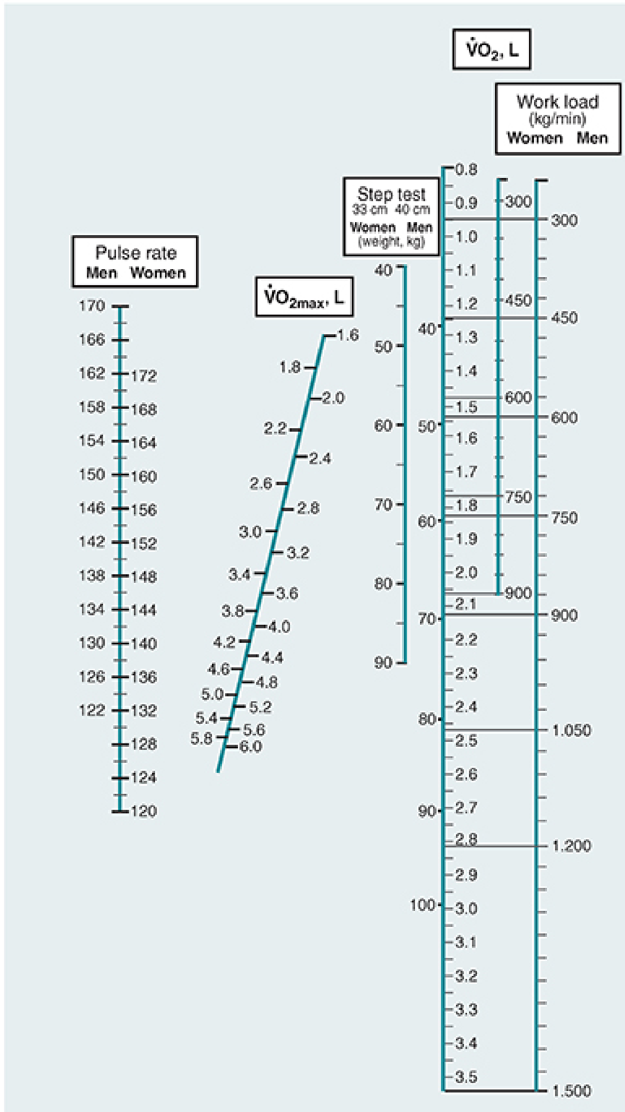

Figure 3.1 Modified Åstrand-Ryhming nomogram. Used with permission from (103).

Because HR_{max} decreases with age, the value from the nomogram must be adjusted for age by multiplying the $\dot{V}O_{2max}$ value by the following correction factors (102):

Age	Correction Factor
15	1.10
25	1.00
35	0.87
40	0.83
45	0.78
50	0.75
55	0.71
60	0.68
65	0.65

In contrast to the Åstrand-Ryhming cycle ergometer single-stage test, Maritz et al. (104) devised a test where HR was measured at a series of submaximal work rates and extrapolated the HR response to the individual's age-predicted HR_{max}. This multistage method is a well-known assessment technique to estimate $\dot{V}O_{2max}$. The HR measured during the last minute of two steady state stages is plotted against work rate. The line generated from the plotted points is then extrapolated to the age-predicted HR_{max}, and a perpendicular line is dropped to the x-axis to estimate the work rate that would have been achieved if the individual had worked to maximum. HR measurements below 110 beats · min^{-1} should not be used to estimate $\dot{V}O_{2max}$ because there is more day-to-day and individual variability at lower HR levels, which reduces the accuracy of prediction, and submaximal exercise tests are terminated if an individual reaches 70% HRR (85% HR_{max}). Therefore, two consecutive HR measurements between 110 beats · min^{-1} and 70% HRR (85% HR_{max}) should be obtained to predict $\dot{V}O_{2max}$ using this method.

Figure 3.2 presents an example of graphing the HR response to two submaximal workloads to estimate $\dot{V}O_{2max}$. The two lines noted as ±1 standard deviation (SD) show what the estimated $\dot{V}O_{2max}$ would be if the individual's true HR_{max} were 168 or 192 beats · min^{-1}, rather than 180 beats · min^{-1}. $\dot{V}O_{2max}$ is estimated from the work rate using the formula in *Appendix D*. This equation is valid to estimate $\dot{V}O_2$ at submaximal steady state workloads (from 300 to 1,200 kg · m · min^{-1}) (50–200 W); therefore, caution must be used if extrapolating to workloads outside this range. However, a larger part of the error involved in estimating $\dot{V}O_{2max}$ from submaximal HR responses occurs as the result of estimating HR_{max} (see *Table 5.3*) (105,106). Accurate submaximal HR recording is also critical, as extrapolation magnifies even the smallest of errors. In addition, errors can be attributed to inaccurate pedaling cadence (workload), imprecise achievement of steady state HR, and the extrapolation of work rate to $\dot{V}O_2$ at maximal intensities. Finally, the test administrator should recognize the error associated with age-predicted HR_{max} (see *Table 5.3*) and should monitor the individual throughout the test to ensure the test remains submaximal.

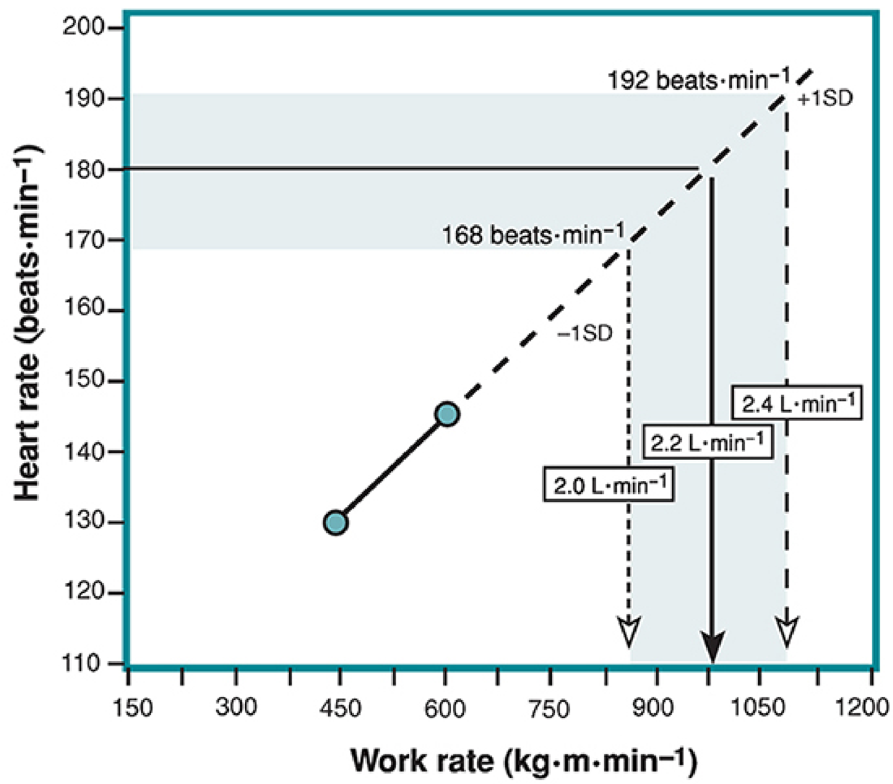

Figure 3.2 Heart rate (HR) responses to two submaximal work rates for a sedentary woman 40 yr of age weighing 64 kg. Maximal workload was estimated by extrapolating the HR response to the age-predicted maximal heart rate (HR_{max}) of 180 beats · min^{-1} (based on 220 − age). The work rate that would have been achieved at that HR was determined by dropping a line from that HR value to the x-axis. The other two lines estimate what the maximal workload would have been if the individual's true HR_{max} was ±1 standard deviation (SD) from the 180 beats · min^{-1} value. $\dot{V}O_{2max}$ estimated using the formula in *Table 5.2* and expressed in L · min^{-1} was 2.2 L · min^{-1}.

The modified YMCA protocol is a good example of a multistage submaximal cycle ergometer test that uses two to four 3-min stages of continuous exercise with a constant pedal rate of 50 rpm on a Monark cycle ergometer (107). Stage 1 requires individuals to pedal against 0.5 kg of resistance (25 W; 150 kgm · min^{-1}). The workload for stage 2 is based on the steady state HR measured during the last minute of the initial stage:

- HR <80 beats · min^{-1} — change the resistance to 2.5 kg (125 W; 750 kgm · min^{-1})
- HR 80−89 beats · min^{-1} — change the resistance to 2.0 kg (100 W; 600 kgm · min^{-1})
- HR 90−100 beats · min^{-1} — change the resistance to 1.5 kg (75 W; 450 kgm · min^{-1})
- HR >100 beats · min^{-1} — change the resistance to 1.0 kg (50 W; 300 kgm · min^{-1})

Use stages 3 and 4 as needed to elicit two consecutive steady state HRs between 110 beats · min^{-1} and 70% HRR (85% HR_{max}). For stages 3 and 4, the resistance used in stage 2 is increased by 0.5 kg (25 W; 150 kgm · min^{-1}) per stage. Normative tables for the YMCA protocol are published elsewhere (107).

Field Tests

Two of the most widely used run/walk tests (individuals may run, walk, or use a combination of both to complete the test) for assessing CRF are the 1.5-mi (2.4 km) test for time and the Cooper 12-min test. The objective of the 1.5-mi (2.4 km) test is to cover the distance in the shortest period of time, whereas the Cooper 12-min test requires the individual to cover the greatest distance in the allotted time period. $\dot{V}O_{2max}$ can be estimated from using the following equations:

1.5-mi run/walk test

$$\dot{V}O_{2max}\ (mL \cdot kg^{-1} \cdot min^{-1}) = 3.5 + 483 / 1.5 \text{ mi time (min)}$$

12-min walk/run test

$$\dot{V}O_{2max}\ (mL \cdot kg^{-1} \cdot min^{-1}) = (\text{distance in meters} - 504.9) / 44.73$$

The Rockport One-Mile Fitness Walking Test is another well-recognized field test for estimating CRF. In this test, an individual walks 1 mi (1.6 km) as fast as possible, preferably on a track or a level surface, and HR is obtained in the final minute. An alternative is to measure a 10-s HR (multiply by 6 for BPM) immediately on completion of the 1-mi (1.6 km) walk, but this may overestimate the $\dot{V}O_{2max}$ compared to when HR is measured during the walk. $\dot{V}O_{2max}$ is estimated using the following regression equation (108):

$$\dot{V}O_{2max}\ (mL \cdot kg^{-1} \cdot min^{-1}) = 132.853 - (0.1692 \times \text{body mass in kg}) - (0.3877 \times \text{age in years}) + (6.315 \times \text{gender}) - (3.2649 \times \text{time in minutes}) - (0.1565 \times HR)$$

$$(SEE = 5.0\ mL \cdot kg^{-1} \cdot min^{-1};\ \text{sex} = 0 \text{ for female, } 1 \text{ for male})$$

In addition to independently predicting morbidity and mortality (109,110), the 6-min walk test has been used to evaluate CRF in populations considered to have reduced CRF, such as older adults and some clinical populations (*e.g.*, individuals with CHF or pulmonary disease). The American Thoracic Society and European Respiratory Society have published technical standards for field walking tests, including the 6-min walk test (111). Even though the test is considered submaximal, it may result in near-maximal performance for those with low physical fitness levels or disease (112). Individuals completing less than 300 m (~984 ft) during the 6-min walk demonstrate a poorer short-term survival compared to those surpassing this threshold (113). Several multivariate equations are available to predict $\dot{V}O_{2peak}$ from the 6-min walk; however, the following equation requires minimal clinical information (114):

$$\dot{V}O_{2peak} = \dot{V}O_2 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1} = (0.02 \times \text{distance [m]}) - (0.191 \times \text{age [yr]}) - (0.07 \times \text{weight [kg]}) + (0.09 \times \text{height [cm]}) + (0.26 \times \text{RPP} [\times 10^{-3}]) + 2.45$$

where m = distance in meters; yr = year; kg = kilogram; cm = centimeter; RPP = rate-pressure product (HR × SBP in mm Hg); SEE = 2.68 $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$

Step tests are also used to estimate $\dot{V}O_{2max}$. Protocols with fixed stepping rates and step heights tend to produce less accurate CRF values compared to protocols individualized for stepping rate and stature, as the required cadence and step height may be inappropriate for the individual (115). In addition to their ease to complete, the results are also easy to explain to individuals (116). Special precautions may be needed for those who have balance problems or are extremely deconditioned. Some single-stage step tests require an energy cost of 7–9 metabolic equivalents (METs), which may exceed the maximal capacity of some individuals (102). Therefore, the protocol chosen must be appropriate for the physical fitness level of the individual. In addition, inadequate compliance to the step cadence and excessive fatigue in the lead limb may diminish the value of a step test. Most tests do not monitor HR and BP while stepping because of the difficulty of these measures during the test. Some tests include RPE along with postexercise HR; others record the time required to complete a specific number of steps at a fixed step height in combination with select anthropometric variables. A summary of common step test protocols is available in *Table 3.7*.

TABLE 3.7 • Summary of Common Step Tests

Test	Population	Step Height (cm)	Step Rate (steps · min^{-1})	Duration
Åstrand-Ryhming (103)	Healthy adults	Women: 33 Men: 40	22.5	5 min
Webb (115)	Young adults	Individualized (0.19 × stature in cm)	Variable; dependent on perceived functional ability; increased by 5 steps · min^{-1} every 2 min	75% of age-predicted HR_{max}
YMCA (104)	Healthy adults	30.5	24	3 min
Queens College (117)	Young adults	41.3	Women: 22 Men: 24	3 min
STEP Tool (118)	All adults	20	Variable	20 stepping cycles

HR_{max}, maximal heart rate.

Åstrand and Ryhming (103) used a single-step height of 33 cm (13 in) for women and 40 cm (15.7 in) for men at a rate of 22.5 steps · min^{-1} (when counting just the leading leg) for 5 min. These tests require $\dot{V}O_2$ of about 25.8 and 29.5 mL · kg^{-1} · min^{-1}, respectively. Because of this, step tests may not be a good choice of modality for individuals who are less fit, have a contraindication for testing, or are taking a medication that affects HR. HR is measured in the last minute as described for the Åstrand-Ryhming cycle ergometer test, and $\dot{V}O_{2max}$ is estimated from a nomogram (see *Figure 3.1*). Multistage step tests are also possible.

Specifically designed for college-aged adults, the Webb protocol stepping cadence is increased by 5 steps · min^{-1} every 2 min until 75% of the age-predicted HR_{max} (HR_{max} = 207 − [0.7 × age]) is attained (119). Step height is individualized based on a person's height; final stepping cadence, recovery HR at 45 s, and the individualized perceived functional ability are needed to estimate $\dot{V}O_{2max}$. Such step tests should be modified to suit the population being tested. The Canadian Home Fitness Test has demonstrated that such testing can be performed on a large scale and at low cost (120).

Instead of estimating $\dot{V}O_{2max}$ from HR responses to submaximal work rates, a wide variety of step tests have been developed to categorize CRF based on an individual's recovery HR following a standardized step test, as postexercise (recovery) HR decreases with improved CRF. This eliminates the potential problem of taking HR during stepping. The 3-Minute YMCA Step Test is a good example of such a test. This test uses a 12-in (30.5-cm) bench, with a stepping rate of 24 steps · min^{-1} (estimated $\dot{V}O_2$ of 25.8 mL · kg^{-1} · min^{-1}). After stepping is completed, the individual immediately sits down, and HR is counted for 1 min. Counting must start within 5 s at the end of exercise. HR values are used to obtain a qualitative rating of fitness from published normative tables (107). Additionally, the Queens College Step Test (also called the McArdle Step Test) requires individuals to step at a rate of 24 steps · min^{-1} for men and 22 steps · min^{-1} for women for 3 min. The bench height is 16.25 in (41.25 cm). After stepping is completed, the individual remains standing. Wait 5 s, take a 15-s HR count, and multiply the HR by 4 to convert to beats · min^{-1}. $\dot{V}O_{2max}$ is calculated using the formulas below (117):

For men:

$$\dot{V}O_{2max}\ (mL \cdot kg^{-1} \cdot min^{-1}) = 111.33 - (0.42 \times HR)$$

For women:

$$\dot{V}O_{2max}\ (mL \cdot kg^{-1} \cdot min^{-1}) = 65.81 - (0.1847 \times HR)$$

where HR = heart rate (beats · min^{-1})

There are self-paced step test alternatives that do not rely on a metronome for controlling stepping rate. These single-stage step tests provide health care practitioners with a feasible opportunity to quickly estimate CRF during an office visit. The STEP Tool protocol requires a standard set of two contiguous steps, each 20 cm (~8 in) in height, and $\dot{V}O_{2max}$ is based on the individual's time to complete 20 stepping cycles, body mass, age, sex, and the 6-s recovery HR (118). For older adults completing this protocol, sex-specific estimations of $\dot{V}O_{2max}$ are based on time to completion, O_2 pulse, age, BMI, and HR immediately following the last stepping cycle (121). For this protocol, O_2 pulse is calculated as the O_2 cost of stepping/HR immediately postexercise, with O_2 cost of stepping = [(stepping frequency × step height (cm) × 1.78 × 1.3) + $\frac{1}{3}$ stepping frequency]. Exercise professionals and clinicians should screen each person carefully and familiarize them with the stepping procedure prior to having them undertake these self-paced step tests.

Submaximal Exercise Tests

Single-stage and multistage submaximal exercise tests are available to estimate $\dot{V}O_{2max}$ from simple HR measurements. Accurate measurement of HR is critical for valid testing. Although HR obtained by palpation is commonly used, the accuracy of this method depends on the experience and technique of the evaluator. It is recommended that an ECG, a stethoscope, or a HR monitor be used to determine HR. The submaximal HR response is easily altered by a number of environmental (*e.g.*, heat, humidity; see *Chapter 7*), dietary (*e.g.*, caffeine, time since last meal), and behavioral (*e.g.*, anxiety, smoking, previous PA) factors. These variables must be controlled to have a valid estimate that can be used as a reference point in an individual's fitness program. In addition, the test mode (*e.g.*, cycle, treadmill, step) should be consistent with the primary exercise modality used by the individual to address specificity of training issues. Standardized procedures for submaximal testing are presented in *Box 3.7*. See *Figure 4.1* for a list of incremental treadmill protocols that may be used to assess submaximal exercise responses.

Box 3.7 General Procedures for Submaximal Testing of Cardiorespiratory Fitness

1. Obtain resting HR and BP immediately prior to exercise in the exercise posture.
2. The individual should be familiarized with the ergometer or treadmill. If using a cycle ergometer, properly position the individual on the ergometer (*i.e.*, upright posture, ~25-degree bend in the knee at maximal leg extension, and hands in proper position on handlebars) (122,123).
3. The exercise test should begin with a 2- to 3-min warm-up to acquaint the individual with the cycle ergometer or treadmill and prepare him or her for the exercise intensity in the first stage of the test.
4. A specific protocol should consist of 2- or 3-min stages with appropriate increments in work rate.
5. HR should be monitored at least two times during each stage, near the end of the second and third minutes of each stage. If HR is >110 beats • min^{-1}, steady state HR (*i.e.*, two HRs within 5 beats • min^{-1}) should be reached before the workload is increased.

6. BP should be monitored in the last minute of each stage and repeated (verified) in the event of a hypotensive or hypertensive response.
7. RPE (using either the Borg category or category-ratio scale [see *Table 3.6* and *Figure 4.2*]) and additional rating scales should be monitored near the end of the last minute of each stage.
8. Individual's appearance and symptoms should be monitored and recorded regularly.
9. The test should be terminated when the individual reaches 70% heart rate reserve (85% of age-predicted HR_{max}), fails to conform to the exercise test protocol, experiences adverse signs or symptoms, requests to stop, or experiences an emergency situation.
10. An appropriate cool-down/recovery period should be initiated consisting of either
    a. Continued exercise at a work rate equivalent to that of the first stage of the exercise test protocol or lower or
    b. A passive cool-down if the individual experiences signs of discomfort or an emergency situation occurs
11. All physiologic observations (*e.g.*, HR, BP, signs, and symptoms) should be continued for at least 5 min of recovery unless abnormal responses occur, which would warrant a longer posttest surveillance period. Continue low-level exercise until HR and BP stabilize but not necessarily until they reach preexercise levels.

BP, blood pressure; HR, heart rate; HR_{max}, maximal heart rate; RPE, rating of perceived exertion.

Interpretation of Results

Tables 3.8 and *3.9* provide normative fitness categories and percentiles by age group for CRF from cardiopulmonary exercise testing on a treadmill and cycle ergometer, respectively, with directly measured $\dot{V}O_{2max}$. These data were obtained from the Fitness Registry and the Importance of Exercise National Database (FRIEND) Registry for men and women who were considered free from known CVD. Research suggests that low CRF, usually defined as the lowest quartile or quintile on an exercise test, is associated with marked increases in CVD or all-cause mortality, independent of other CVD risk factors (74,125).

TABLE 3.8 • Treadmill-Based Cardiorespiratory Fitness Classifications (■ O_{2max}) by Age and Sex

$\dot{V}O_{2max}$ ($mL\ O_2 \cdot kg^{-1} \cdot min^{-1}$)

MEN

Percentile		Age Group (yr) 20–29	30–39	40–49	50–59	60–69
95	Superior	66.3	59.8	55.6	50.7	43.0
90	Excellent	61.8	56.5	52.1	45.6	40.3
85		59.3	54.2	49.3	43.2	38.2
80		57.1	51.6	46.7	41.2	36.1
75	Good	55.2	49.2	45.0	39.7	34.5
70		53.7	48.0	43.9	38.2	32.9
65		52.1	46.6	42.1	36.3	31.6
60		50.2	45.2	40.3	35.1	30.5
55	Fair	49.0	43.8	38.9	33.8	29.1
50		48.0	42.4	37.8	32.6	28.2
45		46.5	41.3	36.7	31.6	27.2
40		44.9	39.6	35.7	30.7	26.6
35	Poor	43.5	38.5	34.6	29.5	25.7
30		41.9	37.4	33.3	28.4	24.6
25		40.1	35.9	31.9	27.1	23.7
20		38.1	34.1	30.5	26.1	22.4
15	Very poor	35.4	32.7	29.0	24.4	21.2
10		32.1	30.2	26.8	22.8	19.8
5		29.0	27.2	24.2	20.9	17.4

WOMEN

Percentile		Age Group (yr) 20–29	30–39	40–49	50–59	60–69
95	Superior	56.0	45.8	41.7	35.9	29.4
90	Excellent	51.3	41.4	38.4	32.0	27.0

85		48.3	39.3	36.0	30.2	25.6
80		46.5	37.5	34.0	28.6	24.6
75		44.7	36.1	32.4	27.6	23.8
70	Good	43.2	34.6	31.1	26.8	23.1
65		41.6	33.5	30.0	26.0	22.0
60		40.6	32.2	28.7	25.2	21.2
55		38.9	31.2	27.7	24.4	20.5
50	Fair	37.6	30.2	26.7	23.4	20.0
45		35.9	29.3	25.9	22.7	19.6
40		34.6	28.2	24.9	21.8	18.9
35		33.6	27.4	24.1	21.2	18.4
30	Poor	32.0	26.4	23.3	20.6	17.9
25		30.5	25.3	22.1	19.9	17.2
20		28.6	24.1	21.3	19.1	16.5
15		26.2	22.5	20.0	18.3	15.6
10	Very poor	23.9	20.9	18.8	17.3	14.6
5		21.7	19.0	17.0	16.0	13.4
		(n = 410)	(n = 608)	(n = 843)	(n = 805)	(n = 408)

Percentiles from cardiopulmonary exercise testing on a treadmill with measured maximal volume of oxygen consumed per unit time ($\dot{V}O_{2max}$) (mL $O_2 \cdot kg^{-1} \cdot min^{-1}$).

Data obtained from the Fitness Registry and the Importance of Exercise National Database (FRIEND) Registry for men and women who were considered free from known cardiovascular disease.

Adapted with permission from (124).

TABLE 3.9 • Cycle Ergometer–Based Cardiorespiratory Fitness Classifications (■O_{2max}) by Age and Sex

$\dot{V}O_{2max}$ (mL $O_2 \cdot kg^{-1} \cdot min^{-1}$)

		MEN				
			Age Group (yr)			
Percentile		**20–29**	**30–39**	**40–49**	**50–59**	**60–69**
95	Superior	58.5	44.7	41.9	37.4	32.4
90	Excellent	55.5	41.7	37.1	34.0	29.9
85		53.9	38.1	34.9	32.1	27.8

80		51.4	36.2	34.2	30.7	26.7
75	Good	49.5	35	31.8	29.3	25.5
70		47.9	33.9	30.4	28.2	24.5
65		46	31.8	29.3	27.1	24
60		44.5	31.1	28.6	26.3	23.2
55	Fair	43.1	30.7	28	25.7	22.9
50		41.9	30.1	27.1	24.8	22.4
45		40.2	29.4	26.2	24.2	21.9
40		38.3	28.1	25.4	23.6	21.4
35	Poor	37.6	27.5	24.9	23	21
30		36.2	26.9	24.0	22.6	20.2
25		34.7	26.2	22.9	22.1	19.7
20		33.2	25.4	22.2	21.5	19.0
15	Very poor	31.8	23.9	21.6	20.8	18.4
10		29.5	21.8	20.6	20.4	17.3
5		25.5	19.3	18.9	18.1	15.3
WOMEN						
		Age Group (yr)				
Percentile		**20–29**	**30–39**	**40–49**	**50–59**	**60–69**
95	Superior	45.2	33.2	29.3	25	22
90	Excellent	42.6	30.0	26.2	22.6	20.5
85		40.9	27.8	24.4	21.5	19.3
80		38.8	26.0	23.4	20.7	18.8
75	Good	37.1	25.1	22.6	20.1	18.3
70		35.6	24.2	22.0	19.3	17.8
65		34.6	23.3	21.4	18.9	17.3
60		33.6	22.5	20.7	18.2	16.7
55	Fair	32.4	22.1	20	17.7	16.3
50		31.0	21.6	19.4	17.3	16.0
45		29.8	21	18.8	17	15.7
40		28.1	20.1	18.4	16.6	15.4
35	Poor	26.6	19.5	17.9	16.2	15.1
30		25.6	18.8	17.1	15.7	14.7

25		23.2	17.9	16.5	15.3	14.4
20		21.6	17.0	15.8	14.9	14.0
15		20.4	16.3	15.4	14.4	13.5
10	Very poor	19.3	15.2	14.6	13.7	13.0
5		17.1	14.4	13.5	12.8	12.2
		(*n* = 410)	(*n* = 608)	(*n* = 843)	(*n* = 805)	(*n* = 408)

Percentiles from cardiopulmonary exercise testing on a cycle ergometer with measured maximal volume of oxygen consumed per unit time ($\dot{V}O_{2max}$) (mL $O_2 \cdot kg^{-1} \cdot min^{-1}$).

Data obtained from the Fitness Registry and the Importance of Exercise National Database (FRIEND) Registry for men and women who were considered free from known cardiovascular disease.

Adapted with permission from (124).

Although submaximal exercise testing is not as precise as maximal exercise testing, it provides a general reflection of an individual's physical fitness at a lower cost, potentially reduced risk for adverse events, and requires less time and effort on the part of the individual. Some of the assumptions inherent in a submaximal test are more easily met (*e.g.*, steady state HR can be verified), whereas others (*e.g.*, estimated HR_{max}) introduce errors into the prediction of $\dot{V}O_{2max}$. Despite this, when an individual is given repeated submaximal exercise tests over the course of an Ex R_x, the HR response to a fixed work rate decreases, which indicates the individual's CRF has improved, independent of the accuracy of the $\dot{V}O_{2max}$ prediction. Despite differences in test accuracy and methodology, virtually all evaluations can establish a baseline and be used to track relative progress during exercise training.

Several regression equations exist for estimating CRF without the need for an exercise test. These age- and sex-based equations produce a single expected aerobic capacity value for comparison to a measured response as opposed to percentiles. Of the available regression equations, research indicates prediction formulas derived from a Veterans Affairs cohort (predicted METs = 18 − 0.15 × age) and the St. James Women Take Heart Project (predicted METs = 14.7 − 0.13 × age) may provide somewhat better prognostic information in men and women, respectively (126). These prediction equations may be useful when CRF testing is not possible.

MUSCULAR FITNESS

The American College of Sports Medicine (ACSM) has melded the terms *muscular strength*, *endurance*, and *power* into a category termed *muscular fitness* and included it as an integral portion of total health-related fitness in the position stand on the quantity and quality of exercise for developing and maintaining fitness (127). It should also be noted, however, that muscle fitness is an integral part of performance-related fitness.

Therefore, muscular strength, endurance, and power are components of both health-related and performance-related fitness. For the purpose of this chapter, which focuses on apparently healthy individuals, the focus is on improving or maintaining the following important health-related fitness characteristics (127–129):

- FFM and resting metabolic rate, which are related to weight management
- Bone mass, which is related to osteoporosis
- Muscle mass, which is related to sarcopenia
- Glucose tolerance, which is pertinent in both the prediabetic and diabetic state
- Musculotendinous integrity, which is related to a lower risk of injury including low back pain
- The ability to carry out the activities of daily living, which is related to perceived quality of life and self-efficacy among other indicators of mental health

Muscular strength refers to the muscle's ability to exert a maximal force on one occasion, muscular endurance is the muscle's ability to continue to perform successive exertions or repetitions against a submaximal load, and muscular power is the muscle's ability to exert force per unit of time (*i.e.*, rate) (62). Traditionally, tests allowing few repetitions (≤3) of a task prior to reaching muscular fatigue have been considered strength measures, whereas those in which numerous repetitions (>12) are performed prior to muscular fatigue were considered measures of muscular endurance. However, the performance of maximal repetitions (*i.e.*, 4, 6, or 8 repetitions at a given resistance) across a wider range can also be used to predict muscle strength.

Furthermore, participating in strength-promoting exercise reduces all-cause mortality risk beyond what is observed with aerobic exercise only (130).

Rationale

Physical fitness tests of muscular strength and muscular endurance before commencing exercise training or as part of a health/fitness screening evaluation can provide valuable information on an individual's baseline physical fitness level. For example, muscular fitness test results can be compared to established standards and can be helpful in identifying weaknesses in certain muscle groups or muscle imbalances that could be targeted in exercise training programs. The information obtained during baseline muscular fitness assessments can also serve as a basis for designing individualized exercise training programs. An equally useful application of physical fitness testing is to show an individual's progressive improvement over time as a result of the training program and thus provide feedback that is often beneficial in promoting long-term exercise adherence.

Principles

Muscle function tests are very specific to the muscle group and joint(s) tested, the type of muscle action, velocity of muscle movement, type of equipment, and joint range of motion (ROM). Results of any one test are specific to the procedures used, and no single test exists for evaluating total body muscular endurance or strength. Individuals should participate in familiarization/practice sessions with test equipment and adhere to a specific protocol including a predetermined repetition duration and ROM in order to obtain a reliable score that can be used to track true physiologic adaptations over time. Moreover, a warm-up consisting of 5–10 min of light intensity aerobic exercise (*i.e.*, treadmill or cycle ergometer), dynamic stretching, and several light intensity repetitions of the specific testing exercise should precede muscular fitness testing (see *Chapter 5* for more detailed information). These warm-up activities increase muscle temperature and localized blood flow and promote appropriate cardiovascular responses for exercise. Standardized conditions for muscular fitness assessment include the following:

- Aerobic warm-up
- Equipment familiarization
- Strict posture
- Consistent repetition duration (movement speed)
- Full ROM
- Use of spotters (when necessary)

Change in muscular fitness over time can be based on the absolute value of the external load or resistance (*e.g.*, newtons, kilograms, or pounds), but when comparisons are made between individuals, the values should be expressed as relative values (per kilogram of body mass [$kg \cdot kg^{-1}$]). In both cases, caution must be used in the interpretation of the scores because the norms may not include a representative sample of the individual being measured, a standardized protocol may be absent, or the exact test being used (*e.g.*, free weight vs. machine weight) may differ. In addition, the biomechanics for a given resistance exercise may differ significantly when using equipment from different manufacturers, further impacting generalizability.

Muscular Strength

Although muscular strength refers to the external force (properly expressed in newtons, although kilograms and pounds are commonly used as well) that can be generated by a specific muscle or muscle group, it is commonly expressed in terms of resistance met or overcome. Strength can be assessed either statically (*i.e.*, no overt muscular movement at a given joint or group of joints) or dynamically (*i.e.*, movement of an external load or body part in which the muscle changes length). Static or isometric strength can be measured conveniently using a variety of devices including cable tensiometers and handgrip dynamometers. Measures of static strength are specific to the muscle group and joint angle involved in testing and thus may be limited in describing overall muscular strength. Despite this limitation, simple measurements, such as handgrip strength, have predicted mortality and functional status in older individuals (131,132). Peak force development in such tests is commonly referred to as the maximal voluntary contraction (MVC). Procedures for the grip strength test are described in *Box 3.8*, and grip strength norms are provided in *Table 3.10*.

Box 3.8 Static Handgrip Strength Test Procedures

1. Adjust the grip bar so the second joint of the fingers fits snugly over the handle. Set the dynamometer to zero.
2. The individual stands with feet slightly apart and holds the handgrip dynamometer in line with the forearm at the level of the thigh, away from the body.
3. The individual squeezes the handgrip dynamometer as hard as possible without holding the breath (to avoid the Valsalva maneuver). Neither the hand nor the handgrip dynamometer should touch the body or any other object.
4. Repeat the test twice with each hand. Maximum grip strength is the highest value attained from either hand (to the nearest kilogram).

Adapted from (133).

TABLE 3.10 • Fitness Categories for Grip Strength[a] by Sex and Age

Age (yr)	5th	10th	25th	50th	75th	90th	95th
Males							
20–24	32	34	38	43	48	52	55
25–29	34	37	41	45	50	54	57
30–34	36	38	42	47	52	56	59
35–39	37	39	43	48	53	57	60
40–44	37	40	44	48	53	57	60
45–49	37	39	43	48	53	57	60
50–54	36	39	43	47	52	56	59
55–59	34	37	41	46	50	54	57
60–64	32	35	39	44	48	52	55
65–69	29	32	36	41	45	49	52
70–74	25	29	33	38	42	46	49
75–79	21	25	29	34	38	42	44
Females							
20–24	20	22	24	27	29	32	34
25–29	21	22	25	28	30	33	35
30–34	22	23	25	28	31	34	35
35–39	22	23	26	28	31	34	36
40–44	22	23	26	29	31	34	36
45–49	22	23	25	28	31	34	36
50–54	21	23	25	28	31	33	35
55–59	20	22	24	27	30	32	34
60–64	19	21	23	26	29	31	33
65–69	17	19	22	25	27	30	31

70–74	15	18	21	23	25	28	29
75–79	13	16	19	21	23	26	27

[a]Norms use the best score measured in kilograms for left or right hands.
Adapted with permission from (133).

Traditionally, the 1-RM, the greatest resistance that can be moved through the full ROM in a controlled manner with good posture, has been the standard for dynamic strength assessment. The exercise professional should be aware that 1-RM measurements may vary between different types of equipment (134), although with appropriate testing familiarization, 1-RM is a reliable indicator of muscle strength (135–137). A multiple RM, such as 5- or 10-RM, can also be used as a measure of muscular strength. It is important when performing 5- to 10-RM that the exercise be performed to failure. When using a multiple RM (*i.e.*, 5- to 10-RM) to estimate the 1-RM, the prediction accuracy improves as the resistance increases and the RM gets closer to 1-RM (134,138). Tables and prediction equations are available to estimate 1-RM from multiple RM (134,138). It is also possible to track strength gains over time without the need to estimate 1-RM. For example, if one were training with 6- to 8-RM, the performance of a 6-RM to muscular fatigue would provide an index of strength changes over time, independent of the true 1-RM.

A conservative approach to assessing maximal muscle strength should be considered in individuals at high risk for or with known CVD, pulmonary, and metabolic diseases and health conditions that present relative contraindications to muscular strength testing. For these groups, assessment of 10- to 15-RM that approximates training recommendations may be prudent (129).

Valid measures of general upper body strength include the 1-RM values for bench press or shoulder press. Corresponding indices of lower body strength include 1-RM values for the leg press or squat. Proposed fitness standards for the upper body strength and lower body strength are provided in *Tables 3.11* and *3.12*, respectively. The normative data must be interpreted with caution, and strict adherence to proper lifting technique must be followed for the comparisons to be valid. There are inherent differences between 1-RM testing done using machines versus free weights; thus, it is important to use the same type of resistance modality when tracking an individual's performance over time. The basic steps in 1-RM (or any multiple RM) testing following familiarization/practice sessions are presented in *Box 3.9*.

TABLE 3.11 • Fitness Categories for Upper Body Strength[a] for Men and Women by Age

Bench Press Weight Ratio = weight pushed in lb ÷ body weight in lb

MEN							
		Age (yr)					
%		<20	20–29	30–39	40–49	50–59	60+
99	Superior	>1.76	>1.63	>1.35	>1.20	>1.05	>0.94
95		1.76	1.63	1.35	1.20	1.05	0.94
90	Excellent	1.46	1.48	1.24	1.10	0.97	0.89
85		1.38	1.37	1.17	1.04	0.93	0.84
80		1.34	1.32	1.12	1.00	0.90	0.82
75	Good	1.29	1.26	1.08	0.96	0.87	0.79
70		1.24	1.22	1.04	0.93	0.84	0.77
65		1.23	1.18	1.01	0.90	0.81	0.74
60		1.19	1.14	0.98	0.88	0.79	0.72
55	Fair	1.16	1.10	0.96	0.86	0.77	0.70
50		1.13	1.06	0.93	0.84	0.75	0.68
45		1.10	1.03	0.90	0.82	0.73	0.67
40		1.06	0.99	0.88	0.80	0.71	0.66
35	Poor	1.01	0.96	0.86	0.78	0.70	0.65
30		0.96	0.93	0.83	0.76	0.68	0.63
25		0.93	0.90	0.81	0.74	0.66	0.60
20		0.89	0.88	0.78	0.72	0.63	0.57
15	Very poor	0.86	0.84	0.75	0.69	0.60	0.56
10		0.81	0.80	0.71	0.65	0.57	0.53
5		0.76	0.72	0.65	0.59	0.53	0.49
1		<0.76	<0.72	<0.65	<0.59	<0.53	<0.49
n		60	425	1,909	2,090	1,279	343

Total *n* = 6,106

WOMEN							
		Age (yr)					
%		<20	20–29	30–39	40–49	50–59	60+
99	Superior	>0.88	>1.01	>0.82	>0.77	>0.68	>0.72
95		0.88	1.01	0.82	0.77	0.68	0.72
90	Excellent	0.83	0.90	0.76	0.71	0.61	0.64
85		0.81	0.83	0.72	0.66	0.57	0.59
80		0.77	0.80	0.70	0.62	0.55	0.54
75	Good	0.76	0.77	0.65	0.60	0.53	0.53
70		0.74	0.74	0.63	0.57	0.52	0.51
65		0.70	0.72	0.62	0.55	0.50	0.48
60		0.65	0.70	0.60	0.54	0.48	0.47
55	Fair	0.64	0.68	0.58	0.53	0.47	0.46
50		0.63	0.65	0.57	0.52	0.46	0.45
45		0.60	0.63	0.55	0.51	0.45	0.44
40		0.58	0.59	0.53	0.50	0.44	0.43
35	Poor	0.57	0.58	0.52	0.48	0.43	0.41
30		0.56	0.56	0.51	0.47	0.42	0.40
25		0.55	0.53	0.49	0.45	0.41	0.39
20		0.53	0.51	0.47	0.43	0.39	0.38
15	Very poor	0.52	0.50	0.45	0.42	0.38	0.36
10		0.50	0.48	0.42	0.38	0.37	0.33
5		0.41	0.44	0.39	0.35	0.31	0.26
1		<0.41	<0.44	<0.39	<0.35	<0.31	<0.26
n		20	191	379	333	189	42

Total *n* = 1,154

[a] One repetition maximum (1-RM) bench press, with bench press weight ratio = weight pushed in pounds per body weight in pounds. 1-RM was measured using a Universal Dynamic Variable Resistance (DVR) machine.

Adapted with permission from *Physical Fitness Assessments and Norms for Adults and Law Enforcement*. The Cooper Institute, Dallas, Texas. 2013. For more information: http://www.cooperinstitute.org.

TABLE 3.12 • Fitness Categories for Leg Strength by Age and Sex[a]

Leg Press Weight Ratio = weight pushed in lb ÷ body weight in lb

MEN						
		Age (yr)				
Percentile		**20–29**	**30–39**	**40–49**	**50–59**	**60+**
90	Well above average	2.27	2.07	1.92	1.80	1.73
80	Above average	2.13	1.93	1.82	1.71	1.62
70		2.05	1.85	1.74	1.64	1.56
60	Average	1.97	1.77	1.68	1.58	1.49
50		1.91	1.71	1.62	1.52	1.43
40	Below average	1.83	1.65	1.57	1.46	1.38
30		1.74	1.59	1.51	1.39	1.30
20	Well below average	1.63	1.52	1.44	1.32	1.25
10		1.51	1.43	1.35	1.22	1.16
WOMEN						
		Age (yr)				
Percentile		**20–29**	**30–39**	**40–49**	**50–59**	**60+**
90	Well above average	1.82	1.61	1.48	1.37	1.32
80	Above average	1.68	1.47	1.37	1.25	1.18
70		1.58	1.39	1.29	1.17	1.13
60	Average	1.50	1.33	1.23	1.10	1.04
50		1.44	1.27	1.18	1.05	0.99
40	Below average	1.37	1.21	1.13	0.99	0.93
30		1.27	1.15	1.08	0.95	0.88
20	Well below	1.22	1.09	1.02	0.88	0.85

10	average	1.14	1.00	0.94	0.78	0.72

[a]One repetition maximum (1-RM) leg press with leg press weight ratio = weight pushed per body weight. 1-RM was measured using a Universal Dynamic Variable Resistance (DVR) machine.

Study population for the data set was predominantly white and college educated.

Adapted from Institute for Aerobics Research, Dallas, 1994.

Box 3.9 One Repetition Maximum (1-RM) and Multiple Repetition Maximum (RM) Test Procedures for Measurement of Muscular Strength

1. Testing should be completed only after the individual has participated in familiarization/practice sessions.
2. The individual should warm up by completing a number of submaximal repetitions of the specific exercise that will be used to determine the 1-RM.
3. Determine the 1-RM (or any multiple of 1-RM) within four trials with rest periods of 3- to 5-min between trials.
4. Select an initial weight that is within the individual's perceived capacity (~50%–70% of capacity).
5. Resistance is progressively increased by 5%–10% for upper body or 10%–20% for lower body exercise from the previous successful attempt until the individual cannot complete the selected repetition(s); all repetitions should be performed at the same speed of movement and ROM to instill consistency between trials.
6. The final weight lifted successfully is recorded as the absolute 1-RM or multiple RM.

ROM, range of motion.
Adapted from (138,139).

Isokinetic testing involves the assessment of maximal muscle tension throughout an ROM set at a constant angular velocity (*e.g.*, 60 degrees · s^{-1}). Equipment that allows control of the speed of joint rotation (degrees · s^{-1}), as well as the ability to test movement around various joints (*e.g.*, knee, hip, shoulder, elbow) is available from commercial sources. Such devices measure peak rotational force or torque, but an important drawback is that this equipment is substantially more expensive compared to other strength testing modalities (140).

Muscular Endurance

Muscular endurance is the ability of a muscle group to execute repeated muscle actions over a period of time sufficient to cause muscular fatigue or to maintain a specific percentage of the 1-RM for a prolonged period of time. If the total number of repetitions at a given amount of resistance is measured, the result is termed *absolute muscular endurance*. If the number of repetitions performed at a percentage of the 1-RM (*e.g.*, 70%) is used pre- and posttesting, the result is termed *relative muscular endurance*. A simple field test such as the maximum number of push-ups that can be performed without rest may be used to evaluate the endurance of upper body muscles (141). Procedures for conducting this push-up endurance test are presented in *Box 3.10*, and physical fitness categories based on sex and age are provided in *Table 3.13*. Historically, the curl-up (crunch) test was included in muscular fitness test batteries. However, most curl-up tests are only moderately related to abdominal endurance (r = .46−.50) and poorly related to abdominal strength (r = −.21−.36) (142,143). In addition, the benefits of this test as an assessment tool do not appear to exceed the potential risk of low back injury; thus, the curl-up test is no longer included in the ACSM *Guidelines*.

Box 3.10 **Push-up Test Procedures for Measurement of Muscular Endurance**

1. The push-up test is administered with men starting in the standard "down" position (fingers pointing forward and under the shoulder, back straight, head up, using the toes as the pivotal point) and women in the modified "knee push-up" position (lower legs in contact with mat with ankles plantarflexed and using the knees as the pivotal point).
2. The individual must raise the body by straightening the elbows and return to the "down" position, until the chin touches the mat. The stomach should not touch the mat.
3. For both men and women, the individual's back must be straight at all times, and the individual must push-up to a straight arm position.
4. The maximal number of push-ups performed consecutively without rest is counted as the score.
5. The test is stopped when the individual strains forcibly or unable to maintain the appropriate technique within two repetitions.

TABLE 3.13 • Fitness Categories for the Push-up by Age and Sex										
	Age (yr)									
Category	20–29		30–39		40–49		50–59		60–69	
Sex	M	W	M	W	M	W	M	W	M	W
Excellent	≥36	≥30	≥30	≥27	≥25	≥24	≥21	≥21	≥18	≥17
Very good	29–35	21–29	22–29	20–26	17–24	15–23	13–20	11–20	11–17	12–16
Good	22–28	15–20	17–21	13–19	13–16	11–14	10–12	7–10	8–10	5–11
Fair	17–21	10–14	12–16	8–12	10–12	5–10	7–9	2–6	5–7	2–4
Poor	≤16	≤9	≤11	≤7	≤9	≤4	≤6	≤1	≤4	≤1

M, men; W, women.
Reprinted with permission from the Canadian Society for Exercise Physiology (141).

Muscular Power

Muscular power is the rate of performing work. Traditionally, muscular power has been considered a performance-related component of fitness rather than a health-related variable, and consequently, it has not been included in health-related fitness batteries. However, muscular power declines at a faster rate than muscular strength or muscular endurance with aging (144), and it may be the most valuable of the muscular fitness variables for predicting maintenance of functional independence and improving quality of life (145). Therefore, fitness professionals should consider including a measurement of muscular power in their assessments of muscular fitness.

Commercially available linear transducers and accelerometers can be used to assess movement velocity of a person or barbell in order to determine muscular power. For example, a linear transducer attached to the waist was used to accurately measure relative power in older adults (>65 yr) rising as quickly as possible from a seated to standing position (146). Unfortunately, standardized field tests that do not require any specialized equipment and corresponding norms have yet to be established for measuring power of older adults. Alternatively, jump height from a countermovement vertical jump is a commonly used surrogate for estimating muscular power in a younger population in whom impact loading is less of a concern. Procedures for measuring the vertical jump are presented in *Box 3.11*, and age-sex norms for the countermovement vertical jump are provided in *Table 3.14*.

Box 3.11 Countermovement Vertical Jump Test Procedures for Measurement of Muscular Power

1. The individual stands flat-footed and reaches as high as possible with the dominant hand. If a commercial vertical jump testing apparatus is being used, measure the individual's reach height with the highest vane that can be touched. If no jump testing apparatus is being used, the individual can put chalk on the fingertips and touch the wall to mark reach height.
2. Without a running start or preparatory steps, the individual makes a ballistic countermovement from a standing position by rapidly flexing the hips and knees and swinging the arms backward, followed immediately by an explosive arm swing upward and extension of the hips and knees to jump as high as possible.
3. During the jump, the dominant hand should reach as high as possible at the height of the jump. If using a jump testing apparatus, swat the vane with the outstretched dominant hand at the highest point of the jump. Alternatively, chalked fingers can place a mark on the wall.
4. The examiner records the difference between the jump height (highest vane moved on a jump apparatus or highest chalk mark on the wall) and the reach height. This is the individual's vertical jump.
5. The best of three trials is used for comparison to normative values.

TABLE 3.14 • Fitness Categories for the Countermovement Vertical Jump by Age and Sex

	Age (yr):					
	15–19	20–29	30–39	40–49	50–59	60–69
Males						
Excellent	≥56	≥58	≥52	≥43	≥41	≥33
Very good	51–55	54–57	46–51	36–42	34–40	29–32
Good	46–50	48–53	40–45	32–35	28–33	25–28
Fair	42–45	42–47	31–39	26–31	18–27	18–24
Poor	≤41	≤41	≤30	≤25	≤17	≤17
Females						
Excellent	≥40	≥38	≥36	≥31	≥25	≥19
Very good	36–39	34–37	32–35	27–30	21–24	15–18
Good	32–35	29–33	28–31	23–26	16–20	11–14
Fair	28–31	25–28	24–27	18–22	10–15	7–10
Poor	≤27	≤24	≤23	≤17	≤9	≤6

All values are in centimeters.
Adapted with permission from (147).

FLEXIBILITY

Flexibility is the ability to move a joint through its complete, pain-free ROM, and is important in athletic performance and in the ability to carry out activities of daily living. Maintaining flexibility of all joints facilitates movement and may prevent injury; however, it is impossible to state with confidence that preactivity stretching unequivocally reduces injuries associated with PA (148). Nevertheless, when an activity moves the structures of a joint beyond its full ROM, tissue damage can occur.

Flexibility depends on a number of specific variables including distensibility of the joint capsule, adequate warm-up, and muscle viscosity. In addition, compliance (*i.e.*, tightness) of various other tissues such as ligaments and tendons affect ROM. Just as muscular strength and endurance are specific to the muscles involved, flexibility is joint specific; therefore, no single flexibility test can be used to evaluate total body flexibility. Laboratory tests usually quantify flexibility in terms of ROM expressed in degrees; therefore, measuring ROM in degrees is considered a direct measurement. Common devices for direct ROM measurement include goniometers, electrogoniometers, the Leighton flexometer, and inclinometers. Goniometers and inclinometers are now available with digital displays that might reduce reading errors. Comprehensive instructions are available for the evaluation of flexibility of most anatomic joints (149,150). Basic instructions for using a goniometer and inclinometer are provided in *Box 3.12*. Accurate joint ROM measurements require in-depth knowledge of bone, muscle, and joint anatomy as well as experience in administering the evaluation. *Table 3.15* provides normative ROM values for select anatomic joints based on age and sex. Additional information can be found elsewhere (62,152).

Box 3.12 General Guidelines for Range of Motion Testing

1. Each individual should participate in a general warm-up followed by static stretching prior to range of motion testing.
2. If using a goniometer, the axis of the goniometer should be placed at the center of the joint being evaluated. The fixed arm of the goniometer should be aligned with a bony landmark of the stationary body part, and the movable arm of the goniometer should be aligned with a bony landmark of the body segment that is going to be moving. For anatomical landmarks, refer to Gibson et al. (62). If using an inclinometer, it should be held on the distal end of the moveable body segment.
3. Record the range of motion in degrees.
4. Administer multiple trials; three are recommended.
5. Use the best score to compare to reference values.

TABLE 3.15 • Range of Motion in Degrees at Select Joints by Age and Sex

	Age (yr):					
	9–19		20–44		45–69	
	M	F	M	F	M	F
Hip extension	18 (17–20)	21 (19–22)	17 (16–19)	18 (17–19)	14 (13–15)	17 (16–18)
Hip flexion	135 (133–137)	135 (133–137)	130 (129–132)	134 (133–135)	127 (126–129)	131 (129–132)
Knee flexion	142 (140–144)	142 (141–144)	138 (137–139)	142 (141–143)	133 (132–134)	138 (137–139)
Knee extension	2 (1–3)	2 (2–3)	1 (1–1)	2 (1–2)	1 (0–1)	1 (1–2)
Ankle dorsiflexion	16 (15–18)	17 (16–19)	13 (12–14)	14 (13–15)	12 (11–13)	12 (11–13)
Ankle plantarflexion	53 (51–55)	57 (55–60)	55 (53–56)	62 (61–64)	49 (48–51)	57 (55–58)
Shoulder flexion	171 (169–173)	172 (170–174)	169 (167–170)	172 (171–173)	164 (162–166)	168 (167–170)
Elbow flexion	148 (147–150)	150 (149–151)	145 (144–146)	150 (149–151)	144 (142–145)	148 (147–149)
Elbow extension	5 (4–7)	6 (5–8)	1 (0–2)	5 (4–6)	−1 (−2–0)	4 (3–5)
Elbow pronation	80 (79–82)	81 (80–83)	77 (76–78)	82 (81–83)	78 (77–79)	81 (80–82)
Elbow supination	88 (86–90)	90 (88–92)	85 (84–86)	91 (89–92)	82 (81–84)	87 (86–88)

M, men; W, women.
Data are means (95% confidence interval).
Adapted with permission from (151).

Previous editions of the *Guidelines* included the sit-and-reach test as a simple field test of low back and hamstring flexibility; however, this test is unrelated to low back pain (153,154) and is questionable as a measure of hamstring flexibility (155). Rather than providing an angular measurement, the sit-and-reach test is an indirect linear measurement of ROM. Furthermore, there are multiple versions and variations of the sit-and-reach test, leading to potential for confusion and misinterpretation of individual results. Given the low cost, portability, and simplicity of the laboratory tests (*i.e.*, goniometer and inclinometer), combined with the questionable validity of the sit-and-reach test, this edition of the *Guidelines* recommends direct measures of ROM rather than indirect methods; thus, the sit-and-reach test is not included.

BALANCE

Historically, balance has not been included in health-related test batteries of physical fitness. However, balance training can reduce the risk of ankle sprains in athletes (156,157), and the ACSM position statement on the quality and quantity of exercise for developing and maintaining fitness (127) recommends balance training for fall prevention. Balance is increasingly becoming an additional component of health-related fitness and should be considered as part of the fitness assessment test battery.

Balance is the ability to maintain a desired position. Tests for balance are subdivided into static balance or dynamic balance. Sophisticated systems that consist of computerized force plates are capable of providing center of pressure data and are considered direct measures of balance. However, these are too costly for field assessments. Simply measuring the time one can stay stationary during a static balance task or the range one can cover while maintaining postural control during a dynamic balance task are indirect, inexpensive alternatives for evaluating balance.

Two common field assessments of balance are the Balance Error Scoring System (BESS) and the Y-balance test for static and dynamic balance, respectively. The BESS involves counting the number of balance errors that a person makes while standing in three different positions: (a) feet side-by-side, (b) unipedal stance on the nondominant foot, and (c) heel-to-toe tandem stance. Each stance position is performed on a firm surface and then repeated on a foam pad, and the eyes are closed for each trial. This field test was originally validated against a direct measure of sway (158). Procedures for the BESS are presented in *Box 3.13*.

Box 3.13 **Instructions for Administering the Balance Error Scoring System (BESS)**

1. The first three tests are performed in bare feet while standing on the floor. The three tests are then repeated while standing on a foam pad. All tests are done with the eyes closed and hands placed on the hips. All tests positions are to be held for 20 s.
2. Test 1 (stance 1): Individual places feet side by side (Romberg stance).
3. Test 2 (stance 2): Individual stands on nondominant foot (unipedal stance).
4. Test 3 (stance 3): Individual stands heel-to-toe with the nondominant foot placed behind the dominant foot (tandem stance).
5. Repeat the three stance positions while standing on a medium-density foam pad (45 cm^2 × 13 cm thick) or an Airex blue pad.
6. The examiner counts the number of errors the individual makes on each of the six tests. Errors include the following: (a) lifting hands off of the hips, (b) opening eyes, (c) stepping/stumbling, (d) excessive hip flexion or abduction (>30 degrees) to correct balance, and (e) lifting foot or heel. If an error is made, the individual should correct it as soon as possible. The number of errors made are summed. The maximal number of errors counted for each of the 20-s trials is 10. Failure to maintain the stance position for at least 5 s of the 20-s trial results in a maximal error score of 10.

The Y-balance test makes use of a commercially available apparatus to measure the distance a person can reach with one foot while maintaining balance on the other foot. The individual slides moveable blocks with their toes as far as possible in the anterior, posteromedial, and posterolateral directions, forming a “Y” (159). This test has been used to assess injury risk in collegiate athletes (156,160). Procedures for the Y-balance test are explained in *Box 3.14*.

Box 3.14 **Instructions for Administering the Y-Balance Test**

1. A Y-balance testing apparatus is needed. These are commercially available.
2. Individual stands bare foot on the center block with one foot. The leg supporting the body weight is the one being tested.
3. The toes of the opposite foot are used to push the anterior block as far forward as possible while maintaining balance on the center block. The distance the block is moved is recorded by the examiner.
4. The individual moves the posteromedial and posterolateral blocks in the same manner.
5. Each direction is tested three times. Switch feet on the center block and repeat the test. Thus, the anterior, posteromedial, and posterolateral directions are each challenged

three times with both the dominant and nondominant leg.
6. The best of the three trials for each direction and each foot is used for evaluation.
7. Leg length is measured (anterior superior iliac spine to the medial malleolus).
8. The best anterior, posteromedial, and posterolateral score for the right leg are summed and divided by 3 times the leg length to get a composite score (percentage of leg length) for the right leg. This is repeated for the left leg.

ONLINE RESOURCES

ACSM certifications: https://www.acsm.org/get-stay-certified

ACSM Exercise is Medicine — Exercise Professionals: https://www.exerciseismedicine.org/support_page.php?p=91

American Heart Association: https://www.heart.org/en/

Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults: The Evidence Report (Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults: The Evidence Report [Internet] 2008): https://www.healthypeople.gov/2020/tools-resources/evidence-based-resource/clinical-guidelines-on-the-identification-evaluation

National Heart, Lung, and Blood Institute Health Information for Professionals: https://www.nhlbi.nih.gov/health/indexpro.htm

Physical Activity Guidelines for Americans, 2nd edition: https://health.gov/our-work/physical-activity/current-guidelines

The Cooper Institute Fitness Adult Education: https://www.cooperinstitute.org/education/

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Clinical Exercise Testing and Interpretation

CHAPTER 4

INTRODUCTION

Clinical exercise testing has been part of the differential diagnosis of individuals with ischemic heart disease (IHD) for more than 50 yr. Although there are several indications for clinical exercise testing, most tests are performed as part of the diagnosis and evaluation of IHD. There are several evidence-based statements from professional organizations related to the conduct and application of clinical exercise testing. This chapter briefly summarizes these statements with a focus on noninvasive, symptom-limited, maximal exercise tests in adults with or suspected of having heart disease. Individuals who regularly perform or supervise clinical exercise tests should be familiar with the professional statements referenced in this chapter, especially those related to the conditions that are regularly presented in their clinic.

During a clinical exercise test, individuals are monitored while performing incremental (most common) or constant work rate exercise using standardized protocols and procedures and typically using a treadmill or a stationary cycle ergometer (1–4). The purpose is to observe physiological responses to increasing or sustained metabolic demand. The clinical exercise test typically continues until the individual reaches a sign (*e.g.*, ST-segment depression) or symptom-limited (*e.g.*, angina, fatigue) maximal level of exertion. A clinical exercise test is often referred to as a graded exercise test (GXT), an exercise stress test, or an exercise tolerance test (ETT). When an exercise test includes the analysis of expired gases during exercise, it is termed a *cardiopulmonary exercise test* (most often abbreviated CPX or CPET) or a metabolic exercise test.

INDICATIONS FOR A CLINICAL EXERCISE TEST

Indications for clinical exercise testing encompass three general categories: (a) diagnosis (*e.g.*, presence of disease or abnormal physiologic response), (b) prognosis (*e.g.*, risk for an adverse event), and (c) evaluation of the physiologic response to exercise (*e.g.*, blood pressure [BP] and peak exercise capacity). All three of these indications are useful for evaluating therapy for individuals with cardiovascular or pulmonary disease. The most common diagnostic indication is the assessment of symptoms suggestive of IHD. The American College of Cardiology (ACC) and the American Heart Association (AHA) recommend a logistic approach to determining the type of test to be used in the evaluation of someone presenting with stable chest pain (3). In this approach, a symptom-limited maximal exercise test with electrocardiographic monitoring only (*i.e.*, without adjunctive cardiac imaging) should initially be considered when the diagnosis of IHD is not certain, the individual has an interpretable resting electrocardiogram (ECG) (see "Electrocardiogram" section), and the individual is able to exercise (5,6).

Current evidence does not support the routine use of exercise testing (with or without imaging) to screen for IHD or the risk of IHD-related events in asymptomatic individuals who have a very low or low pretest probability of IHD (5,7,8). This is because the exercise test is less accurate in low-risk individuals (3,5,8). Evidence also does not support the routine use of the test among individuals with a high pretest probability of IHD based on age, symptoms, and gender, given that the diagnosis is generally already known (5). Pretest likelihood of IHD is described in *Table 4.1*. In addition, the exercise ECG is less accurate in diagnosing IHD among individuals on digitalis therapy with ST-segment depression on their resting ECG and among those who meet the ECG criteria for left ventricular hypertrophy with ST-segment depression on their resting ECG (5). Additionally, the exercise test with ECG alone is not useful for the diagnosis of IHD in individuals with Wolff-Parkinson-White (W-P-W), ventricular pacing, >1.0 mm of ST-segment depression on their resting ECG, or left bundle-branch block (LBBB) (5). Although these ECG abnormalities limit the utility of the exercise test with ECG alone in the diagnosis of IHD, there may be other indications in which the exercise test is appropriate, such as the assessment of symptoms or the measurement of exercise capacity.

TABLE 4.1 • Pretest Likelihood of Ischemic Heart Disease[a]

Age	Sex	Typical/Definite Angina Pectoris	Atypical/Probable Angina Pectoris	Nonanginal Chest Pain	Asymptomatic
30 to 39 yr	Men	Intermediate	Intermediate	Low	Very low
	Women	Intermediate	Very low	Very low	Very low
40 to 49 yr	Men	High	Intermediate	Intermediate	Low
	Women	Intermediate	Low	Very low	Very low
50 to 59 yr	Men	High	Intermediate	Intermediate	Low
	Women	Intermediate	Intermediate	Low	Very low
60 to 69 yr	Men	High	Intermediate	Intermediate	Low
	Women	High	Intermediate	Intermediate	Low

[a]No data exist for patients who are <30 or >69 yr, but it can be assumed that prevalence of ischemic heart disease increases with age. In a few cases, patients with ages at the extremes of the decades listed may have probabilities slightly outside the

high or low range. High indicates >90%; intermediate, 10%–90%; low, <10%; and very low, <5%.
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The clinical utility of exercise testing is described in several evidence-based guideline statements aimed at specific cardiac diagnoses (9–15). In addition, an exercise test can be useful in the evaluation of individuals who present to emergency departments with chest pain. This practice (a) appears to be safe in individuals who are at low-to-intermediate risk for IHD and have been appropriately screened by a physician, (b) may improve the accuracy of diagnosing acute coronary syndrome, and (c) may reduce the cost of care by reducing the need for additional tests and length of stay (16). Generally, exercise testing may be appropriate for individuals whose symptoms have resolved, have a normal ECG, and had no change in enzymes reflecting cardiac muscle damage. Exercise testing in this setting should be performed only as part of well-defined clinical care pathway (16).

Additional indications that might warrant the use of a clinical exercise test include the assessment of various pulmonary diseases (*e.g.*, chronic obstructive pulmonary disease) (1,17), exercise intolerance and unexplained dyspnea (1,17,18), exercise-induced bronchoconstriction (1,17,19), exercise-induced arrhythmias (5), pacemaker or heart rate (HR) response to exercise (5), preoperative risk evaluation (1,12,17), claudication in peripheral arterial disease (20), disability evaluation (1,18), and physical activity (PA) counseling (1,5,17,21).

In addition to diagnostic utility, data from a clinical exercise test can be useful to predict prognosis. There is an inverse relationship between cardiorespiratory fitness (CRF) measured from an exercise test and the risk of mortality among apparently healthy individuals (2,21); individuals at risk for IHD (21,22); and those with diagnosed heart disease (1,18,23), heart failure (1,18,24), and lung disease (2,25–27). In addition to CRF, other measures from an exercise test have been associated with prognosis, such as the chronotropic response during or after an exercise test (17,27–30).

Clinical exercise testing is useful in guiding recommendations for return to work after a cardiac event (see *Chapter 8*) as well as developing an exercise prescription (Ex R_x) in those with known heart disease (5). In addition, the maximal exercise test is the gold standard to objectively measure exercise capacity. Although exercise time and/or peak workload achieved during an exercise test can be used to estimate peak metabolic equivalents (METs), the best measurement of exercise capacity is via respiratory gas analysis using open circuit indirect calorimetry for the determination of maximal volume of oxygen consumed per unit of time ($\dot{V}O_{2max}$) (2,5,18,24).

CONDUCTING THE CLINICAL EXERCISE TEST

When administering clinical exercise tests, it is important to consider contraindications, the exercise test protocol and mode, test endpoint indicators, safety, medications, and staff and facility emergency preparedness (3,4). The AHA (3) has outlined both absolute and relative contraindications to clinical exercise testing (*Box 4.1*). These contraindications are intended to avoid unstable ischemic, rhythm, or hemodynamic conditions or other situations in which the risk associated with undergoing the exercise test is likely to exceed the information to be gained from it.

Box 4.1 Contraindications to Symptom-Limited Maximal Exercise Testing

Absolute Contraindications

- Acute myocardial infarction within 2 d
- Ongoing unstable angina
- Uncontrolled cardiac arrhythmia with hemodynamic compromise
- Active endocarditis
- Symptomatic severe aortic stenosis
- Decompensated heart failure
- Acute pulmonary embolism, pulmonary infarction, or deep venous thrombosis
- Acute myocarditis or pericarditis
- Acute aortic dissection
- Physical disability that precludes safe and adequate testing

Relative Contraindications

- Known obstructive left main coronary artery stenosis
- Moderate to severe aortic stenosis with uncertain relationship to symptoms
- Tachyarrhythmias with uncontrolled ventricular rates
- Acquired advanced or complete heart block
- Recent stroke or transient ischemia attack
- Mental impairment with limited ability to cooperate
- Resting hypertension with systolic >200 mm Hg or diastolic >110 mm Hg
- Uncorrected medical conditions, such as significant anemia, important electrolyte imbalance, and hyperthyroidism

Reprinted with permission from (3).

Prior to the exercise test, individuals should be provided informed consent to ensure that they understand the purpose, expectations, and risks associated with the test (see *Chapter 2*) (4). The extent and quality of data obtained from a symptom-limited maximal exercise test depends on the individual's ability and willingness to provide maximal exertion; therefore, it is important to educate the individual about what he or she may experience during the test (*e.g.*, fatigue, dyspnea, chest pain) (4). Prior to performing an exercise test, the medical history (including current and recent symptoms), current medications (see *Appendix A*), and indications for the test should be noted (4). Lastly, the resting ECG should be examined for abnormalities that may preclude testing, such as new-onset atrial fibrillation or new repolarization changes (4,5). In addition, if the purpose of the exercise test is the assessment of exercise-induced myocardial ischemia, the resting ECG must allow for interpretation of exercise-induced repolarization changes (4,5); otherwise, consideration should be given to adjunctive imaging procedures such as nuclear or echocardiographic imaging (5). These additional imaging procedures are not necessary if the exercise test is being conducted for reasons other than the assessment of myocardial ischemia.

Testing Staff

Over the past several decades there has been a transition in many exercise testing laboratories from tests being administered by physicians to nonphysician allied health professionals, such as clinical exercise physiologists, nurses, physical therapists, and physician assistants. This shift from physician to nonphysician staff has occurred to contain staffing costs and improve utilization of physician time (31). These allied health care professionals are not intended to replace the knowledge and skills of a physician (31). The overall supervision of clinical exercise testing laboratories, as well as the interpretation of test results, remains the legal responsibility of the supervising physician (4,31,32).

According to the ACC and AHA, the nonphysician allied health care professional who administers clinical exercise tests should have cognitive skills similar to, although not as extensive as, the physician who provides the final interpretation (31,32). These skills are presented in *Box 4.2*. In addition, this individual should perform at least 50 exercise tests with preceptor supervision (32). However, 200 supervised exercise tests before independence has also been recommended (31). Recommendations for maintenance of competency vary between 25 (32) and 50 (31) exercise tests per year. Appropriately trained nonphysician staff can safely administer maximal clinical exercise tests when a qualified physician is "in the immediate vicinity . . . and available for emergencies" (31) and who later reviews and provides final interpretation of the test results (4). There are no differences in morbidity and mortality rates related to maximal exercise testing when the testing is performed by an appropriately trained allied health professional compared to a physician (31). The AHA has defined high-risk groups in which they recommend that a physician provide "personal supervision" (*i.e.*, the physician is directly present in the exercise testing room) (*Table 4.2*) (31). Empirical evidence suggests, however, that "direct supervision" (*i.e.*, the physician is available within the vicinity of the exercise testing room) and "general supervision" (*i.e.*, the physician is available by phone) (31) are the models employed in the majority of noninvasive clinical exercise testing laboratories in the United States, regardless of the disease severity of individuals being tested.

TABLE 4.2 • Recommendations for Patients Requiring Personal Physician Supervision Based on Clinical Safety Criteria*

- Moderate to severe aortic stenosis in an asymptomatic or questionably symptomatic patient
- Moderate to severe mitral stenosis in an asymptomatic or questionably symptomatic patient
- Hypertrophic cardiomyopathy: risk stratification and exercise gradient assessment
- History of malignant or exertional arrhythmias; sudden cardiac death
- History of exertional syncope or presyncope
- Intracardiac shunts
- Genetic channelopathies
- Within 7 d of myocardial infarction or other acute coronary syndrome
- New York Heart Association class III heart failure
- Severe left ventricular dysfunction (particularly patients whose clinical status has recently deteriorated and those who have never undergone prior exercise testing)
- Severe pulmonary arterial hypertension
- Broader context of potential instability resulting from noncardiovascular comorbidities (*e.g.*, frailty, dehydration, orthopedic limitations, chronic obstructive lung disease)

**Personal supervision defined as physical presence in the room*

Reprinted from (31).

Box 4.2 Cognitive Skills Required to Competently Supervise Clinical Exercise Tests

- Knowledge of appropriate indications for exercise testing
- Knowledge of alternative physiologic cardiovascular tests
- Knowledge of appropriate contraindications, risks, and risk assessment of testing
- Knowledge to promptly recognize and treat complications of exercise testing
- Competence in cardiopulmonary resuscitation and successful completion of an American Heart Association–sponsored course in advanced cardiovascular life support and renewal on a regular basis
- Knowledge of various exercise protocols and indications for each
- Knowledge of basic cardiovascular and exercise physiology including hemodynamic response to exercise
- Knowledge of cardiac arrhythmias and the ability to recognize and treat serious arrhythmias (see *Appendix B*)
- Knowledge of cardiovascular drugs and how they can affect exercise performance, hemodynamics, and the electrocardiogram (see *Appendix A*)

- Knowledge of the effects of age and disease on hemodynamic and the electrocardiographic response to exercise
- Knowledge of principles and details of exercise testing including proper lead placement and skin preparation
- Knowledge of endpoints of exercise testing and indications to terminate exercise testing

Adapted from (32).

In addition to the test administrator (physician or nonphysician), at least one support technician should assist with testing (4). This individual should have knowledge and skills in obtaining informed consent and medical history, skin preparation and ECG electrode placement, equipment operation, the measurement of BP at rest and during exercise, and effective interaction skills (4).

Testing Mode and Protocol

The mode selected for the exercise test can impact the results and should be selected based on the purpose of the test and the individual being tested (3). In the United States, the treadmill is the most frequently used mode, whereas a cycle ergometer is more common in Europe. With the potential exception of highly trained cyclists, peak exercise capacity (*e.g.*, peak oxygen consumption [$\dot{V}O_{2peak}$]) is typically 5%–20% lower during a maximal exercise test performed on a cycle ergometer compared to a treadmill due to regional muscle fatigue (1–4). This range of 5%–20% suggests interstudy and interindividual variability. Based on anecdotal evidence, a 10% difference is typically used by clinicians when comparing peak exercise responses between cycle ergometry and treadmill exercise. Optimally, the same exercise mode would be used at each time point when tracking an individual's response over time. Other exercise testing modes may be considered as needed, such as arm ergometry, dual-action ergometry, or seated stepping ergometry. These can be useful options for individuals with balance issues, amputation, extreme obesity, and other mobility deficiencies. Notably, when using modalities that require less muscle mass, there will be a concomitant lower peak oxygen consumption ($\dot{V}O_2$).

The use of a standardized exercise protocol, such as those shown in *Figure 4.1*, represents a convenient and repeatable way to conduct the exercise test for both the individual and the clinician supervising the test. Many exercise laboratories use the same exercise protocol regardless of the individual tested because of convenience. However, guidelines have consistently recommended that the protocol should be individualized based on a given individual's age, exercise tolerance, or symptoms (2–5). Protocols most suitable for clinical exercise testing include a low intensity warm-up phase followed by progressive, continuous exercise in which the demand is elevated to an individual's maximal level. The Bruce treadmill protocol is the most widely used exercise protocol in the United States (33). This will likely continue due to physician familiarity and the breadth of research based on the Bruce protocol (34–36).

METS	CYCLE ERGOMETER (FOR 70 KG BODY WEIGHT; 1 WATT = 6.1 Kpm/min) Kpm/min	MODIFIED BRUCE 3 min Stages MPH	MODIFIED BRUCE %GR	BRUCE 3 min Stages MPH	BRUCE %GR
21					
20		6.0	22	6.0	22
19					
18		5.5	20	5.5	20
17					
16					
15		5.0	18	5.0	18
14	1500				
13		4.2	16	4.2	16
12	1350				
11	1200				
10	1050	3.4	14	3.4	14
9	900				
8					
7	750	2.5	12	2.5	12
6	600				
5	450	1.7	10	1.7	10
4	300				
3		1.7	5		
2	150	1.7	0		
1					

TREADMILL PROTOCOLS

RAMP — PER 30 SEC

MPH	%GR
3.0	25.0
3.0	24.0
3.0	23.0
3.0	22.0
3.0	21.0
3.0	20.0
3.0	19.0
3.0	18.0
3.0	17.0
3.0	16.0
3.0	15.0
3.0	14.0
3.0	13.0
3.0	12.0
3.0	11.0
3.0	10.0
3.0	9.0
3.0	8.0
3.0	7.0
3.0	6.0
3.0	5.0
3.0	4.0
3.0	3.0
3.0	2.0
3.0	1.0
3.0	0
2.5	0
2.0	0
1.5	0
1.0	0
0.5	0

NAUGHTON 2 min Stages

MPH	%GR
2	17.5
2	14.0
2	10.5
2	7.0
2	3.5
2	0
1	0

MODIFIED NAUGHTON (CHF) 2 min Stages

MPH	%GR
3.0	25
3.0	22.5
3.0	20
3.0	17.5
3.0	15
3.0	12.5
3.0	10
3.0	7.5
2.0	10.5
2.0	7.0
2.0	3.5
1.5	0
1.0	0

Figure 4.1 Common treadmill and stationary cycle ergometry protocols used in symptom-limited maximal exercise testing with exercise workload and metabolic demand. METs reflect the estimated value for each stage. CHF, chronic heart failure; kg, kilogram; KPM, kilopond meter; METs, metabolic equivalents of task; min, minute; MPH, miles per hour; %GR, percent grade. Modified with permission from (3).

When performing a sign- and symptom-limited maximal exercise test, it is often recommended that the selected exercise testing protocol results in a total exercise duration between 8 and 12 min (3–5). To assist in the protocol selection, the individual's medical and PA history and symptomatology should be considered. The aerobic requirements associated with the first stage of the Bruce protocol (~5 METs) and the large increases between stages (~3

METs) make it less than optimal for individuals with cardiovascular or pulmonary disease who may have a low functional capacity. As such, the Bruce protocol can result in extensive handrail support and an overestimation of the individual's peak exercise capacity based on the exercise duration or peak workload achieved (35,37). In response to these limitations, modifications of the Bruce protocol and other treadmill and cycle ergometry protocols have been developed, including individual-specific ramping protocols (26,36–39). *Figure 4.1* shows some common protocols and the estimated metabolic requirement for each.

Monitoring and Test Termination

Variables that are typically monitored during clinical exercise testing include HR; ECG; cardiac rhythm; BP; perceived exertion; clinical signs/symptoms or clinician-observed symptoms; and self-reported symptoms suggestive of myocardial ischemia, inadequate blood perfusion, inadequate gas diffusion, and limitations in pulmonary ventilation (3–5). Measurement of expired gases through open circuit spirometry during a CPET and oxygen saturation of blood through pulse oximetry and/or arterial blood gases may also be obtained when indicated (1,2,4,18).

Table 4.3 outlines best practices for monitoring during a symptom-limited maximal exercise test. A high-quality ECG tracing should be obtained during an exercise test. However, this requires more attention to preparation of the individual and lead placement than is typically required for a resting ECG. A thorough discussion of ECG preparation is provided in the AHA Exercise Standards for Exercise Testing and Training (3). HR and BP should be assessed and an ECG recorded regularly during the test (*e.g.*, each minute or each stage), at peak exercise and regularly through at least 6 min of recovery (3–5). Monitoring should continue into the recovery period until HR, BP, symptoms, and ECG changes stabilize. It can also be helpful to assess the individual's perceived exertion regularly during the exercise test and at peak exercise. Throughout the test, the ECG should be continuously monitored for repolarization changes suggestive of myocardial ischemia and dysrhythmias (3–5).

TABLE 4.3 • Best Practices for Monitoring during a Symptom-Limited Maximal Exercise Test

Variable	Before Exercise Test	During Exercise Test	After Exercise Test
Electrocardiogram	Monitor continuously; record in supine position and position of exercise (*e.g.*, standing).	Monitor continuously; record during the last 5–10 s of each stage or every 2 min (ramp protocol).	Monitor continuously; record immediately postexercise, after 60 s of recovery and then every 2 min.
Heart rate[a]	Monitor continuously; record in supine position and position of exercise (*e.g.*, standing).	Monitor continuously; record during the last 5–10 s of each minute.	Monitor continuously; record during the last 5–10 s of each minute.
Blood pressure[a,b]	Monitor continuously; record in supine position and position of exercise (*e.g.*, standing).	Measure and record during the last 30–60 s of each stage or every 2 min (ramp protocol).	Measure and record immediately postexercise, after 60 s of recovery and then every 2 min.
Signs and symptoms	Monitor continuously; record as observed.	Monitor continuously; record as observed.	Monitor continuously; record as observed or as symptoms resolve.
Rating of perceived exertion	Explain scale.	Record during the last 5–10 s each stage or every 2	Obtain peak exercise shortly after exercise is terminated.

		min (ramp protocol).

[a]In addition, heart rate and blood pressure should be assessed and recorded whenever adverse symptoms or abnormal electrocardiogram changes occur.

[b]An unchanged or decreasing systolic blood pressure with increasing workloads should be retaken (*i.e.*, verified immediately).

Adapted and used with permission from Brubaker PH, Kaminsky LA, Whaley MH. *Coronary Artery Disease: Essentials of Prevention and Rehabilitation Programs*. Champaign (IL): Human Kinetics; 2002. 364 p.

During the test and throughout postexercise recovery, the clinician should also monitor the individual for untoward symptoms, such as light-headedness, angina, dyspnea, claudication (if suspected by history), and fatigue (see *Table 2.1*) (3–5). In the case of chest pain that is suspected to be angina pectoris, the timing, character, magnitude, and resolution should be described (4). The appearance of symptoms should be correlated with HR, BP, and ECG abnormalities (when present). Standardized scales to assess perceived exertion (see *Table 3.6* and *Figure 4.2*), angina, dyspnea, and claudication (*Figure 4.3*) are available. For each of these symptoms, a rating of 3 out of 4 is an indication to stop the test. Although scales to assess these symptoms have been recommended by the AHA (4), some clinical exercise testing laboratories use a 10-point visual analog pain scale (see *Figure 10.1*).

Borg CR10 Scale®

0	Nothing at all	
0.3		
0.5	Extremely weak	Just noticeable
0.7		
1	Very weak	
1.5		
2	Weak	Light
2.5		
3	Moderate	
4		
5	Strong	Heavy
6		
7	Very strong	
8		
9		
10	Extremely strong	"Maximal"
11		
≀		
•	Absolute maximum	Highest possible

Figure 4.2 The Borg category–ratio scale. Printed with permission from Borg G, Borg E. *The Borg CR Scales Folder*. Hässelby (Sweden): Borg Perception; 2010.

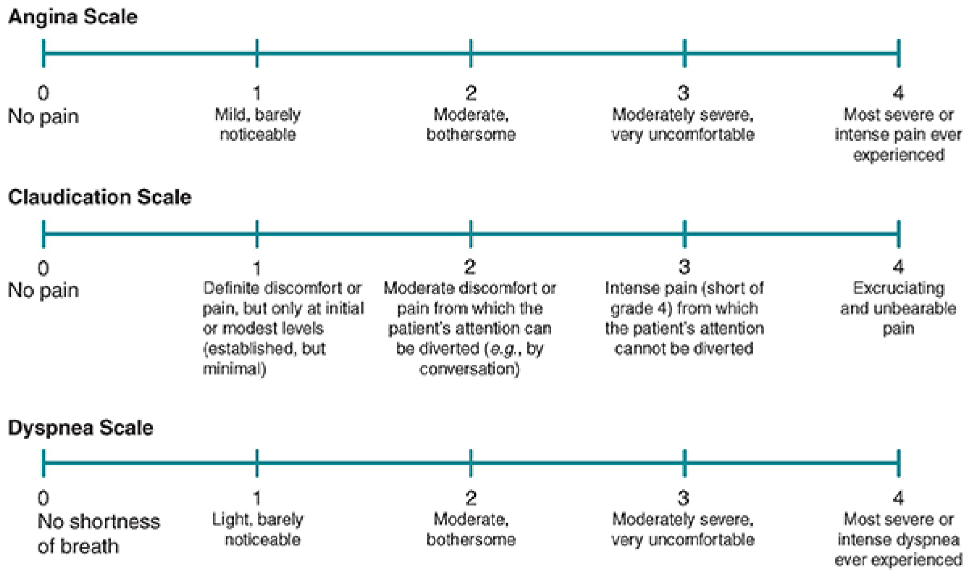

Figure 4.3 Frequently used scales for assessing the individual's level of angina (*top*), claudication (*middle*), and dyspnea (*bottom*).

The analysis of expired gas during a CPET overcomes the potential inaccuracies associated with estimating exercise capacity from peak workload (*e.g.*, treadmill speed and grade). The direct measurement of $\dot{V}O_2$ is the most accurate measure of exercise capacity and is a useful index of overall cardiopulmonary health (1,18,24). The CPET provides additional data that are not available without expired gas analysis, such as the respiratory exchange ratio (RER), ventilatory-derived anaerobic threshold (VAT), and the rate of change of minute ventilation (volume of expired air per unit time [$\dot{V}E$]) to change in volume of carbon dioxide exhaled ($\dot{V}CO_2$) during exercise (*i.e.*, $\dot{V}E/\dot{V}CO_2$ slope; an indicator of ventilatory efficiency). CPET responses have been shown to be useful in the differentiation of the cause of exertional dyspnea and in risk stratification of many individual groups, particularly those with heart failure (1,2,18,24). There are several extensive resources available on CPET (1,18,24,40).

Oxygen desaturation may be a cause of exertional dyspnea in some individuals. Although measurement of the partial pressure of arterial oxygen (P_aO_2) and partial pressure of carbon dioxide in arterial blood (P_aCO_2) via the measurement of arterial blood gases is the gold standard, pulse oximetry provides a noninvasive, indirect measure of arterial oxygen saturation (SpO_2). In individuals with pulmonary disease, direct measurements of percent saturation of arterial oxygen (SaO_2) correlate reasonably well with SpO_2 (±2%–3%), provided SpO_2 remains >85% (1,18). An absolute decrease in SpO_2 ≥5% during exercise is considered an abnormal response suggestive of exercise-induced hypoxemia, and follow-up testing with arterial blood gases may be indicated (1,18). An SpO_2 ≤80% with signs or symptoms of hypoxemia is an indication to stop a test (1). The measurement of SpO_2 with pulse oximetry through a fingertip probe can be affected by low perfusion or low pulse wave, hemoglobin abnormalities, low oxygen saturation, very dark skin tone, nail polish, acrylic nails (41), and movement during exercise. Alternate probe locations such as the earlobe or forehead can be helpful.

Termination criteria for clinical exercise testing have been established by the AHA and ACC (*Box 4.3*) (3). When the goal is a symptom-limited maximal exercise test, a predetermined intensity, such as an 85% of the age-predicted maximal heart rate (HR_{max}), should not be used as a reason to end the test (3,5). Failure to continue a test until the individual attains maximal exertion, or a clinical limitation, will result in an underestimation of the person's peak exercise capacity. Some clinicians view the achievement of 85% of the age-predicted HR_{max} as adequate level of stress for revealing exertional ischemia. However, age-predicted HRs are highly inaccurate, and the sensitivity of exercise test results is increased when the HR achieved is greater than 85% of predicted (3).

Box 4.3 Indications for Terminating a Symptom-Limited Maximal Exercise Test

Absolute Indications

- ST elevation (>1.0 mm) in leads without preexisting Q waves because of prior MI (other than aVR, aVL, or V_1)
- Drop in systolic blood pressure of >10 mm Hg, despite an increase in workload, when accompanied by other evidence of ischemia
- Moderate-to-severe angina
- Central nervous system symptoms (*e.g.*, ataxia, dizziness, or near syncope)
- Signs of poor perfusion (cyanosis or pallor)
- Sustained ventricular tachycardia or other arrhythmia, including second- or third-degree atrioventricular block, that interferes with normal maintenance of cardiac output during exercise
- Technical difficulties monitoring the ECG or systolic blood pressure
- The individual's request to stop

Relative Indications

- Marked ST displacement (horizontal or downsloping of >2 mm, measured 60–80 ms after the J point in an individual with suspected ischemia)
- Drop in systolic blood pressure >10 mm Hg (persistently below baseline) despite an increase in workload, *in the absence* of other evidence of ischemia
- Increasing chest pain
- Fatigue, shortness of breath, wheezing, leg cramps, or claudication
- Arrhythmias other than sustained ventricular tachycardia, including multifocal ectopy, ventricular triplets, supraventricular tachycardia, and bradyarrhythmias that have the potential to become more complex or to interfere with hemodynamic stability

- Exaggerated hypertensive response (systolic blood pressure >250 mm Hg or diastolic blood pressure >115 mm Hg)
- Development of bundle-branch block that cannot be distinguished from ventricular tachycardia
- SpO_2 ≤80% (3)

ECG, electrocardiogram; MI, myocardial infarction; SpO_2, percent saturation of arterial oxygen.

Postexercise

The sensitivity of the exercise test for the diagnosis of IHD can be maximized when the individual is placed in a supine position immediately following exercise (3,4). Therefore, if the primary indication of the test is suspected IHD and nonsignificant repolarization changes are observed at peak exercise, then placing the individual in the supine position without active recovery should be considered. However, exercise cessation can cause an excessive drop in venous return resulting in profound hypotension during recovery and ischemia secondary to decreased perfusion pressure into the myocardium. Therefore, continuation of low intensity active recovery during the postexercise period is often practiced in order to support venous return and hemodynamic stability. Each laboratory should develop standardized procedures for the postexercise recovery period (active vs. inactive and monitoring duration) with the laboratory's medical director that considers the indication for the exercise test and the individual's status during the test.

Safety

Although untoward events do occur, clinical exercise testing is very safe when performed by appropriately trained clinicians. The classic data of Rochmis and Blackburn (42) in 1971 reported a rate of serious complications (morbidity or mortality) of 34 events per 10,000 tests. Numerous studies have shown that the event rate has improved considerably in the years since. Excluding studies of individuals tested with a history of life-threatening ventricular arrhythmias, among 17 studies, serious complications during clinical exercise tests ranged from 0 to 35 events per 10,000 tests, with rates typically higher among individuals known to have higher risk, such as individuals with heart failure (31). However, prior studies likely overestimate the risk of today's individuals given advances in medicine, such as the implantable cardioverter defibrillator (31). Current consensus suggests that an event rate of approximately 1–2 per 10,000 tests occurs with modern exercise testing.

In tests that are performed to assess the likelihood of IHD, some physicians might request that select individuals withhold medications that are known to limit the hemodynamic response to exercise (*e.g.*, β-adrenergic blocking agents) because they may limit test sensitivity (3,5). However, for most test indications, individuals are encouraged to continue to take their medications on the day of testing (5). If the indication for the exercise test is to evaluate the effectiveness (*e.g.*, change in exercise capacity) of medical therapy, then individuals should be instructed to continue their normal medical regimen (5).

INTERPRETING THE CLINICAL EXERCISE TEST

Multiple factors should be considered during the interpretation of exercise test data including individual symptoms, ECG responses, exercise capacity, hemodynamic responses, and the combination of multiple responses, as reflected by exercise test scores such as the Duke Treadmill Score (discussed later).

Heart Rate Response

The normal HR response to incremental exercise is an increase with progressive workloads at a rate of ≈10 beats · min^{-1} per 1 MET (3). HR_{max} decreases with age and is attenuated in individuals on β-adrenergic blocking agents. Several equations have been published to predict HR_{max} in individuals who are not taking a β-adrenergic blocking agent (see *Table 5.3*) (3). All of these estimates have large interindividual variability with standard deviations of 10 beats or more (5,43), thus limiting the utility of age-predicted HR during exercise testing.

Among individuals referred for testing secondary to IHD and in the absence of β-adrenergic blocking agents, failure to achieve an age-predicted HR_{max} ≥85% in the presence of maximal effort is an indicator of chronotropic incompetence and is independently associated with increased risk of morbidity and mortality (3). The metabolic chronotropic reserve (MCR), also known as the chronotropic index, can be calculated from the ratio of the HR reserve to the metabolic reserve during submaximal exercise. The advantage of using the MCR is that it adjusts for age and fitness and appears to be unaffected by the exercise testing mode or protocol (25). An abnormal chronotropic response provides prognostic information that is independent of myocardial perfusion. The combination of a myocardial perfusion abnormality and an abnormal chronotropic response suggests a worse prognosis than either abnormality alone (44).

The rate of decline in HR following exercise (HR recovery) provides independent information related to prognosis (3,30). A failure of the HR to decrease by at least 12 beats during the first minute or 22 beats by the end of the second minute of active postexercise recovery is strongly associated with an increased risk of mortality in individuals diagnosed with or at increased risk for IHD (3,30,44). The failure of HR to recover adequately may be related to the inability of the parasympathetic nervous system to reassert vagal control of HR, which is known to predispose individuals to ventricular dysrhythmias (44).

Blood Pressure Response

The normal systolic blood pressure (SBP) response to exercise is an increase with increasing workloads at a rate of ~10 mm Hg per 1 MET (3). On average, this response is greater among men; increases with age; and is attenuated in individuals on vasodilators, calcium channel blockers, angiotensin-converting enzyme inhibitors, and α- or β-adrenergic blockers. Specific SBP responses are outlined in the following:

- Hypertensive response: An SBP >250 mm Hg is a relative indication to stop a test (see *Box 4.3*) (3). An SBP ≥210 mm Hg in men and ≥190 mm Hg in women during exercise is considered an exaggerated response (3). A peak SBP >250 mm Hg or an increase in SBP >140 mm Hg during exercise above the pretest resting value is predictive of future resting hypertension (45).
- Hypotensive response: A decrease of SBP below the pretest resting value or by >10 mm Hg after a preliminary increase, particularly in the presence of other indices of ischemia, is abnormal and often associated with myocardial ischemia, left ventricular dysfunction, and an increased risk of subsequent cardiac events (3). Either of these responses are indications to stop the test (see *Box 4.3*).
- Blunted response: In individuals with a limited ability to augment cardiac output, the response of SBP during exercise will be slower compared to normal.
- Postexercise response: SBP typically returns to preexercise levels or lower by 6 min of recovery (3). Studies have demonstrated that a delay in the recovery of SBP is highly related both to ischemic abnormalities and to a poor prognosis (46,47).

There is normally no change or a slight decrease in diastolic blood pressure (DBP) during an exercise test. A peak DBP >90 mm Hg or an increase in DBP >10 mm Hg during exercise above the pretest resting value is considered an abnormal response (3) and may occur with exertional ischemia. A DBP >115 mm Hg is an exaggerated response and a relative indication to stop a test (see *Box 4.3*) (3).

Rate-Pressure Product

Rate-pressure product (also known as *double product*) is calculated by multiplying the values for HR and SBP that occur at the same time during rest or exercise. Rate-pressure product is a surrogate for myocardial oxygen uptake. There is a linear relationship between myocardial oxygen uptake and both coronary blood flow and exercise intensity (3). Coronary blood flow increases due to increased myocardial oxygen demand as a result of increases in HR and myocardial contractility. If coronary blood supply is impaired, which can occur in obstructive IHD, then signs or symptoms of myocardial ischemia may be present. The point during exercise when this occurs is the ischemic threshold. Rate-pressure product is a repeatable estimate of the ischemic threshold and more reliable than external workload. The normal range for peak rate-pressure product is 25,000–40,000 mm Hg · beats · min^{-1} (3). Rate-pressure product at peak exercise and at the ischemic threshold (when applicable) should be reported.

Electrocardiogram

The normal response of the ECG (see *Appendix B*) during exercise includes the following (3):

- P-wave: increased magnitude among inferior leads
- PR segment: shortens and slopes downward among inferior leads
- QRS: Duration decreases, septal Q-waves increase among lateral leads, R waves decrease, and S waves increase among inferior leads
- J point (J junction): depresses below isoelectric line with upsloping ST segments that reach the isoelectric line within 80 ms
- T-wave: decreases amplitude in early exercise, returns to preexercise amplitude at higher exercise intensities, and may exceed preexercise amplitude in recovery
- QT interval: absolute QT interval decreases. The QT interval corrected for HR increases with early exercise and then decreases at higher HRs

ST-segment changes (*i.e.*, depression and elevation) are the cornerstone of the exercise test clinically and are associated with myocardial ischemia and injury. The interpretation of ST segments may be affected by the resting ECG configuration and the presence of digitalis therapy and should be interpreted in the context of the pretest probability of IHD (3,5). Considerations that may indicate that an exercise test with ECG only would be inadequate for the diagnosis of IHD are shown in *Box 4.4*.

Box 4.4 Considerations That May Necessitate Adjunctive Imaging When the Indication Is the Assessment of Ischemic Heart Disease (5)

- Resting ST-segment depression >1.0 mm
- Ventricular paced rhythm
- Left ventricular hypertrophy with repolarization abnormalities
- Left bundle-branch block
- Leads V1–V3 will not be interpretable with right bundle-branch block.
- Wolff-Parkinson-White
- Digitalis therapy

Abnormal responses of the ST segment during exercise include the following (3):

- To be clinically meaningful, ST-segment depression or elevation should be present in at least three consecutive cardiac cycles within the same lead. The level of the ST segment should be compared relative to the end of the PR segment. Automated computer-averaged complexes should not be relied on for interpretation and should be visually confirmed by the raw ECG.
- Horizontal or downsloping ST-segment depression ≥1.0 mm (0.1 mV) at 80 ms after the J point is a strong indicator of myocardial ischemia.

- Clinically significant ST-segment depression that occurs during postexercise recovery is an indicator of myocardial ischemia.
- ST-segment depression at a low workload or low rate-pressure product is associated with worse prognosis and increased likelihood for multivessel disease.
- When ST-segment depression is present on the upright resting ECG, only additional ST-segment depression during exercise is considered for ischemia.
- When ST-segment elevation is present in the upright resting ECG, only ST-segment depression below the isoelectric line during exercise is considered for ischemia.
- Upsloping ST-segment depression ≥2.0 mm (0.2 mV) at 80 ms after the J point may represent myocardial ischemia, especially in the presence of angina. However, this response has a low positive predictive value; it is often categorized as equivocal.
- Among individuals after myocardial infarction (MI), exercise-induced ST-segment elevation (>1.0 mm or >0.1 mV for 60 ms) in leads with Q waves is an abnormal response and may represent reversible ischemia or wall motion abnormalities.
- Among individuals without prior MI, exercise-induced ST-segment elevation most often represents transient combined endocardial and subepicardial ischemia but may also be due to acute coronary spasm.
- Repolarization changes (ST-segment depression or T-wave inversion) that normalize with exercise may represent exercise-induced myocardial ischemia but is considered a normal response in young individuals with early repolarization on the resting ECG.

In general, dysrhythmias that increase in frequency or complexity with progressive exercise intensity and are associated with ischemia or with hemodynamic instability are more likely to cause a poor outcome than isolated dysrhythmias (3). The clinical significance of ventricular ectopy during exercise has varied. Although ventricular ectopy is more common with some pathologies, such as cardiomyopathy, in general, frequent and complex ventricular ectopy during exercise and especially in recovery are associated with increased risk for cardiac arrest (3). Sustained ventricular tachycardia is an absolute criterion to terminate a test. There are several relative termination criteria related to atrial and ventricular dysrhythmias and blocks that should be considered based on the presence of signs or symptoms of myocardial ischemia or inadequate perfusion (see *Box 4.3*) (3).

Symptoms

Symptoms that are consistent with myocardial ischemia (*e.g.*, angina, dyspnea) or hemodynamic instability (*e.g.*, light-headedness) should be noted and considered in context with ECG, HR, and BP abnormalities (when present). Exercise-induced angina is associated with an increased risk for IHD (3). The occurrence of angina during exercise is generally considered to supersede other exercise test responses as an indicator of IHD, but risk for IHD is greater when angina and ST-segment depression occur together (3). It is important to recognize that dyspnea can be an anginal equivalent. Compared to leg fatigue or general exhaustion, an exercise test that is limited by dyspnea has been associated with a worse prognosis (3).

Exercise Capacity

Evaluating exercise capacity is an important component of exercise testing. A high exercise capacity is generally indicative of good overall cardiopulmonary health and the absence of serious limitations in left ventricular function. Over the past two decades, many studies have been published demonstrating the importance of exercise capacity relative to prognosis among individuals with cardiovascular disease (1,2,18,24,40). Both absolute and age- and gender-normalized exercise capacities are strongly related to survival (2,21,40). A significant issue relative to exercise capacity is the imprecision of estimating exercise capacity from exercise time or peak workload (2). The error in estimating exercise capacity from various published prediction equations is at least ±1 MET (26,34,36–39). This measurement error is less meaningful in young, healthy individuals with a peak exercise capacity >13 METs (7%–8% error), but more significant in individuals with reduced exercise capacities typical of those observed among individuals with cardiovascular or pulmonary disease (4–8 METs; 13%–25% error). Estimating exercise capacity on a treadmill is confounded by several factors, including treadmill experience, walking efficiency, presence of disease, the exercise protocol used, and use of the handrails for support. In addition, there is an inherent error associated with regression equations developed to estimate $\dot{V}O_{2max}$ by extrapolation of $\dot{V}O_{2max}$ achieved at submaximal, steady state workloads (2,5,26,33–35,37,40).

Together, these factors tend to result in an overestimation of exercise capacity (2,35). Although equations exist to predict exercise capacity from an exercise test using handrail support, the standard error of the estimate remains large (35). Safety of treadmill walking is always an important consideration, and allowing an individual to use the handrails should be determined on a case-by-case basis. Because of these limitations associated with estimating exercise capacity from work rate, it is important to state when exercise capacity is measured directly (*i.e.*, $\dot{V}O_{2peak}$) or estimated from the work rate. More accurate equations for treadmill and cycle ergometry have recently been developed based on the Fitness Registry and the Importance of Exercise National Database (FRIEND). The overall error of the FRIEND equations was significantly lower for both treadmill and cycle ergometer testing compared to the existing equations (48,49).

In addition to describing an individual's exercise capacity as estimated peak METs or measured $\dot{V}O_{2peak}$, exercise capacity is frequently expressed relative to age- and gender-based normal standards (1,18,40,50). This is especially true for $\dot{V}O_{2peak}$. Expressing $\dot{V}O_{2peak}$ as a percentage of age-predicted normal value is advantageous because exercise capacity declines with age and is higher among men compared to women. Accurate knowledge of an individual's $\dot{V}O_{2peak}$ relative to his or her peers provides a context with which to optimize the prognostic applications of the test and the assessment of therapy and provides support for activity counseling. Several equations exist to estimate $\dot{V}O_{2peak}$ based on select demographics (*e.g.*, gender, age, height, weight) (1,18,50). These equations vary due to population specificity, and thus, it can be problematic to determine precisely which equation is best for a particular individual. Reference tables are also available that provide percentile rankings for an individual's measured exercise capacity by gender and age categories (for treadmill, see *Table 3.8*; for cycle ergometer, see *Table 3.9*) (51), and nomograms have been developed to enable estimation of an individual's age-predicted exercise capacity at a glance (52–54).

The most widely used prediction equations for directly measured $\dot{V}O_{2peak}$ were developed by Hansen, Sue, and Wasserman (commonly termed the *Wasserman equations*) (55). Although these equations have been commonly used for more than 30 yr, they were derived from a relatively limited sample and often do not function well in particular populations (18,50,56,57). When expressing exercise capacity as a percentage of age-predicted normal value, it is important that the equation used is derived from a population representative of the individual tested, that it reflects whether exercise capacity was measured directly or estimated from the work rate, that it reflects the appropriate exercise mode used (cycle ergometer or treadmill), and that exercise capacity is expressed appropriately ($\dot{V}O_{2peak}$ in $mL \cdot min^{-1}$, $mL \cdot kg^{-1} \cdot min^{-1}$, or estimated METs). Examples of commonly used regression equations for age-predicted exercise capacity are presented in *Box 4.5*.

Box 4.5 Examples of Regression Equations for Age-Predicted Normal Standards for Exercise Capacity

Directly measured versus estimated values are indicated for each equation.

Hansen, Sue, and Wasserman equations for measured $\dot{V}O_{2peak}$ (55):

	Mode	Overweight	Predicted $\dot{V}O_{2max}$ (mL • min^{-1})
Males	Cycle[a]	No	Wt × [50.72 − (0.372 × A)]
		Yes	[0.79 × (Ht − 60.7)] × [50.72 − (0.372 × A)]
	Treadmill[b]	No	Wt × [56.36 − (0.413 × A)]
		Yes	[0.79 × (Ht − 60.7)] × [56.36 − (0.413 × A)]
Females	Cycle[a]	No	(42.8 + Wt) × [22.78 − (0.17 × A)]
		Yes	Ht × [14.81 − (0.11 × A)]
	Treadmill[c]	No	Wt × [44.37 − (0.413 × A)]
		Yes	[0.79 × (Ht − 68.2)] × [44.37 − (0.413 × A)]

[a] Overweight is Wt > [0.79 × (Ht − 60.7)].

[b] Overweight is Wt > [0.65 × (Ht − 42.8)].

[c] Overweight is Wt > [0.79 × (Ht − 68.2)].

Fitness Registry and the Importance of Exercise National Data Base (FRIEND) equation for measured $\dot{V}O_{2peak}$ (50):

$$\dot{V}O_{2peak}\ (\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}) = 45.2 - 0.35 \times \text{age} - 10.9 \times \text{gender (male = 1; female = 2)} - 0.15 \times \text{weight (lb)} + 0.68 \times \text{height (in)} - 0.46 \times \text{exercise mode (treadmill = 1; bike = 2)}$$

Percentage exercise capacity achieved in estimated METs among male veterans (54):

All individuals:	METs = 14.7 − 0.11(age)
Active individuals:	METs = 16.4 − 0.13(age)
Sedentary individuals:	METs = 11.9 − 0.07(age)

Percentage predicted $\dot{V}O_{2peak}$ in men and women with a medical or surgical diagnosis (mL · kg^{-1} · min^{-1}) (52):

Men: 33.97 − 0.242 × age

Women: 21.69 − 0.116 × age

Percentage predicted exercise capacity achieved in healthy women (estimated METs) (53):

METs = 14.7 − (0.13 × age).

A, age in years; Ht, height in cm; Wt, weight in kg.

Cardiopulmonary Exercise Testing

A major advantage of measuring ventilatory gas exchange during exercise is a more accurate measurement of exercise capacity. Several thorough reviews on CPET are available (1,18,24,58). In addition to a more accurate measurement of exercise capacity, CPET data may be particularly useful in estimating prognosis and defining the timing of cardiac transplantation and other advanced therapies in individuals with heart failure. CPET is also helpful in the differential diagnosis of individuals with suspected cardiovascular and respiratory diseases (1,18,24,58). In addition to $\dot{V}O_{2peak}$, the slope of the change in ventilation to change in carbon dioxide (CO_2) production (termed the *$\dot{V}E/\dot{V}CO2$ slope*) during an exercise test strongly predicts prognosis, especially in individuals with heart failure (1,18,24,58). Other variables that can be determined through the measurement of respiratory gas exchange include the VAT, oxygen pulse, slope of the change in work rate to change in oxygen, oxygen uptake efficiency slope (OUES), partial pressure of end-tidal CO_2, breathing reserve, and the RER (1,18,24,58). CPET is particularly useful in identifying whether the cause of dyspnea has a cardiac or pulmonary etiology (1,18).

Maximal versus Peak Cardiorespiratory Stress

When an exercise test is performed as part of the evaluation of IHD, individuals should be encouraged to exercise to their maximal level of exertion or until a clinical indication to stop the test is observed. However, the determination of what constitutes “maximal” effort, although important for interpreting test results, can be difficult. Various criteria have been used to confirm that a maximal effort has been elicited during a GXT:

- A plateau in $\dot{V}O_2$ (or failure to increase $\dot{V}O_2$ by 150 mL · min^{-1}) with increased workload (59,60). This criterion has fallen out of favor because a plateau is not consistently observed during maximal exercise testing, particularly in individuals with cardiovascular or pulmonary disease (61).
- Failure of HR to increase with increases in workload.
- A postexercise venous lactate concentration >8.0 mmol · L^{-1}
- A rating of perceived exertion (RPE) at peak exercise >17 on the 6–20 scale or >7 on the 0–10 scale

- A peak RER ≥1.10. Peak RER is perhaps the most accurate and objective noninvasive indicator of individual effort during a GXT (18).

There is no consensus on the number of criteria that should be met in order to call a test maximal (62). In addition, interindividual and interprotocol variability may limit the validity of these criteria (62). In the absence of data supporting that an individual reached their physiologic maximum, data at maximal exercise are commonly described as "peak" (*e.g.*, HR_{peak}, $\dot{V}O_{2peak}$) instead of "maximal" (*e.g.*, HR_{max}, $\dot{V}O_{2max}$) (1–3).

DIAGNOSTIC VALUE OF EXERCISE TESTING FOR THE DETECTION OF ISCHEMIC HEART DISEASE

The diagnostic value of the clinical exercise test for the detection of IHD is influenced by the principles of conditional probability (*i.e.*, the probability of identifying an individual with IHD given the probability of IHD in the underlying population). Key metrics that describe the diagnostic value of exercise testing (and other diagnostic tests) are the sensitivity, specificity, and predictive value of the test procedure. Each of these are affected by the prevalence of IHD in the population tested (5).

Sensitivity, Specificity, and Predictive Value

Sensitivity refers to the ability to positively identify individuals who truly have IHD. Exercise ECG sensitivity for the detection of IHD has traditionally been based on angiographic evidence of a coronary artery stenosis ≥70% in at least one vessel. In a true positive (TP) test, the test is positive for myocardial ischemia (*e.g.*, ≥1.0 mm of horizontal or downsloping ST-segment depression), and the individual truly has IHD. Conversely, in a false negative (FN) test, the test is negative for myocardial ischemia, but the individual truly has IHD (5).

Common factors that contribute to FN exercise tests are summarized in *Box 4.6*. The sensitivity of an exercise test is decreased by inadequate myocardial stress, medications that attenuate the cardiac demand to exercise or reduce myocardial ischemia (*e.g.*, β-adrenergic blockers, nitrates, calcium channel blocking agents), and insufficient ECG lead monitoring (3,5). Preexisting ECG changes such as left ventricular hypertrophy, LBBB, or the preexcitation syndrome (W-P-W) limit the ability to interpret exercise-induced ST-segment changes (5).

Box 4.6 Causes of False Negative Symptom-Limited Maximal Exercise Test Results for the Diagnosis of Ischemic Heart Disease

- Failure to reach an ischemic threshold
- Monitoring an insufficient number of leads to detect ECG changes

- Failure to recognize non-ECG signs and symptoms that may be associated with underlying CVD (*e.g.*, exertional hypotension)
- Angiographically significant CVD compensated by collateral circulation
- Musculoskeletal limitations to exercise preceding cardiac abnormalities
- Technical or observer error

CVD, cardiovascular disease; ECG, electrocardiogram.

Specificity refers to the ability to correctly identify individuals who do not have IHD. In a true negative (TN) test, the test is negative for myocardial ischemia and the individual is free of IHD (5). Conversely, in a false positive (FP) test result, the test is positive for myocardial ischemia, but the individual does not have IHD. Conditions that may cause an abnormal exercise ECG response in the absence of significant IHD are shown in *Box 4.7* (5).

Box 4.7 **Causes of False Positive Symptom-Limited Maximal Exercise Test Results for the Diagnosis of Ischemic Heart Disease**

- ST-segment depression >1.0 mm at rest
- Left ventricular hypertrophy
- Accelerated conduction defects (*e.g.*, Wolff-Parkinson-White syndrome)
- Digitalis therapy
- Nonischemic cardiomyopathy
- Hypokalemia
- Vasoregulatory abnormalities
- Mitral valve prolapse
- Pericardial disorders
- Technical or observer error
- Coronary spasm
- Anemia

Reported values for the specificity and sensitivity of exercise testing with ECG vary because of differences in disease prevalence of the cohort studied, test protocols, ECG criteria for a positive test, and the angiographic definition of IHD. In studies that accounted for these variables, the pooled results show a sensitivity of 68% and specificity of 77% (5). Sensitivity, however, is somewhat lower, and specificity is higher when workup bias (*i.e.*, only assessing individuals with a higher likelihood for IHD) is removed (63).

The *predictive value* of clinical exercise testing is a measure of how accurately a test result (positive or negative) correctly identifies the presence or absence of IHD in individuals and is calculated from sensitivity and specificity (*Box 4.8*). The positive predictive value is the percentage of individuals with an abnormal test who truly have IHD. The negative predictive value is the percentage of individuals with a negative test who are free of IHD (5).

Box 4.8 Sensitivity, Specificity, and Predictive Value of Symptom-Limited Maximal Exercise Testing for the Diagnosis of Ischemic Heart Disease

Sensitivity = [TP / (TP + FN)] × 100

- The percentage of individuals with IHD who have a positive test

Specificity = [TN / (TN + FP)] × 100

- The percentage of individuals without IHD who have a negative test

Positive predictive value = [TP / (TP + FP)] × 100

- The percentage of positive tests that correctly identify individuals with IHD

Negative predictive value = [TN / (TN + FN)] × 100

- The percentage of negative tests that correct identify individuals without IHD

FN, false negative; FP, false positive; IHD, ischemic heart disease; TN, true negative; TP, true positive.

Clinical Exercise Test Data and Prognosis

First introduced in 1987 when the Duke Treadmill Score was published (64,65), the implementation of various exercise test scores that combine information derived during the exercise test into a single prognostic estimate has gained popularity. The most widely accepted and used of these prognostic scores is the Duke Treadmill Score or the related Duke Treadmill Nomogram (3,5). Both are appropriate for individuals with or without a history of IHD being considered for coronary angiography without a history of a MI or revascularization procedure. The Duke Score/Nomogram (*Figure 4.4*) considers exercise capacity, the magnitude of ST-segment depression, and the presence and severity of angina pectoris. The calculated score is related to annual and 5-yr survival rates and allows the categorization of individuals into low-, moderate-, and high-risk subgroups. This categorization may help the physician choose between more conservative or more aggressive therapies. Physicians may also use prognostic estimates based on other hemodynamic findings, such as chronotropic incompetence or an abnormal HR recovery, to guide their clinical decisions (3,5). Each of these abnormalities from exercise testing contributes independent prognostic information. Although there is a general belief that physicians informally integrate much of this information without the specific calculation of an exercise test score, estimates of the presence of IHD provided by scores are superior to physician estimates and analysis of ST-segment changes alone (66).

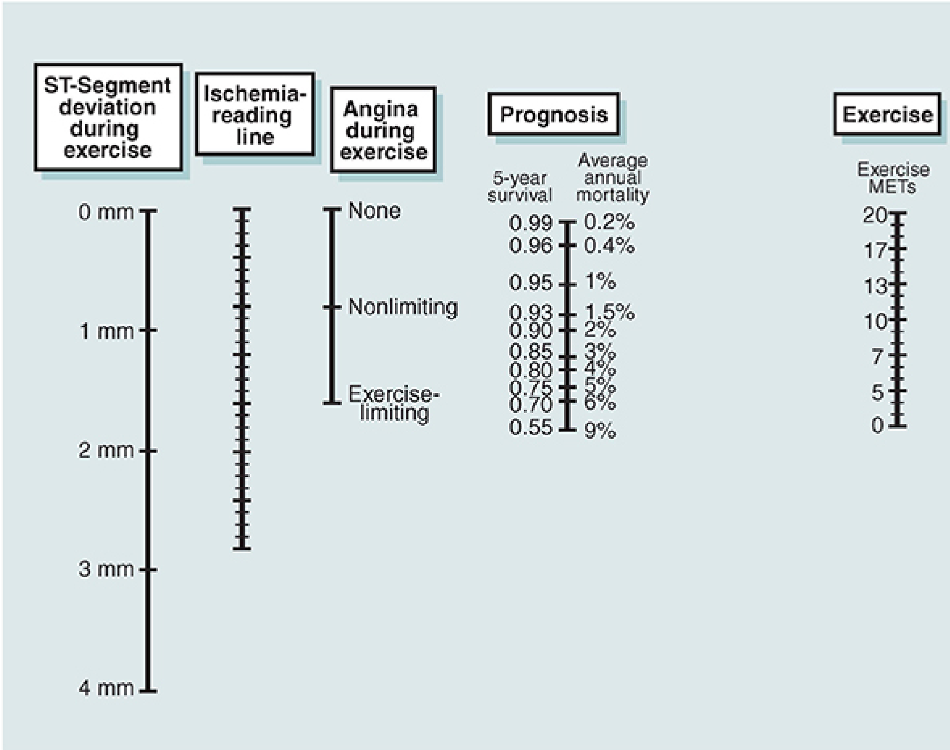

Figure 4.4 The Duke Nomogram. This nomogram uses five variables to estimate prognosis for a given individual. First, the observed amount of ST-segment depression is marked on the ST-segment deviation line. Second, the observed degree of angina is marked on the line for angina, and these two points are connected. Third, the point where this line intersects the ischemia reading line is noted. Fourth, the observed exercise tolerance is marked on the line for exercise capacity. Finally, the mark on the ischemia reading line is connected to the mark on the exercise capacity line, and the estimated 5-yr survival or average annual mortality rate is read from the point at which this line intersects the prognosis scale. Reprinted with permission from (65).

CLINICAL EXERCISE TESTS WITH IMAGING

When the resting ECG is abnormal, exercise testing may be coupled with other techniques designed to either augment the information provided by the ECG or to replace the ECG when resting abnormalities (see *Box 4.4*) make evaluation of changes during exercise impossible. Various radioisotopes can be used to evaluate the presence of a myocardial perfusion abnormality, which is the initiating event in exertional ischemia and the beginning of the "ischemic cascade," or abnormalities of ventricular function that often occur with MI or myocardial ischemia (3,5). When exercise testing is coupled with myocardial perfusion imaging (*e.g.*, nuclear stress test) or echocardiography, all other aspects of the exercise test should remain the same, including HR and BP monitoring during and after exercise, symptom evaluation, rhythm monitoring, and symptom-limited maximal exertion.

Myocardial perfusion imaging can be performed with a variety of agents and imaging approaches, although the two most common isotopes are ^{201}thallium and ^{199m}technetium sestamibi (Cardiolite). Delivery of the isotope is proportional to coronary blood flow. These agents cross cell membranes of metabolically active tissue either actively (thallium) or passively (sestamibi). In the case of an MI, the isotope does not cross the cell membrane of the necrotic tissue, and thus, a permanent reduction of isotope activity is observed on the image, referred to as a nonreversible, or fixed, perfusion defect. In the case of exertional myocardial ischemia, the tissue uptake in the ischemic region is reduced during exercise by virtue of the relative reduction of blood flow (and thus isotope) to the ischemic tissue. This abnormality is reversed when myocardial perfusion is evaluated at rest. This is called a reversible, or transient, perfusion defect and is diagnostic of exertional myocardial ischemia.

Echocardiography can also be used as an adjunct during an exercise test and is often called *stress echocardiography*. Echocardiographic examination allows evaluation of wall motion, wall thickness, and valve function. Although it is theoretically possible to perform echocardiography during the course of upright cycle ergometer exercise, it is technically challenging. Typical practice is to have the individual lie down on their left side immediately following completion of the exercise test (treadmill or upright cycle ergometer) or for exercise to involve recumbent cycle ergometry. This allows optimization of the echocardiographic window to the heart. Regional wall motion is assessed for various segments of the left ventricle. Deterioration in regional wall motion with exercise (compared to rest) is a sign of myocardial ischemia. Left ventricular ejection fraction (LVEF) is also measured before and after exercise.

Imaging techniques, such as radionuclide myocardial perfusion imaging and echocardiography, allow the physician to identify the location and magnitude of myocardial ischemia. For individuals incapable of exercising, it is also possible to perform either myocardial perfusion imaging or stress echocardiography with pharmacologic stress. These techniques are beyond the scope of this chapter.

FIELD WALKING TESTS

This chapter focuses on the traditional sign- and symptom-limited, maximal exercise test with ECG monitoring that is performed in a clinical laboratory, often with a treadmill or cycle ergometer. However, non-laboratory-based clinical exercise tests are also frequently used in individuals with chronic disease. These are generally classified as field or hallway walking tests and are typically considered submaximal. Similar to maximal exercise tests, field walking tests are used to evaluate exercise capacity, estimate prognosis, and evaluate response to treatment (1,2,67,68). The most common among the field walking tests is the 6-min walk test (6-MWT), but evidence has been building for other field walking tests, such as the incremental and endurance shuttle walk tests (67,68). The 6-MWT was originally developed to assess individuals with pulmonary disease (67); however, it has been applied in various individual groups and is a popular tool to assess individuals with heart failure.

The advantages of field walking tests are the simplicity and minimal cost, often requiring just a hallway. In addition, because the individual walks at a self-selected pace, a field walking test might be more representative of an individual's ability to perform activities of daily living (2,67,68). Additional discussion of field walking tests is provided in *Chapter 3*.

Given the increasing recognition of the importance of exercise capacity in prognosis, and the recent call for the recognition of exercise capacity as a "vital sign" (21), there have been numerous "non-exercise" approaches to estimate CRF (21,69). Because it is inappropriate as well as impractical to perform a maximal exercise test on most individuals without a specific indication, these approaches permit a reasonable estimate of CRF easily without performing the test. Nonexercise estimates of CRF can be useful for activity counseling as well as to provide information on risk stratification (21,69).

ONLINE RESOURCES

American College of Cardiology, guidelines: http://www.acc.org/guidelines

American Heart Association, guidelines and statements: https://professional.heart.org/professional/GuidelinesStatements/UCM_316885_Guidelines-Statements.jsp

American Thoracic Society, statements, guidelines, and reports: "https://www.thoracic.org/statements/

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CHAPTER 5

General Principles of Exercise Prescription

The scientific evidence demonstrating the beneficial effects of exercise is indisputable (1). Moreover, the benefits of exercise far outweigh the risks for most adults (see *Chapters 1* and *2*) (1–3). In addition, sedentary behaviors have shown to increase adverse health outcomes, even among those who exercise regularly (4–8). Although activity breaks, or frequent daily activity bouts of any duration, are recommended by the *2018 Physical Activity Guidelines* (1) and believed to mitigate some of the negative consequences of sedentary behavior, gaps still exist in the literature related to sedentary behavior and activity breaks (9,10).

Therefore, in addition to minimizing sedentary activities, the optimal exercise prescription (Ex R_x) should address components of cardiorespiratory (aerobic) and muscular fitness, mobility/flexibility, and body composition. Thus, a well-crafted Ex R_x should aim to improve at least one component of health or fitness and also include a plan to decrease periods of physical inactivity (2,3,8,11).

AN INTRODUCTION TO THE PRINCIPLES OF EXERCISE PRESCRIPTION

This chapter employs the FITT principles of Ex R_x:

- F: Frequency (how often)
- I: Intensity (how hard)
- T: Time (duration or how long)
- T: Type (mode or what kind)

In addition, components such as Volume (V) (total amount of exercise) and Progression (P) (exercise advancement) should also be considered when designing an individualized Ex R_x consistent with American College of Sports Medicine (ACSM) recommendations.

The FITT principles of Ex R_x presented in this chapter are based on the application of the existing evidence on the physiologic, psychological, and health benefits of exercise (see *Chapter 1*). Nonetheless, some individuals may not respond as expected, considering appreciable individual variability in the magnitude of responses to a particular exercise regimen (3,12–15). Furthermore, the FITT principles of Ex R_x may not apply in certain cases because of individual characteristics (*e.g.*, health status, physical ability, age) or athletic and performance goals. Accommodations to the Ex R_x should be made for individuals with clinical conditions and healthy individuals with special considerations and as indicated in other related chapters of the *Guidelines* (see *Chapters 4*, *6*–*11*).

For most adults, an exercise program including aerobic and resistance training is indispensable to improve and maintain physical fitness and health (1). The FITT Ex R_x guidelines present recommended targets for exercise derived from the available scientific evidence showing most individuals will realize benefit when following the stated quantity and quality of exercise. However, some individuals will want or need to include only some of the health-related components of physical fitness in their training regimen or exercise less than suggested by the guidelines presented in this chapter. Even if an individual cannot meet the recommended targets in this chapter, performing some exercise is beneficial, especially in inactive or deconditioned individuals, and, for that reason, should be encouraged except where there are safety concerns.

GENERAL CONSIDERATIONS FOR EXERCISE PRESCRIPTION

Even though exercise is primarily safe (1), the risk of cardiovascular disease (CVD) and musculoskeletal complications can be minimized by (a) following the preparticipation health screening and evaluation procedures outlined in *Chapter 2*; (b) beginning a new program of exercise at light-to-moderate intensity, with a gradual progression of volume and intensity (3); and (c) employing an individualized exercise program that adheres to the Ex R_x guidelines set forth in this chapter. Moreover, behavioral interventions that may reduce barriers and enhance the adoption and adherence to exercise participation are also important to the implementation of the Ex R_x (see *Chapter 12*).

Aside from the components of the Ex R_x, variables such as an individual's goals, physical ability, physical fitness, health status, schedule, physical and social environment, as well as the available facilities and equipment, should be considered when designing an Ex R_x. This chapter presents evidence-informed recommendations for aerobic, flexibility, and resistance training exercise, as based on a combination of the FITT principles. The following sections present specific recommendations for the Ex R_x to improve health and fitness.

COMPONENTS OF THE EXERCISE TRAINING SESSION

A single exercise training session is typically composed of the following phases:

- Warm-up/initiation
- Conditioning
- Cool-down

Regardless of the individual goal, a training program should be divided into one of three phases — warm-up/initiation, conditioning, and cool-down (16). Each single exercise session should be designed with a training goal in mind and include some type of conditioning exercise, preceded by a movement-specific warm-up (17). Flexibility exercises may also be incorporated into the training session, either before or after the conditioning exercise, and/or separately, in order to improve range of motion (ROM) and enhance muscular coordination (18).

The warm-up, or initiation phase, is a transitional phase that allows the body to adjust to the changing physiologic, biomechanical, and bioenergetic demands of the specific exercise session, and should include light-to-moderate intensity activities specific to the muscle groups that will be employed during exercise (3,17). Warming up also improves ROM and may reduce the risk of injury during the exercise session (3,17). A dynamic warm-up, primarily involving large muscle groups, is superior to static flexibility exercises for the purpose of enhancing the performance of cardiorespiratory endurance, aerobic exercise, sports, or resistance exercise, especially activities that are of long duration or with many repetitions (3,17,19). The specific time dedicated to a warm-up may vary depending on the metabolic demands of the activity; however, evidence suggests this period should be limited to less than 15 min (17).

During the conditioning phase, training exercises could include aerobic, resistance, flexibility, and/or sports activities, depending on the specific goals of the exercise session. Specifics about these modes of exercise are discussed in subsequent sections of this chapter; however, the conditioning portion of any exercise program may last anywhere between 10 and 60 min, depending on the intensity of the activity.

Although cool-downs have been suggested as an integral part of any exercise session, recent evidence suggests cool-downs have limited impact on improving psychobiological markers of recovery (20). Nonetheless, cool-downs may be useful to allow the body to return to near-resting levels (*e.g.*, volume of oxygen consumed per unit time[$\dot{V}O_2$], heart rate [HR]) after the exercise session. Low-to-moderate intensity flexibility exercises, such as static stretching, may also be performed during the cool-down phase to help facilitate a more relaxed physiologic state (21).

CARDIORESPIRATORY FITNESS

The term cardiorespiratory fitness (CRF) reflects the functional capabilities of the heart, blood vessels, lungs, and skeletal muscles to transport and utilize oxygen to perform physical work (22). An Ex R_x featuring moderate-to-vigorous intensity continuous training consisting of rhythmic, aerobic-type endurance exercises has been the traditional means promoted to improve CRF (3). However, emerging evidence points to the efficacy of interval training, in which high intensity efforts and recovery bouts are performed intermittently, demonstrating similar improvements in CRF as observed in traditional endurance training, with a reduced total exercise volume and time commitment (23,24). Whereas improvements in CRF are primarily driven by intensity, frequency, and duration, all types and subsequent combinations of aerobic activities (*e.g.*, walking, jogging, running, sprinting) can contribute toward meeting physical activity (PA) recommendations (1) and improving health outcomes, independent of improvements in CRF; this is especially true for individuals with lower CRF. However, for the purpose of enhancing CRF, an Ex R_x consisting solely of 150 $min \cdot wk^{-1}$ of moderate intensity exercise may not be sufficient to improve CRF in a large proportion of the population, thus requiring a marked increase in the dose-response exercise stimulus, specifically increases in intensity and/or duration (25–27).

To optimize CRF, the FITT principle of Ex R_x is presented as *F*requency ($d \cdot wk^{-1}$), *I*ntensity (% of heart rate reserve [HRR], maximal volume of oxygen consumed per unit time [$\dot{V}O_{2max}$]), *T*ime (duration per session), and *T*ype (mode of PA), with additional recommendations for quantifying volume (product of training frequency, exercise intensity, and exercise duration) and the implementation of progressive overload. The FITT principle of Ex R_x for CRF is summarized in *Table 5.1.*

TABLE 5.1 • Aerobic (Cardiovascular Endurance) Exercise Recommendations

FITT	Recommendation
***F**requency*	• At least 3 d · wk^{-1} • For most adults, spreading the exercise sessions across 3–5 d · wk^{-1} may be the most conducive strategy to reach the recommended amounts of PA.
***I**ntensity*	• Moderate (40%–59% HRR) and/or vigorous (60%–89% HRR) intensity is recommended for most adults.
***T**ime*	• Most adults should accumulate 30–60 min · d^{-1} (≥150 min · wk^{-1}) of moderate intensity exercise, 20–60 min · d^{-1} (≥75 min · wk^{-1}) of vigorous intensity exercise, or a combination of moderate and vigorous intensity exercise daily to attain the recommended targeted volumes of exercise.
***T**ype*	• Aerobic exercise performed in a continuous or intermittent manner that involves major muscle groups is recommended for most adults.

HRR, heart rate reserve; PA, physical activity.

Frequency of Aerobic Exercise

The frequency of PA (*i.e.*, the number of days per week dedicated to an exercise program) is an important contributor to health and fitness benefits. According to the *2018 Physical Activity Guidelines*, aerobic exercise is recommended to be performed on at least 3 d · wk^{-1} (1). For most adults, spreading the exercise sessions across 3–5 d · wk^{-1} may be best to reach the recommended amount of PA. The frequency of exercise can vary, as can the intensity and duration, as these three variables are interdependent on each other (3). The current evidence on PA frequency/intensity is not conclusive to state that 5 d · wk^{-1} of 30 min of aerobic exercise is superior to 3 d · wk^{-1} of 50 min; therefore, multiple combinations of frequency and duration can be combined to meet recommendations (28). Furthermore, a weekly combination of 3–5 $d \cdot wk^{-1}$ of moderate and vigorous intensity exercise options can be performed, which may be more suitable for most individuals (3,28).

Aerobic exercise performed at a frequency of only once or twice per week at moderate-to-vigorous intensity can still bring substantial health/fitness benefits (3,29,30). This exercise pattern may be sufficient to reduce risks for all-cause, CVD, and cancer mortality, regardless of adherence to prevailing PA guidelines (29).

Intensity of Aerobic Exercise

There is a positive dose response of health/fitness benefits that results from increasing exercise intensity (3). The overload principle of training states that exercising below a minimum intensity, or threshold, will not challenge the body sufficiently to result in changes in physiologic parameters (3). However, the minimum threshold of intensity for benefit seems to vary depending on an individual's current CRF level and other factors such as age, health status, physiologic differences, genetics, habitual PA, and social and psychological factors; therefore, precisely defining an exact threshold to improve CRF may be difficult (3,31). For example, highly trained individuals may need to exercise at near-maximal (*i.e.*, 95%–100% $\dot{V}O_{2max}$) training intensities to improve $\dot{V}O_{2max}$, whereas 70%–80% $\dot{V}O_{2max}$ may provide a sufficient stimulus in moderately trained individuals (3,31). Whereas both moderate and vigorous intensity exercise can be used to meet PA recommendations, in order to improve CRF, vigorous intensity exercise (>6 metabolic equivalents [METs]; 60%–84% HRR) is more effective at increasing $\dot{V}O_{2max}$ than moderate intensity exercise (3.0–5.9 METs; 40%–59% HRR) (31–33).

Interval training broadly defined as intermittent periods of intense exercise separated by periods of recovery, is an emerging area of interest for Ex R_x (34). Interval training typically consists of alternating bouts of vigorous-to-supramaximal intensity exercise (20–240 s) followed by equal or longer bouts of light-to-moderate intensity exercise (60–360 s). However, for detrained individuals, a much less demanding implementation of interval training could simply incorporate walking in an interval manner, in which periods of brisk walking are alternated with periods of walking at a reduced pace (35).

Previous research has found that interval training elicits physiologic adaptations similar to traditional endurance training despite a lower total workload, and superior physiologic adaptations when total exercise dose is matched (23,24,34,36,37).

Interval training can be classified as either high intensity interval training (HIIT) or sprint interval training (SIT) (38). HIIT, characterized by near-maximal efforts, is often performed at an intensity close to that which elicits ≥80%–100% peak HR; SIT is characterized by an all-out, supramaximal effort equal to or greater than the pace that elicits ≥100% peak oxygen uptake ($\dot{V}O_{2peak}$) (34,38). However, interval training is not limited to only aerobic-based exercises (*e.g.*, cycling, running). Resistance-based interval training can be implemented via a combination of body weight exercises, plyometrics, and resistance training equipment, which can also result in a potent CRF stimulus depending on the length of the intervals performed and subsequent recovery bouts (39). See *Box 5.1* for examples of interval protocols.

Box 5.1 Examples of Interval Training Protocols

High Intensity Interval Training (HIIT): 4 × 4 protocol (four intervals at 4 min each completed at 90%–95% peak heart rate, with 3 min rest between intervals) (38).

Sprint Interval Training (SIT): 3 × 20 protocol (three intervals at 20 s, each completed with an all-out effort, with 2 min rest between intervals) (40).

Resistance-Based Interval Training: barbell complex — five repetitions of the following five exercises performed back-to-back: Romanian deadlift, bent-over row, hang clean, front squat, overhead press; rest 2 min, repeat for one to two additional rounds.

High Intensity Functional Training (HIFT): three rounds for time of: 400-m run, 10 clean and press, 10 burpees.

During interval training, several aspects of the Ex R_x can be varied based on the incorporation of aerobic-based, resistance-based, or a hybrid of both aerobic- and resistance-based exercises, all of which are ultimately dependent on the goals of the training session and physical fitness level of the individual. However, the primary factors of interval-based Ex R_x primarily concern the intensity and duration of the exercise and recovery interval and the total number of intervals performed (41,42).

Methods of Estimating Intensity of Aerobic Exercise

Several effective methods for prescribing exercise intensity result in improvements in CRF that can be recommended for individualized Ex R_x (3). *Table 5.2* shows the approximate classification of exercise intensity commonly used in practice.

TABLE 5.2 • Methods of Estimating Intensity of Cardiorespiratory Exercise

	Cardiorespiratory Endurance Exercise										
	Relative Intensity				Intensity (% $\dot{V}O_{2max}$) Relative to Maximal Exercise Capacity in MET			Absolute Intensity	Absolute Intensity (MET) by Age		
Intensity	%HRR or % $\dot{V}O_2R$	% HR_{max}	% $\dot{V}O_{2max}$	Perceived Exertion (Rating on 6–20 RPE Scale)	20 METs % $\dot{V}O_{2max}$	10 METs % $\dot{V}O_{2max}$	5 METs % $\dot{V}O_{2max}$	METs	Young (20–39 yr)	Middle Age (40–64 yr)	Older (≥65 yr)
Very light	<30	<57	<37	Very light (RPE <9)	<34	<37	<44	<2.0	<2.4	<2.0	<1.6
Light	30–39	57–63	37–45	Very light to fairly light (RPE 9–11)	34–42	37–45	44–51	2.0–2.9	2.4–4.7	2.0–3.9	1.6–3.1
Moderate	40–59	64–76	46–63	Fairly light to somewhat hard (RPE 12–13)	43–61	46–63	52–67	3.0–5.9	4.8–7.1	4.0–5.9	3.2–4.7
Vigorous	60–89	77–95	64–90	Somewhat hard to very hard (RPE 14–17)	62–90	64–90	68–91	6.0–8.7	7.2–10.1	6.0–8.4	4.8–6.7
Near-maximal to maximal	≥90	≥96	≥91	≥ Very hard (RPE ≥18)	≥91	≥91	≥92	≥8.8	≥10.2	≥8.5	≥6.8

HR_{max}, maximal heart rate; HRR, heart rate reserve; MET, metabolic equivalent; RPE, rating of perceived exertion; $\dot{V}O_{2max}$, maximal volume of oxygen consumed per unit time; $\dot{V}O_2R$, oxygen uptake reserve.

Adapted from (3).

A summary of methods for calculating exercise intensity is presented in *Box 5.2*. Intensity of exercise training is usually determined as a range, so the calculation using the formulas presented in *Box 5.2* need to be repeated twice (*i.e.*, once for the lower limit of the desired intensity range and once for the upper limit of the desired intensity range). The prescribed exercise intensity range for an individual should be determined by taking various factors into consideration, including age, habitual PA level, physical fitness level, and health status. The accuracy of any of these methods may be influenced by the method of measurement or estimation used, therefore direct measurement of the physiologic responses to exercise through an incremental (graded) cardiopulmonary exercise test is the preferred method for Ex R_x whenever possible (3). In fact, recent evidence suggests that Ex R_x's based on intensity produce more predictable metabolic responses compared to Ex R_x's based on maximal fixed variables (*i.e.*, maximal heart rate [HR_{max}]) (46). Examples illustrating the use of several methods for prescribing exercise intensity are found in *Appendix D*.

Box 5.2 Summary of Methods for Prescribing Exercise Intensity Using Heart Rate (HR), Oxygen Uptake ($\dot{V}O_2$), and Metabolic Equivalents (METs)

- HRR method: target HR (THR) = $[(HR_{max/peak}$[a] $- HR_{rest}) \times$ % intensity desired] + HR_{rest}
- $\dot{V}O_2$ method: target $\dot{V}O_2R$[b] = $[(\dot{V}O_{2max/peak}$[c] $- \dot{V}O_{2rest}) \times$ % intensity desired + $\dot{V}O_{2rest}$
- HR method: target HR = $HR_{max/peak}$[a] × % intensity desired
- $\dot{V}O_2$ method: target $\dot{V}O_2$[b] = $\dot{V}O_{2max/peak}$[c] × % intensity desired
- MET method: target MET[b] = $[(\dot{V}O_{2max/peak}$[c]$) / 3.5\ mL \cdot kg^{-1} \cdot min^{-1}] \times$ % intensity desired

[a] $HR_{max/peak}$ is the highest value obtained during maximal/peak exercise or it can be estimated via a prediction equation (see *Table 5.3*).

[b] Activities at the target $\dot{V}O_2$ and MET can be determined using a compendium of physical activity (43,44) or metabolic calculations (45) (see *Table D.1*).

[c] $\dot{V}O_{2max/peak}$ is the highest value obtained during maximal/peak exercise or it can be estimated from a submaximal exercise test. See "The Concept of Maximal Oxygen Uptake" section in *Chapter 3* for the distinction between $\dot{V}O_{2max}$ and $\dot{V}O_{2peak}$. $HR_{max/peak}$, maximal or peak heart rate; HRR, heart rate reserve; HR_{rest}, resting heart rate; $\dot{V}O_{2max/peak}$, maximal or peak volume of oxygen consumed per unit of time; $\dot{V}O_2R$, oxygen uptake reserve; $\dot{V}O_{2rest}$, resting volume of oxygen consumed per unit of time.

The formula (220 − age) is commonly used to predict HR_{max} (47). This formula is simple to use but can underestimate or overestimate measured HR_{max} and therefore is no longer recommended (48,49). Specialized regression equations for estimating HR_{max} may be superior to the equation of 220 − age in some individuals (48–50). Although these equations are promising, they cannot yet be recommended for universal application, although they may be applied to populations similar to those in which they were derived (3). *Table 5.3* shows the more commonly used equations to estimate HR_{max}. For greater accuracy in determining exercise intensity for the Ex R_x, using the directly measured HR_{max} is preferred to estimated methods, but when not feasible, estimation of HR_{max} is acceptable.

TABLE 5.3 • Commonly Used Equations for Estimating Maximal Heart Rate (HR_{max})

Author	Equation	Population
Astrand (51)	$HR_{max} = 216.6 - (0.84 \times \text{age})$	Men and women age 4–34 yr
Tanaka et al. (48)	$HR_{max} = 208 - (0.7 \times \text{age})$	Healthy men and women
Gellish et al. (50)	$HR_{max} = 207 - (0.7 \times \text{age})$	Men and women in an adult fitness program with broad range of age and fitness levels
Gulati et al. (52)	$HR_{max} = 206 - (0.88 \times \text{age})$	Asymptomatic middle-aged women referred for stress testing

Measured or estimated measures of absolute exercise intensity include caloric expenditure ($kcal \cdot min^{-1}$), absolute oxygen uptake ($mL \cdot min^{-1}$ or $L \cdot min^{-1}$), and METs. These absolute measures can result in misclassification of exercise intensity (*e.g.*, moderate and vigorous intensity) because they do not take into consideration individual factors such as body weight, sex, and fitness level (43,44,53). Measurement error, and consequently misclassification, is greater when using estimated rather than directly measured absolute energy expenditure (EE) and under free living compared to laboratory conditions (43,44,53). For example, an older individual working at 6 METs may be exercising at a vigorous-to-maximal intensity, whereas a younger individual working at the same absolute intensity may be exercising at a moderate intensity (53). Therefore, for individual Ex R_x, a *relative* measure of intensity (*i.e.*, the energy cost of the activity relative to the individual's peak or maximal capacity such as $\%\dot{V}O_2$ [*i.e.*, $\dot{V}O_2$ $mL \cdot kg^{-1} \cdot min^{-1}$], HRR, and oxygen uptake reserve [$\dot{V}O_2R$]), is more appropriate, especially for deconditioned individuals (53,54).

When using $\dot{V}O_2$ or METs to prescribe exercise, activities within the desired intensity range can be identified by using a compendium of PAs (43,44) or metabolic calculations (45). Metabolic equations for estimation of EE during common physical activities are found in *Appendix D*.

Measures of perceived effort and affective valence (*i.e.*, the pleasantness of exercise) can be used to modulate or refine the prescribed exercise intensity. The talk test is a valid and reliable measure of exercise intensity that is a reasonable surrogate of the lactate threshold, ventilatory threshold, and respiratory compensation point across a broad range of individuals, and can now be recommended as an effective primary method for prescribing and monitoring exercise intensity (55,56). Other methods (*i.e.*, rating of perceived exertion, OMNI, Feeling Scale) are recommended as adjunct methods for prescribing and monitoring exercise due to the need for further research to validate these methods (3).

Time (Duration) of Aerobic Exercise

Exercise time/duration is prescribed as a measure of the amount of time PA is performed. The recommended time/duration of PA may be performed continuously (*i.e.*, one session) or intermittently and can be accumulated over the course of a day in one or more sessions (1). Most adults are recommended to accumulate 30–60 $\text{min} \cdot \text{d}^{-1}$ of moderate intensity exercise, 20–60 $\text{min} \cdot \text{d}^{-1}$ of vigorous intensity exercise, or a combination of moderate and vigorous intensity exercise per day (1,3). A general guideline for aerobic Ex R_x is that 2-min of moderate intensity aerobic exercise is equivalent to 1-min of vigorous intensity aerobic exercise (1).

Any amount of PA can lead to health benefits, which is particularly encouraging for individuals who are currently sedentary or minimally active, because moving from a state of physical inactivity to any level of activity can result in significant mortality risk reductions (57). Emerging evidence suggests that PA accumulated in bouts of less than 10 min are associated with favorable health-related outcomes, thus engaging in PA, regardless of length of the bout, has health-enhancing effects, reinforcing the benefits of PA regardless of the duration (1).

Type (Mode)

The principle of specificity of training (the physiologic adaptations to exercise are specific to the type of exercise performed) should be kept in mind when selecting the exercise modalities to be included in the Ex R_x (3). Exercise mode or type can be classified as types A–D. Mode or type is based on the nature of the activity, including major body parts used, skill level needed, etc. Additionally, including a variety of exercise modes that place varying impact stresses on the body (*e.g.*, running, cycling), or using different muscle groups (*e.g.*, swimming, running), may be a worthwhile consideration for Ex R_x. The modes of exercise that result in improvement and maintenance of CRF are found in *Table 5.4*.

TABLE 5.4 • Modes of Aerobic (Cardiorespiratory Endurance) Exercises to Improve Physical Fitness

Exercise Group	Exercise Description	Recommended for	Examples
A	Endurance activities requiring minimal skill or physical fitness to perform	All adults	Walking, leisurely cycling, aqua-aerobics, slow dancing
B	Vigorous intensity endurance activities requiring minimal skill	Adults (as per the preparticipation screening guidelines in *Chapter 2*) who are habitually physically active and/or at least average physical fitness	Jogging, running, rowing, aerobics, spinning, elliptical exercise, stepping exercise, fast dancing
C	Endurance activities requiring skill to perform	Adults with acquired skill and/or at least average physical fitness levels	Swimming, cross-country skiing, skating
D	Recreational sports	Adults with a regular exercise program and at least average physical fitness	Racquet sports, basketball, soccer, downhill

	skiing, hiking

Volume (Quantity) of Aerobic Exercise

Exercise volume is the product of training frequency, exercise intensity, and the duration of the exercise session. Evidence supports the important role of exercise volume in realizing health/fitness outcomes, particularly with respect to body composition and weight management. For substantial health benefits, adults are recommended to accumulate 150 min $\cdot$ wk^{-1} of moderate intensity aerobic exercise, or 75 min $\cdot$ wk^{-1} of vigorous intensity aerobic exercise, or an equivalent combination of moderate and vigorous intensity aerobic exercise per week to attain the volume of recommended PA (1). For additional and more extensive health benefits, adults should increase their aerobic PA to 300 min $\cdot$ wk^{-1} of moderate intensity aerobic exercise, or 150 min $\cdot$ wk^{-1} of vigorous intensity aerobic exercise, or an equivalent combination of moderate and vigorous intensity aerobic exercise (1).

Exercise volume may also be used to estimate the gross EE of an individual's Ex R_x. MET-min $\cdot$ wk^{-1} and kcal $\cdot$ wk^{-1} can be used to estimate exercise volume in a standardized manner. *Box 5.3* shows the definition and calculations for METs, MET-min, and kcal $\cdot$ min^{-1} for a wide array of PAs. These variables can also be estimated using previously published tables (43,44). MET-min and kcal $\cdot$ min^{-1} can then be used to calculate MET-min $\cdot$ wk^{-1} and kcal $\cdot$ wk^{-1} that are accumulated as part of an exercise program to evaluate whether the exercise volume is within the ranges described later in this chapter that will likely result in health/fitness benefits.

Box 5.3 Calculation of Metabolic Equivalents (METs), MET-min^{-1}, and kcal $\cdot$ min^{-1}

METs: an index of energy expenditure (EE). "A MET is the ratio of the rate of energy expended during an activity to the rate of energy expended at rest. . . . [One] MET is the rate of EE while sitting at rest . . . by convention . . . [1 MET is equal to] an oxygen uptake of 3.5 [mL $\cdot$ kg^{-1} $\cdot$ min^{-1}]" (1).

MET-min: an index of EE that quantifies the total amount of physical activity performed in a standardized manner across individuals and types of activities (1). Calculated as the product of the number of METs associated with one or more physical activities and the number of minutes the activities were performed (*i.e.*, METs × min), usually standardized per week or per day as a measure of exercise volume.

Kilocalorie (kcal): the energy needed to increase the temperature of 1 kg of water by 1° C. To convert METs to kcal · min^{-1}, it is necessary to know an individual's body weight, kcal · min^{-1} = [(METs × 3.5 mL · kg^{-1} · min^{-1} × body weight in kg) / 1,000)] × 5. Usually standardized as kilocalorie per week or per day as a measure of exercise volume.

Example:

Jogging (at ~7 METs) for 30 min on 3 d · wk^{-1} for a 70-kg male:

7 METs × 30 min × 3 times per week = 630 MET-min · wk^{-1}

[(7 METs × 3.5 mL · kg^{-1} · min^{-1} × 70 kg) / 1,000)] × 5 = 8.575 kcal · min^{-1}

8.575 kcal · min^{-1} × 30 min × 3 times per week = 771.75 kcal · wk^{-1}

Adapted from (3).

The results of epidemiologic studies and randomized clinical trials have demonstrated a dose-response association between the volume of exercise and health/fitness outcomes (*i.e.*, with greater amounts of PA, the health/fitness benefits also increase) (1,3). Whether or not there is a minimum or maximum amount of exercise that is needed to attain health/fitness benefits is not clear. However, a total EE of ≥500–1,000 MET-min · wk^{-1} is consistently associated with lower rates of CVD and premature mortality. Thus, ≥500–1,000 MET-min · wk^{-1} is a reasonable target volume for an exercise program for most adults (1,3). This volume is approximately equal to (a) 1,000 kcal · wk^{-1} of moderate intensity PA (or about 150 min · wk^{-1}), (b) an exercise intensity of 3–5.9 METs (for individuals weighing ~68–91 kg [~150–200 lb]), and (c) 10 MET-h · wk^{-1} (1,3). Lower volumes of exercise (*i.e.*, 4 kcal · kg^{-1} · wk^{-1} or 330 kcal · wk^{-1}) can result in health/fitness benefits in some individuals, especially in those who are deconditioned (1,3).

Pedometers are effective tools for promoting PA and can be used to approximate exercise volume in steps per day (57). With the advances in wearable technologies allowing for improved tracking of PA, a walking pattern or cadence of at least 100 steps · min^{-1} in adults appears to meet the minimum threshold for moderate intensity PA (59). The goal of 10,000 steps · d^{-1} is often cited as a target; however, a daily step count of 7,000–8,000 steps · d^{-1}, with at least 3,000 steps · d^{-1} at a brisk pace (3 METs/>100 steps · min^{-1}), is a reasonable minimum daily threshold associated with health benefits (60).

Progression of Aerobic Exercise

The recommended rate of progression in an exercise program depends on the individual's health status, physical fitness, training responses, and exercise program goals. Progression may consist of increasing any of the components of the FITT principle of Ex R_x as tolerated by the individual. During the initial phase of the exercise program, applying the suggestion of "*start low and go slow*" is prudent to reduce risks of adverse cardiovascular events and injury, as well as to enhance adoption and adherence to exercise (see *Chapters 1*, *2*, and *12*) (3). Initiating exercise at a light-to-moderate intensity in currently inactive individuals and then increasing exercise time/duration (*i.e.*, minutes per session) as tolerated is recommended. An increase in exercise time/duration per session of 5–10 min every 1–2 wk over the first 4–6 wk of an exercise training program is reasonable for the average adult (3). After the individual has been exercising regularly for ≥1 mo, the Ex R_x is gradually adjusted upward over the next 4–8 mo or longer for very deconditioned individuals. Any progression in Ex R_x should be made gradually, avoiding large increases in any of the FITT components to minimize risks of muscular soreness, injury, undue fatigue, and the long-term risk of overtraining. Following any adjustments in the Ex R_x, the individual should be monitored for any adverse effects of the increased volume, such as excessive shortness of breath, fatigue, and muscle soreness, and downward adjustments should be made if the exercise is not well tolerated (3).

RESISTANCE TRAINING

The phrase *muscular fitness* refers collectively to the characteristics of strength, hypertrophy, power, and local muscular endurance (LME) (*Box 5.4*) (61). Muscular fitness is optimized through the implementation of resistance training, which can encompass free weights, machines, body weight, bands/tubing, or any other object that requires one to exert force against a resistance (61).

Box 5.4 **Components of Muscular Fitness (61)**

- **Strength** — the maximal amount of force that can be generated during a specific movement pattern at a specified velocity of contraction.
- **Hypertrophy** — an increase in the size of a muscle.
- **Power** — the rate of performing work; the product of force and velocity.
- **Local muscular endurance** — the ability of the muscle groups involved a movement to sustain exercise.

As stated in the *2018 Physical Activity Guidelines for Americans*, for additional musculoskeletal benefits not found with aerobic activity, adults should perform resistance training exercises that involve all major muscle groups for at least 1 set of 8–12 repetitions at least 2 $d \cdot wk^{-1}$ (1). For individuals that are seeking additional or more specific levels of muscular fitness, the principles of Ex R_x for resistance training are summarized in *Table 5.5* and are presented as *F*requency ($d \cdot wk^{-1}$), *I*ntensity (magnitude of loading), and *T*ype (resistance training exercises selected), with additional recommendations for rest intervals, volume (number of sets performed), and the implementation of progressive overload.

TABLE 5.5 • Resistance Training Exercise Recommendations	
FITT	**Recommendation**
***F**requency*	• For novice trainers, each major muscle group should be trained at least 2 d · wk^{-1}. • For experienced exercisers frequency is secondary to training volume, thus individuals can choose a weekly frequency per muscle group based on personal preference.
***I**ntensity*	• For novices, 60%–70% 1-RM, performed for 8–12 repetitions are recommended to improve muscular fitness. • For experienced exercisers, a wide range of intensities and repetitions are effective dependent on the specific muscular fitness goals.
***T**ype*	• Multijoint exercises affecting more than one muscle group and targeting agonist and antagonist muscle groups are recommended for all adults. • Single-joint and core exercises may also be included in a resistance training program, typically after performing multijoint exercise(s) for that particular muscle group. • A variety of exercise equipment and/or body weight can be used to perform these exercises.

Frequency of Resistance Training Exercise

For individuals who are previously untrained, marked improvements in muscular fitness can be gained by training each muscle group as little as once per week (62,63). The very rapid improvements in muscular fitness that are observed in untrained individuals are likely attributed to neural adaptations; thus, a higher frequency of training may allow for greater levels of motor unit activation and subsequent motor learning to take place (64). For individuals who have progressed beyond the novice stage, the principal driver for improvements in muscular fitness is the total training volume per muscle group per week, with training frequency considered secondary in importance to total volume (62,63,65). The incorporation of higher training frequencies is certainly a viable option to increase total weekly training volume; however, when weekly training volume is equivalent, no appreciable difference in muscular hypertrophy or strength is observed between low ($1\ d \cdot wk^{-1}$), medium ($2\ d \cdot wk^{-1}$) or high-frequency training ($>3\ d \cdot wk^{-1}$) (62,63,66). Therefore, a wide variation in program design options can be achieved by adopting periods of both low, medium, and high frequencies throughout an individualized training plan.

Intensity of Resistance Training Exercise

Within resistance training, intensity refers to the magnitude of loading (*i.e.*, amount of weight lifted) during resistance training exercises (61). Intensity is most often prescribed as a percentage of an individual's one repetition maximum (1-RM) for a given exercise, but any RM or RM range may be chosen when assigning load (*e.g.*, 5-RM, 10-RM, 10–15-RM) (65). Depending on the component of muscular fitness the individual wishes to pursue (strength, hypertrophy, power, LME), the recommended range for intensity and repetitions can vary greatly (65). However, for general muscular fitness goals, a load corresponding with a repetition range of 8–12 is effective (1).

When training for muscular strength, loads >60% 1-RM are recommended (67). For untrained individuals, improvements in strength are elicited across a wide spectrum of intensities (40%–85% 1-RM) with maximal gains observed at a mean training intensity of 60% of 1-RM (8–12-RM) (64,68). For trained individuals, improvements in 1-RM strength necessitate a greater intensity (80%–100% 1-RM) and wider loading range (1–12-RM), with maximal strength gains optimized at a mean training intensity of 80% 1-RM and a greater emphasis on heavier loads (1–6-RM) (64,65,67,68).

When training for muscular hypertrophy (*i.e.*, attempting to increase or preserve muscle mass), improvements can occur across a much wider range than those required for muscular strength (67). Previous research had indicated loads >60% of 1-RM were necessary to stimulate hypertrophy, with a load of 70%–80% of 1-RM/8–12-RM considered optimal (65,69). However, emerging research into low-load training has found that the lifting of heavy loads is not the sole driver of muscle hypertrophy (67,70). It has been demonstrated that regardless of the load lifted, performing resistance training sets to volitional failure results in hypertrophy, even with loads as little as 30% of 1-RM (67,70,71). Thus, muscle hypertrophy can be achieved across a wide spectrum of light and heavy loads, with a repetition range of 6–20-RM as most practical (67).

Power training is an essential component of muscular fitness and is performed with the intent to move as fast as possible through the full ROM. For healthy, active adults, it should be noted that throughout the lifespan, muscular power decreases at a greater rate than muscular strength (65). Therefore, the incorporation of power training is valuable for recreational athletes, for manual labor tasks, and for activities of daily living (65). Furthermore, as active adults age, power training has been shown to be valuable to maintain balance and prevent falls (3). Power training is best incorporated with one to three sets per exercise, using light-to-moderate loading, for three to six repetitions (30%–60% of 1-RM for upper body exercises, 0%–60% of 1-RM for lower body exercises); all performed with the intent to move the resistance with maximal velocity (65).

When training to improve LME, light, moderate, and heavy loading have all been shown to be effective, with no clear indication of a superior repetition range (65,72). Therefore, when training for LME, lighter loads may be coupled with higher repetitions (15–25 repetitions or more) or moderate to heavy loading could be coupled with short rest periods via circuit training, resistance-based interval training, or high intensity functional training, each creating specific metabolic demands for the desired adaptations (39,65,73).

Types of Resistance Training Exercises

A wide variety of resistance training equipment can effectively be used to improve muscular fitness, including free weights (*e.g.*, barbells, dumbbells, kettlebells), body weight/body weight suspension devices, machines (*e.g.*, weight stack, plate loaded, pneumatic resistance), and resistance bands/tubing. Resistance training regimens can be composed of (a) multijoint exercises that target more than one muscle group (*e.g.*, bench press, push-ups, shoulder press, lat pull-downs, pull-ups, bent-over rows, leg press, squats, deadlifts), (b) single-joint exercises targeting individual muscle groups (*e.g.*, biceps curls, triceps extensions, leg extensions, leg curls, calf raises), and (c) core exercises that engage the musculature of the trunk/torso (*e.g.*, curl-ups, medicine ball throws, planks). It is recommended that resistance training addresses concentric (muscle shortening), eccentric (muscle lengthening), and isometric (no change in muscle length) muscle actions through the selection and subsequent performance of dynamic and static exercises (3,65).

To avoid creating muscle imbalances, opposing muscle groups (*i.e.*, agonists and antagonists) should be included in the resistance training routine (3,65). Examples of resistance training exercises that address opposing muscle groups are push-ups and dumbbell rows (chest and upper back), leg extensions and leg curls (quadriceps and hamstrings), or planks and bird dogs (abdominals and spinal erectors).

Rest Intervals for Resistance Training Exercises

Rest intervals are ultimately driven by the amount of total time available for a given training session. When time is not a factor, a longer rest interval (>2 min) may allow for the ability to do greater amounts of work, which may subsequently lead to greater improvements in the component of muscular fitness sought (74,75). However, shorter rest intervals (60–120 s) may be a more time-efficient option for some individuals because improvements in muscular fitness can still be achieved across a range of rest interval durations (74,75).

Volume (Number of Sets per Week) of Resistance Training Exercise

The volume of a resistance training program can be quantified as the total amount of sets performed for a given muscle group/movement pattern per week. For untrained individuals, significant improvements in muscular fitness are realized with as few as one set per muscle group per session. Therefore, low-volume protocols (<4 weekly sets per muscle group) can be a viable option for untrained or individuals with limited time (3,76). However, for individuals seeking advanced muscular fitness goals (*e.g.*, bodybuilding, powerlifting, sports performance), a graded dose-response relationship exists between the number of weekly sets per muscle group and the levels of hypertrophy and strength that can be attained (76,77). For improvements in both muscular hypertrophy and strength, a dose-response relationship is observed between the number of sets per muscle group. The dose-response continuum for muscular hypertrophy and strength includes low weekly sets (<5 sets per muscle group per week), medium weekly sets (5–9 sets per muscle group per week), and high weekly sets (10+ sets per muscle group per week) (63,76,77). To date, the upper limit of the dose-response relationship that may result in a plateau or regression of muscular fitness has not been conclusively determined (63). There is insufficient research at this time for evidence-based volume recommendations on muscular power or LME.

When accumulating the recommended amount of volume per week, the sets may be derived from the same exercise or from a combination of exercises affecting the same muscle group (3,65). For example, over the course of a week, the quadriceps could be trained either with (a) six sets of squats; (b) three sets of squats and three sets of leg press; or (c) two sets of squats, two sets of leg press, and two sets of leg extensions. Using different exercises to train the same muscle group may add variety and allow for the training stimulus to remain novel, allowing for continual progression to occur (65).

Progression of Resistance Training Exercise

Progressive overload is the gradual increase of stress placed on the body (65). As adaptations to a resistance exercise training program occur, the individual should continue to subject the muscles to greater stimuli for continued increases in muscular fitness. However, as per the principle of diminishing returns, as an individual gets closer to their genetic ceiling, the rate and magnitude of further improvements will be limited (63). The principle of progressive overload may be performed in several ways. For example, if an individual could complete 100 lb (45.5 kg) for 10 repetitions until volitional exhaustion on the chest press exercise, progressive overload could be achieved by increasing the load by 5% for the next training session. Another way progressive overload could be achieved is by performing more repetitions with the same load (*e.g.*, day 1: 100 lb × 9 repetitions; day 2: 100 lb × 11 repetitions). Other ways to progressively overload muscles could include increasing the number of sets per muscle group per week (*e.g.*, three sets per muscle group per week to four sets per muscle group per week) or increasing the number of days per week each muscle groups is trained (*e.g.*, two total body workouts per week to three total body workouts per week). At minimum, if the individual seeks to simply maintain a given level of muscular fitness, training muscle groups as little as 1 $d \cdot wk^{-1}$ may be sufficient as long as the training intensity or the resistance lifted is held constant (3,65).

FLEXIBILITY

Flexibility, or the ability to move through a joint's ROM, has long been considered a component of fitness and therefore can be included as part of any Ex R_x (21). Joint ROM and flexibility can be improved by engaging in flexibility exercises that are specific to the joint of interest (3). In addition, improved flexibility can be achieved not only with the specific stretched muscle or joint, but ROM increases can also occur in nonstretched muscles in other parts of the body. Research has shown that unilateral stretching of the quadriceps will improve ROM of the contralateral quadriceps (78), whereas stretching the hip adductor muscles (groin) can improve the flexibility of the shoulders and stretching the shoulders can improve flexibility of the hamstrings (hip flexion) (79). These findings may be important for individuals who are rehabilitating an injury and cannot stretch particular muscle groups. Stretching major muscle groups seem to have global flexibility effects on the body. Joint ROM can be improved immediately after performing stretching exercises and has shown chronic improvement after about 3–4 wk of regular stretching two to three times per week (3). Postural stability and balance can also be improved by consistently or regularly engaging in flexibility exercises (80). Overall, the goal of a flexibility program should be to develop ROM in the major joints and muscle/tendon groups in accordance with individualized goals. Moreover, flexibility, along with aerobic capacity and muscular fitness, is a core aspect of minimizing mobility deficits experienced with aging and therefore should be considered as part of an Ex R_x for such purposes (81).

Recent evidence suggests that the type of stretch (*Box 5.5*) and when the stretching is performed may impact exercise performance. Although stretching exercises for the purpose of increasing ROM are encouraged for all populations, performing stretching exercises for the purpose of improving exercise performance or reducing muscle soreness is not recommended (19,82–84). Static stretching, where one slowly stretches a muscle/tendon group to a point of mild discomfort for a period of time, is very common in fitness environments. This type of stretching results in improvements in ROM that can be a result of decreases in neural inhibition, musculotendinous unit stiffness, or tolerance to the stretch (85–88). However, there is a diminishing rate of return with static stretching, such that stretches performed for more than 60 s have a deleterious effect on exercise performance (*i.e.*, sprinting, maximal contractions, etc.) (83).

Box 5.5 Flexibility Exercise Definitions

Ballistic methods or bouncing stretches use the momentum of the moving body segment to produce the stretch.

Dynamic or slow movement stretching involves a gradual transition from one body position to another and a progressive increase in reach and range of motion as the movement is repeated several times.

Static stretching involves slowly stretching a muscle/tendon group and holding the position for a period of time (*i.e.*, 10–30 s). Static stretches can be active or passive.

Active static stretching involves holding the stretched position using the strength of the agonist muscle as is common in many forms of yoga.

Passive static stretching involves assuming a position while holding a limb or other part of the body with or without the assistance of a partner or device (such as elastic bands or a ballet barre).

Proprioceptive neuromuscular facilitation (PNF) methods take several forms but typically involve an isometric contraction of the selected muscle/tendon group followed by a static stretching of the same group (*i.e.*, contract-relax).

Adapted from (3).

Proprioceptive neuromuscular facilitation (PNF) stretching (89) is also used to stimulate the musculotendinous unit and is characterized by an isometric contraction of a target muscle and a concentric contraction of an opposing muscle, along with a controlled approach to the stretch (89). Even though PNF stretching has been suggested to yield greater gains than static and ballistic stretching (90), recent evidence suggest this is not the case (91,92). Therefore, for the purpose of improving ROM, it is reasonable to recommend any type of stretching exercise for individuals engaged in a general fitness program.

Dynamic stretching, which involves controlled movements through an active ROM, is a recommended component of the warm-up. Dynamic movements mimic the intended exercise or sport activity subsequent to the warm-up. Dynamic stretching can elevate core temperature, which leads to increased neuromuscular conduction and compliance, and enzymatic activity, which may accelerate energy production (83). The available evidence suggests that short sessions of dynamic stretches (<30 s) do not adversely affect exercise bout performance, and prolonged sessions (>30 s) may facilitate performance (82,83). Therefore, dynamic stretching is recommended both prior to more vigorous exercise and also as a potential adjunct to improving sport performance.

FITT **FLEXIBILITY EXERCISE RECOMMENDATION**

Flexibility exercises are recommended to improve joint-specific ROM and to improve performance. ROM can be improved with static, ballistic, and/or PNF stretching. Joint-specific flexibility exercises are most effective when the muscles are warm and should be avoided prior to an exercise bout. Static, ballistic, and/or PNF stretching should be performed on their own, as part of a specific program to increase ROM, and not preceding any exercise activity. Dynamic stretches are encouraged prior to any exercise bout and may also be used to improve performance.

Types of Flexibility Exercises

Flexibility exercise should target the major muscle tendon units of the shoulder girdle, chest, neck, trunk, lower back, hips, posterior and anterior legs, and ankles (3). *Box 5.5* shows the several types of flexibility exercises that can improve ROM. Properly performed ballistic stretching has been shown in some studies to be equally as effective as static stretching in increasing joint ROM and may be considered for adults who engage in activities that involve ballistic movements such as basketball (91,92).

Volume of Flexibility Exercise (Time, Repetitions, and Frequency)

The progression of flexibility exercises is as complex as any other component of the Ex R_x and should be individualized just like the aerobic and muscular fitness components. Evidence suggests that flexibility exercises should be progressed based on individuals' level of discomfort and within their current ROM. Additionally, static and PNF stretching should be performed exclusively as part of a program to improve ROM. For the purpose of improved performance, prolonged static stretching exercises should be avoided, unless included as part of a dynamic warm-up that are specific to the activity being performed. Because static stretching can reduce the incidence of musculotendinous injuries and is effective for increasing ROM for many sport applications, it can still be included in a preevent warm-up if combined with aerobic activities, dynamic stretching, and dynamic sport-specific activities (82,83). Although a number of studies have shown no adverse effects of static stretching when incorporated into a full dynamic warm-up (93,94), there can be positive psychological effects as well (95).

If the individual goal is to improve ROM, holding a stretch for 10–30 s to the point of tightness or slight discomfort enhances joint ROM. Moreover, evidence suggests that holding a static stretch for over 60–90 s without additional dynamic activities will lead to performance decrements (82,83,96). In older adults, stretching for 30–60 s may result in greater flexibility gains than shorter duration stretches (3) (see *Chapter 6*). For PNF stretches, it is recommended that individuals of all ages hold a light-to-moderate contraction (*i.e.*, 20%–75% of maximum voluntary contraction) for 3–6 s, followed by an assisted stretch for

10–30 s (3). During a flexibility training session, stretching exercises should be repeated two to four times to accumulate a total of 90 s of stretching for each flexibility exercise by adjusting time/duration and repetitions according to individual needs (83). Performing flexibility exercises ≥2–3 d · wk^{-1} will improve ROM, but stretching exercises are most effective when performed daily (3). A stretching routine following these guidelines can be completed by most individuals in ≤10 min (3).

FITT **FLEXIBILITY VOLUME RECOMMENDATION**

A total of 90 s of discontinuous flexibility exercise per joint is recommended. Holding a single flexibility exercise for 10–30 s to the point of tightness or slight discomfort is most effective. Older adults can benefit from holding the stretch for 30–60 s. A 20%–75% maximum voluntary contraction held for 3–6 s followed by a 10- to 30 s assisted stretch is recommended for PNF techniques. Performing flexibility exercises ≥2–3 d · wk^{-1} is recommended with daily flexibility exercise being most effective. For individuals who are seeking additional or more specific levels of flexibility, the principles of Ex R_x for flexibility training are summarized in *Table 5.6* and are presented as *F*requency (d · wk^{-1}), *I*ntensity (magnitude of loading), and *T*ype (resistance training exercises selected).

TABLE 5.6 • Flexibility Exercise Recommendations	
FITT	**Recommendation**
Frequency	• ≥2–3 d · wk^{-1} with daily being most effective.
Intensity	• Stretch to the point of feeling tightness or slight discomfort.
Time	• Holding a static stretch for 10–30 s is recommended for most adults. • In older individuals, holding a stretch for 30–60 s may confer greater benefit. • For proprioceptive neuromuscular facilitation (PNF) stretching, a 3–6 s light-to-moderate contraction (*e.g.*, 20%–75% of maximum voluntary contraction) followed by a 10- to 30-s assisted stretch is desirable.
Type	• A series of flexibility exercises for each of the major muscle-tendon units is recommended. • Static flexibility (*i.e.*, active or passive), dynamic flexibility, ballistic flexibility, and PNF are each effective.

Adapted from (3).

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Exercise Prescription for Healthy Populations with Special Considerations

CHAPTER 6

CHILDREN AND ADOLESCENTS

Physical activity (PA) provides a multitude of physiological and psychological benefits to adults and children alike (1). Children and adolescents, defined as individuals aged 6–19 yr (also referred to as *youth*), are typically more physically active than their adult counterparts. The *2018 Physical Activity Guidelines for Americans* recommends that children and adolescents should engage in at least 60 min $\cdot$ d^{-1} of moderate-to-vigorous intensity PA (1). Resistance exercise and bone loading activities are also recommended on at least 3 d $\cdot$ wk^{-1} and count toward the 60 min $\cdot$ d^{-1} total (1). Overall, only 21.6% of U.S. youth meet PA guidelines, with more boys (26.0%) than girls (16.9%) considered physically active (2). Furthermore, there is a strong age-related decline in youth PA that is evident throughout childhood and adolescence (3,4) in which 42.5% of 6–11-yr-olds meet PA guidelines but only 7.5% and 5.1% of 12–15-yr-olds and 16–19-yr-olds, respectively (2).

The intensity of PA can be defined in terms of the rate of energy expenditure required for a given activity or based on a perceived level of effort. Energy expenditure-based intensity metrics, such as metabolic equivalents (METs) or kilocalories, are not comparable to children due to differences in basal metabolic rates, energy expenditures per unit body mass, and movement efficiency for certain activities (5,6). Although MET-based intensities for PA specific to youth are available (7,8), the *2018 Physical Activity Guidelines for Americans* recommends estimating youth PA intensity relatively, using a perceived effort scale from 0 (sitting) to 10 (highest effort possible), with moderate intensity at a 5 or 6, and vigorous intensity starting at a 7 or 8 (1).

In addition to the health benefits associated with PA, there is also evidence that limiting screen time, a marker of sedentary behavior, is independently related to avoiding health problems in youth, such as increased adiposity and depressive symptoms, decreased fitness, and elevated blood pressure, blood lipids, and glycohemoglobin levels (9–11). Expert panels from the National Heart, Lung, and Blood Institute (NHLBI) and the American Academy of Pediatrics (AAP) have recommended that children and adolescents limit total recreational screen time to $<2\ \mathrm{h} \cdot \mathrm{d}^{-1}$ (12,13). Guidelines for young children are lower, including $<1\ \mathrm{h} \cdot \mathrm{d}^{-1}$ of screen time for 2–5-yr-olds and none for infants <18 mo old (13,14). More recently, the AAP has updated their screen time guidelines, recommending a more tailored approach, encouraging families to seek a balance in screen time through the development of a Family Media Use Plan that incorporates rules regarding the quantity and quality of media content (15). Yet nationally, slightly more than half of children aged 6–11 yr adhere to these guidelines of viewing $<2\ \mathrm{h} \cdot \mathrm{d}^{-1}$ of screen time (16). Perhaps most importantly, the PA and sedentary behavior patterns of children can track into adulthood, so it is vital that youth initiate and maintain a physically active lifestyle from an early age (17–20), while also making a habit of reducing unnecessary sedentary time.

Children and adolescents are physiologically adaptive to aerobic exercise training (21), resistance training (22), and bone loading exercise (23–26). In fact, evidence suggests that prepubescent children who participate in resistance training can achieve relative strength gains similar to those seen in adolescents (27). Furthermore, there is strong evidence that aerobic and resistance exercise training produces improvements in weight control, bone strength, and psychosocial well-being, and moderate evidence supporting improvements in cardiometabolic risk factors and prevention of sports-related injuries (1). Thus, the benefits of exercise are much greater than the risks (*e.g.*, overuse injuries). Recent evidence also supports the concept that PA and physical fitness are positively associated with cognition and academic achievement (28).

Young, healthy individuals are able to start moderate intensity exercise training without medical screening, and vigorous exercise can be initiated after safely participating in moderate exercise. Physiologic responses to acute, graded aerobic exercise are qualitatively similar to those seen in adults. However, there are important quantitative differences, many of which are related to the effects of body mass, muscle mass, and height. In addition, it is notable that children have a much lower anaerobic capacity than adults, limiting their ability to perform sustained vigorous intensity exercise (29).

Exercise Testing

Generally, the adult guidelines for standard exercise testing apply to children and adolescents (see *Chapter 3*). However, physiologic responses during exercise differ from those of adults (*Table 6.1*) so that the following issues should be considered (21,32):

- Exercise testing for clinical purposes is generally not indicated for children or adolescents unless there is a health concern.
- The exercise testing protocol should be based on the reason the test is being performed and the functional capability of the child or adolescent.

- Children and adolescents should be familiarized with the test protocol before testing to minimize stress and maximize the potential for a successful test.
- Treadmill and cycle ergometers should be available for testing.

  Treadmills tend to elicit a higher peak oxygen uptake ($\dot{V}O_{2peak}$) and maximal heart rate (HR_{max}). Cycle ergometers provide less risk for injury but need to be correctly sized for the child or adolescent. Cycle ergometers also require additional focus and attention in order for the appropriate self-propelled cadence to be maintained, which may be difficult for some children.
- Children and adolescents may require extra motivation and support during the test compared to adults.

TABLE 6.1 • Physiologic Responses to Acute Exercise in Children Compared to Adults (30,31)

Variable	Response
Absolute oxygen uptake	Lower
Relative oxygen uptake	Higher
Heart rate	Higher
Cardiac output	Lower
Stroke volume	Lower
Systolic blood pressure	Lower
Diastolic blood pressure	Lower
Respiratory rate	Higher
Tidal volume	Lower
Minute ventilation	Lower
Respiratory exchange ratio	Lower

In addition, health/fitness testing may be performed outside of the clinical setting. In school-based settings, the FITNESSGRAM test battery may be used to assess the components of health-related fitness (33). The components of the FITNESSGRAM test battery include body composition (*i.e.*, body mass index [BMI], skinfold measurements, or bioelectrical impedance analysis), cardiorespiratory fitness (CRF) (*i.e.*, 1-mi walk/run and progressive aerobic cardiovascular endurance run [PACER]), muscular fitness (*i.e.*, curl-up test, trunk lift test, pull-ups, and push-up test), and flexibility (*i.e.*, back-saver sit-and-reach test and shoulder stretch) (33). Age- and gender-specific, criterion-referenced standards are available, which allow results to be compared across demographic characteristics (33). Due to the strong correlation between health and fitness, tests that evaluate aerobic and muscular fitness remain important screening tools.

Exercise Prescription

The exercise prescription (Ex R_x) guidelines outlined in this chapter for children and adolescents establish the minimal amount of PA needed to achieve the health/fitness benefits associated with regular PA (1). Children and adolescents should be encouraged to participate in various PAs that are enjoyable and age-appropriate. PA in young children should include unstructured active play, which typically consists of sporadic bursts of moderate and vigorous intensity PA alternating with brief periods of rest. It is important to recognize that these small bouts of PA, however brief, count toward Frequency, Intensity, Time, and Type (FITT) recommendations.

FITT — FITT RECOMMENDATIONS FOR CHILDREN AND ADOLESCENTS (1)

	Aerobic	**Resistance**	**Bone Strengthening**
Frequency	Daily; include vigorous intensity at least 3 d · wk^{-1}.	≥3 d · wk^{-1}	≥3 d · wk^{-1}
Intensity	Moderate (noticeable increase in HR and breathing) to vigorous intensity (substantial increases in HR and breathing)	Use of body weight as resistance or 8–15 submaximal repetitions of an exercise to the point of moderate fatigue with good mechanical form	Variable with emphasis on activities that produce moderate to high bone loading through impact or muscle force production
Time	As part of ≥60 min · d^{-1} of exercise	As part of ≥60 min · d^{-1} of exercise	As part of ≥60 min · d^{-1} of exercise
Type	Enjoyable and developmentally appropriate activities, including tag/running games, hiking/brisk walking, hopping,	Muscle strengthening physical activities can be unstructured (*e.g.*, playing on playground equipment, climbing trees, tug-of-war), or	Examples of bone strengthening activities include running, jump rope, basketball, tennis, resistance training, and hopscotch.

	skipping, jumping rope, swimming, dancing, bicycling, and sports such as soccer, basketball, or tennis	structured and appropriately supervised (*e.g.*, performing body weight exercises such as push-ups and sit-ups, lifting weights, working with resistance bands).	

HR, heart rate.

Aerobic Exercise

Enjoyable and developmentally appropriate activities can take on a wide range of meanings for youth, depending on physical, social, and emotional maturation status (1). Although aerobic exercise training in adults is commonly performed as steady-state exercise, such prolonged bouts of exercise will likely be neither enjoyable nor appropriate for many children. Rather, children's natural play patterns have an intermittent quality (*e.g.*, tag games, many team sports) that can be emulated in more structured intervention efforts while also contributing to improvements in aerobic fitness. If improvements in aerobic fitness are assessed by maximal or $\dot{V}O_{2peak}$, prepubertal children will demonstrate a blunted response to aerobic exercise training; about 5%–10% increase for children, compared with about a 20% increase for adults (21). However, measures of aerobic performance (*e.g.*, 1-mi walk/run, PACER), rather than maximal capacity, may be more practical and meaningful in many situations.

Resistance Exercise

In addition to the FITT recommendations above, there are several additional factors that need to be incorporated into any structured youth resistance training program. Additional factors include education on proper form and technique, knowledgeable adult supervision, and appropriately determined initial resistance (weight) plus the timing and magnitude of resistance progressions (22,34). Most injuries associated with resistance training in youth are due to a failure in one of these three key areas, not due to the exercise itself (22,34). As with adults, working larger muscle groups and performing more complex multijoint exercises first is recommended, to avoid excess fatigue when performing the more dynamic exercises. Currently, there is no ideal modality for resistance training in youth. Free weights, weight machines, body weight, and resistance bands have all demonstrated effectiveness in improving strength (22,34).

Bone Strengthening Exercise

There is strong evidence supporting the beneficial role of PA on bone health. A review of 22 intervention trials in children aged 3–18 yr (23) identified an augmented annual increase in bone accrual of 0.6%–1.7% due to a PA or an exercise intervention. However, the precise FITT prescription for improving bone health is not clearly defined (25). Bone responds to PA or exercise stimuli that produce a strain on the bone due to impact (*e.g.*, running, jumping, racket sports) or mechanical load (lifting) and responds optimally when these stimuli are dynamic, relatively short in duration, moderate to high in intensity, and inconsistent in the type of stimuli or direction of the applied load (25). These important factors should be considered in youth training programs where an increase in bone health is an important outcome.

Special Considerations

- Children and adolescents may safely participate in strength training activities provided they receive proper instruction and supervision. Generally, adult guidelines for resistance training may be applied (see *Chapter 5*), although the additional design and supervision elements mentioned above are crucial for youth resistance training programs.
- Because of immature thermoregulatory systems, youth are at greater risk of heat-related injury. Therefore, youth should avoid sustained, heavy exercise in exceptionally hot humid environments, be properly hydrated before, during, and after activity, and appropriately modify activities. See *Chapter 7* and the American College of Sports Medicine (ACSM) position stand on exercising in the heat and fluid replacement for additional information (35).
- Children and adolescents who have excess weight or are physically inactive may not be able to achieve 60 min $\cdot$ d^{-1} of moderate-to-vigorous intensity PA, initially. Instead, they should start out with moderate intensity PA using a relative estimate of intensity (*e.g.*, perceived exertion) and gradually increase the frequency, intensity, and duration of PA to achieve the 60-min $\cdot$ d^{-1} goal.
- Children and adolescents with diseases or disabilities such as asthma (see *Chapter 8*), diabetes mellitus (see *Chapter 9*), obesity (see *Chapter 9*), cystic fibrosis, and cerebral palsy (see *Chapter 11*) should be referred to individuals with expertise in these areas.
- Efforts should be made to decrease sedentary activities (*i.e.*, television watching, Web surfing, and playing inactive video games) and increase activities that promote lifelong activity and fitness (*i.e.*, active play, walking, running, cycling, and resistance training).

ONLINE RESOURCES

U.S. Department of Health and Human Services. *Physical Activity Guidelines for Americans* [Internet]. 2nd ed. Washington (DC): U.S. Department of Health and Human Services; 2018 [cited 2020 Mar 30]. 118 p. Available from: https://health.gov/our-work/physical-activity/current-guidelines

LOW BACK PAIN

Low back pain (LBP) is defined as pain, muscle tension, or stiffness localized below the rib margin and above the inferior gluteal folds, with or without leg pain (36,37). LBP is considered a major public health problem, with the lifetime prevalence reported as high as 84% (38). However, the presence of LBP disability is not consistent across cultures (39). In western countries, between 4% and 33% of the adult population experience LBP at any given point in time (40), and recurrent episodes of LBP can occur in over 70% of cases (41). Approximately 20% of LBP cases become chronic, and about 10% of the cases progress to a disability (38).

Individuals with LBP can be classified into one of three broad categories: (a) LBP potentially associated with another specific spinal cause (*e.g.*, cancer, fracture, infection, ankylosing spondylitis, or cauda equina syndrome); (b) LBP potentially associated with radiculopathy or spinal stenosis; and (c) and nonspecific LBP (LBP with no known pathoanatomical cause), which encompass over 85% of all cases (29). For prognosis and outcome purposes, LBP can be described as acute (<6 wk), subacute (6–12 wk), and chronic (>12 wk) (38,42). The best available evidence supports a classification approach that de-emphasizes the importance of identifying specific anatomical lesions after red flag screening is completed (42). The American Physical Therapy Association suggests five classifications of LBP:

- LBP with mobility deficits
- LBP with radiating pain
- LBP with referred lower extremity pain

- LBP with movement coordination impairments
- LBP with related generalized pain

It is frequently stated that approximately 90% of acute low back episodes resolve within 6 wk regardless of treatment (43). However, it is more accurate to state that 90% of individuals with LBP who receive primary care will have stopped consulting with symptoms within 3 mo, yet most individuals will still be experiencing LBP and related disability 1 yr after consultation (44).

To reduce the probability of disability, individuals with LBP should stay active by continuing ordinary activity within pain limits, avoid bed rest, and return to work as soon as possible (45). Current research shows that following an acute bout of LBP, early access (within 3 wk of acute onset) to physical therapy results in dramatic reductions in the need for advanced imaging, opioid use, injections, and surgery, as well as decreased disability (46–48). If disabling pain continues beyond 6 wk, a multidisciplinary approach that includes addressing psychosocial factors is recommended (42). Many individuals with LBP have fear, anxiety, or misinformation regarding their LBP, exacerbating a persistent pain state (49). A combination of therapeutic and aerobic exercise, in conjunction with pain education, improves individual attitudes, outcomes, perceptions, and pain thresholds (50,51). Psychosocial factors that increase the risk of developing or perpetuating long-term disability and work loss associated with LBP can be found in *Box 6.1*.

Box 6.1 Psychosocial Factors for Long-Term Disability and Work Loss Associated with Low Back Pain (52)

- A negative attitude that back pain is harmful or potentially severely disabling
- Fear avoidance behavior and reduced activity levels
- An expectation that passive, rather than active, treatment will be beneficial
- A tendency to depression, low morale, and social withdrawal
- Social or financial problems

Current literature does not support a definitive cause for initial bouts of LBP (42). However, previous LBP is one of the strongest predictors for future back pain episodes (36); therefore, once an individual suffers an initial episode of LBP, they are in fact more susceptible to future episodes of LBP. Recurrent episodes of LBP tend toward increased severity and duration, higher levels of disability, including work disability, and higher medical and indemnity costs (53,54). Current guidelines place a heavy emphasis on preventive measures and early interventions to minimize the risk of an acute LBP episode from becoming chronic and/or disabling (55). Additionally, best evidence for treating LBP indicates PA as a key component in managing the condition (56–59). The biopsychosocial model is the prevailing framework used for understanding, managing, and treating back pain. This approach suggests that in addition to biology, psychological, socioeconomic, environmental, and cultural factors all contribute to the incidence and persistence of back pain symptoms (60).

Within this framework, specific considerations must be given to individuals with LBP who are fearful of pain or reinjury and thus avoid PA, and equally to those individuals who persist in PA despite worsening symptoms (61,62). Individuals with LBP who are fearful of pain or reinjury often misinterpret any aggravation of symptoms as a worsening of their spinal condition and hold the mistaken belief that pain necessarily implies tissue damage (63). In contrast, those with LBP who persist in PA may not allow injured tissues the time that is needed to heal. Both behaviors, persistent PA during pain and being fearful of pain, are associated with chronic pain (61). Therefore, when designing and implementing exercise programs it is imperative that a thorough understanding of the patient's beliefs have been considered. *Box 6.2* further highlights the LBP clinical practice guidelines from the Orthopedic Section of the American Physical Therapy Association (42).

Box 6.2 Low Back Pain: Clinical Practice Guidelines (42)

Clinicians should not utilize patient education and counseling strategies that either directly or indirectly increase the perceived threat or fear associated with low back pain, such as education and counseling strategies that

- Promote extended bed rest
- Provide in-depth, pathoanatomical explanations for the specific cause of the patient's low back pain.

Patient education and counseling strategies for patients with low back pain should emphasize

- The promotion of the understanding of the anatomical/structural strength inherent in the human spine
- The neuroscience that explains pain perception
- The overall favorable prognosis of low back pain
- The use of active pain coping strategies that decrease fear and catastrophizing
- The early resumption of normal or vocational activities, even when still experiencing pain
- The importance of improvement in activity levels, not just pain relief.

When LBP is a symptom of another serious pathology (*e.g.*, cancer), exercise testing and prescription should be performed in consultation with the health care team managing the serious pathology. For all other causes, and in the absence of a comorbid condition (*e.g.*, cardiovascular disease [CVD] with its associated risk factors), recommendations for exercise testing and prescription are similar as for healthy individuals (see *Chapter 5*). Given that the vast majority of LBP cases are nonspecific, the focus of the Ex R_x recommendations presented here will address individuals with

LBP that are not associated with trauma or any specific underlying conditions (*e.g.*, cancer or infection).

Exercise Testing

Individuals with acute or subacute LBP appear to vary in their individual levels of PA independent of their pain-related disability. However, chronic LBP with high levels of disability may lead to low levels of PA (64). Individual beliefs about the back pain will often influence one's willingness to exercise (65). As such, exercise testing and subsequent activities may be symptom limited in the first weeks following symptom onset (62,66).

Cardiorespiratory Fitness

Avoidance behavior due to pain may result in decreased PA, which may lead to the unavoidable consequence of reduced CRF (67). Current evidence, however, has failed to find a clear relationship between CRF and pain (68). Few studies have subjected individuals with LBP to exercise tests to exhaustion (69). Submaximal exercise tests are considered reliable and valid for individuals with LBP (62), however, actual or anticipated pain may limit submaximal testing as often as maximal testing (62,69–72). Therefore, the choice of maximal versus submaximal testing in individuals with LBP should be guided by the same considerations as for the general population (see *Chapter 3*).

Muscular Strength and Endurance

Individuals with LBP frequently have deficits in trunk muscle strength and endurance (73–75) and neuromuscular imbalance (76,77); however, the role these play in the development and progression of LBP remains unclear (74,78). Decreases in muscular strength and endurance may be independent of the period and intensity of LBP (79,80). General testing of muscular strength and endurance in individuals with LBP should be guided by the same considerations as for the general population (see *Chapter 3*). In addition, tests of the strength and endurance of the trunk musculature (*e.g.*, isokinetic dynamometers with back attachments, resistance machines with weight stack, and back hyperextension benches) are commonly assessed in individuals with LBP (55). However, the reliability of these tests is questionable because of the considerable learning effect in particular between the first and second sessions (81,82). Performance of muscular strength and endurance assessments are often limited by actual or anticipated fear of reinjury in individuals with LBP (83).

Flexibility

There is no clear relationship between gross spinal flexibility and LBP or associated disability (56). A range of studies have shown associations between measures of spine flexibility, hip flexibility, and LBP (84), yet the nature of these associations is likely complex and requires further study. There appears to be some justification, although based on relatively weak evidence, for flexibility testing in the lower limbs, and in particular the hips of individuals with LBP (42,85). In general, flexibility testing in individuals with LBP should be guided by the same considerations as for the general population (see *Chapter 5*). It is essential, however, to identify whether the assessment is limited by stretch tolerance of the target structures or exacerbation of LBP symptoms.

Exercise Prescription

Current guidelines for the management of LBP consistently recommend staying physically active and avoiding bed rest (38,42,55,59,86). Although it may be best to avoid exercise in the first few days immediately following an acute and severe episode of LBP so as not to exacerbate symptoms (57,59), individuals with subacute and chronic LBP, as well as recurrent LBP, are encouraged to be physically active (57). Within 2 wk of an acute LBP episode, activities can be carefully introduced. Regular walking is a good way to encourage individuals with LBP to participate in activity that does not worsen symptoms (55). Both progressive aerobic training and progressive resistance training have been shown to be equally effective at decreasing pain intensity in individuals with chronic LBP (87).

When recommendations are provided, they should follow very closely with the recommendations for the general population, combining resistance, aerobic, and flexibility exercise (see *Chapter 5*). In chronic LBP, exercise programs that incorporate individual tailoring, supervision, stretching, and strengthening, coupled with client preference and practitioner expertise, are associated with the best outcomes (57,59,88). Furthermore, the evidence supporting the multidimensional nature of nonspecific chronic LBP shows most favorable outcomes with an individualized approach that addresses psychological distress, fear avoidance beliefs, self-efficacy in controlling pain, and coping strategies (78). Whereas Ex R_x can play an integral role in helping a client manage LBP, the diagnosis and treatment of LBP falls outside the scope of practice of most exercise professionals and needs to be referred to a licensed health care provider (89).

Special Considerations

- Exercises that address coordination, endurance, and strengthening of the trunk can be used to reduce LBP and disability in individuals with subacute and chronic LBP with movement coordination impairments (44). However, there is insufficient evidence for any benefit of emphasizing single-dimension therapies such as abdominal strengthening (78,85,90).
- Individual response to back pain symptoms can be improved by providing assurance, encouraging activity, and providing early referral to physical therapy (46,47,85).
- There is a lack of agreement on the definition, components, and assessment techniques related to core stability. Furthermore, the majority of tests used to assess core stability have not demonstrated validity (91,92).

- Certain exercises or positions may aggravate symptoms of LBP. Walking, especially downhill, may aggravate symptoms in older adults with LBP (93). However, walking on an inclined treadmill or cycling with the lumbar spine flexed may be helpful for individuals that find more upright positions bothersome.
- Certain individuals with LBP may experience a "peripheralization" of symptoms, that is, a spread of pain into the lower limbs with certain sustained or repeated movements of the lumbar spine (94). Limits should be placed on any activity or exercise that causes spread of symptoms (58).
- Repeated movements and exercises such as prone press-ups or knees to chest in supine that promote centralization (*i.e.*, a reduction of pain in the lower limb from distal to proximal) are encouraged to reduce symptoms in patients with acute LBP with related lower extremity pain (42).
- Flexibility exercises are generally encouraged as part of an overall exercise program. Hip and lower limb flexibility should be promoted (56,84). However, in individuals with LBP and movement coordination impairments, strengthening and/or motor control exercises should be emphasized, not flexibility (42).
- Consider progressive, low intensity aerobic exercise for individuals with chronic LBP with generalized pain (pain in more than one body area) and moderate-to-high intensity aerobic exercise for individuals with chronic LBP without generalized pain (42).
- Exercises such as yoga and Pilates have shown to be effective interventions for LBP, however, the research is not clear on whether any single intervention is superior to another; therefore, the choice of exercise should fundamentally be driven by client preference and practitioner expertise (95,96).

ONLINE RESOURCES

American Physical Therapy Association. *Low Back Pain* [Internet]. Alexandria (VA): American Physical Therapy Association; 2011 [cited 2019 Apr 22]. Available from: https://www.choosept.com/symptomsconditionsdetail/physical-therapy-guide-to-low-back-pain

Go4Life Resources [Internet]. Washington (DC): National Institute on Aging. Available from: https://www.nia.nih.gov/health/exercise-physical-activity

National Council on Aging. *Senior Fitness & Exercise Programs* [Internet]. Arlington, VA: National Council on Aging; 2015 [cited 2019 Apr 22]. Available from: https://www.ncoa.org/center-for-healthy-aging/basics-of-evidence-based-programs/physical-activity-programs-for-older-adults/

OLDER ADULTS

The term *older adult* represents a diverse spectrum of ages and physiologic capabilities, typically including individuals aged ≥65 yr and individuals aged 50–64 yr with clinically significant conditions or physical limitations that affect movement, physical fitness, or PA (97). Because physiologic, or normal, aging does not occur uniformly across the population, individuals of similar chronological age may differ dramatically in their response to exercise. In addition, it is difficult to distinguish the effects of aging on normal function from the effects of deconditioning or disease (*Table 6.2* provides a list of age-related changes in key physiologic variables). Therefore, health and functional status are often better indicators of the ability to engage in PA than chronological age.

TABLE 6.2 • Effects of Aging on Selected Physiologic and Health-Related Variables (97)

Variable	Change
Resting heart rate	Unchanged
Maximum heart rate	Lower
Maximum cardiac output	Lower
Resting and exercise blood pressure	Higher
Absolute and relative maximum oxygen uptake reserve ($\dot{V}O_2R_{max}$ $L \cdot min^{-1}$ and $mL \cdot kg^{-1} \cdot min^{-1}$)	Lower
Residual volume	Higher
Vital capacity	Lower
Reaction time	Slower
Muscular strength	Lower
Flexibility	Lower
Bone mass	Lower
Fat-free body mass	Lower
% Body fat	Higher
Glucose tolerance	Lower
Recovery time	Longer

Overwhelming evidence exists that supports the benefits of PA in (a) slowing typical age-related changes that impair exercise capacity, (b) optimizing age-related changes in body composition, (c) promoting psychological and cognitive well-being, (d) managing chronic diseases, (e) reducing the risks of physical disability, and (f) increasing longevity (1). Despite these benefits, older adults are the least physically active of all age groups. In fact, only about 12% of individuals aged ≥65 yr report engaging in aerobic and muscle strengthening activities that meet federal guidelines, and less than 5% of individuals aged 85 yr and older meet these same guidelines (98).

Exercise Testing

Most older adults do not require an exercise test prior to initiating a moderate intensity PA program (see *Chapter 2*). However, if exercise testing is recommended, it should be noted that the associated electrocardiogram (ECG) has higher sensitivity (*i.e.*, ~84%) and lower specificity (*i.e.*, ~70%) than in younger age groups (*i.e.*, <50% sensitivity and >80% specificity), producing a higher proportion of false positive outcomes. This situation may be related to the greater frequency of left ventricular hypertrophy (LVH) and the increased presence of conduction disturbances among older rather than younger adults (99).

Although there are no specific exercise test termination criteria for older adults beyond those presented for all adults in *Chapter 3*, the increased prevalence of cardiovascular, metabolic, and orthopedic problems among older adults increases the overall likelihood of an early test termination. Therefore, exercise testing in older adults may require subtle differences in both protocol and methodology, and should only be performed when indicated by a physician or other health care provider. Special considerations when testing older adults include the following

- Initial workload should be light (*i.e.*, <3 METs) and workload increments should be small (*i.e.*, 0.5–1.0 MET) for those with low work capacities. The modified Naughton treadmill protocol is a good example of such a protocol (see *Figure 4.1*) (97).
- A cycle ergometer may be preferable to a treadmill for those with poor balance, poor neuromotor coordination, impaired vision, impaired gait patterns, weight-bearing limitations, and/or orthopedic problems.

However, local muscle fatigue may be a factor for premature test termination when using a cycle ergometer (97).

- Adding a treadmill handrail support may be required because of reduced balance, decreased muscular strength, poor neuromotor coordination, and fear. However, handrail support for gait abnormalities will reduce the accuracy of estimating peak MET capacity based on the exercise duration or peak workload achieved (97).
- Treadmill workload may need to be adapted according to walking ability by increasing grade rather than speed (97).
- Many older adults exceed the age-predicted HR_{max} during a maximal exercise test. The frequently used (220 − age) HR_{max} equation tends to underpredict HR_{max} in older adults (100); therefore, it is best to use other HR_{max} equations (see *Table 5.3*).
- The influence of prescribed medications on the ECG and hemodynamic responses to exercise may differ from usual expectations (see *Appendix A*).

Currently, there is little evidence demonstrating increased mortality or cardiovascular event risk during exercise, or exercise testing, in this segment of the population, therefore eliminating the need for exercise testing unless medically indicated (*e.g.*, symptomatic CVD, uncontrolled diabetes). Otherwise, individuals free from CVD symptoms should be able to initiate a light intensity (<3 METs) exercise program without undue risk (101).

Physical Performance Testing

Physical performance testing has largely replaced exercise stress testing for the assessment of functional status of older adults (102). Some test batteries have been developed and validated as correlates of underlying fitness domains, whereas others have been developed and validated as predictors of subsequent disability, institutionalization, and death. Physical performance testing is appealing in that most performance tests require little space, equipment, and cost; can be administered by lay or health/fitness personnel with minimal training; and are considered extremely safe in healthy and clinical populations (53,103). The most widely used physical performance tests have identified cutpoints indicative of functional limitations associated with poorer health status that can be targeted for an exercise intervention. Some of the most commonly used physical performance tests are described in *Table 6.3*. Before performing these assessments, (a) carefully consider the specific population for which each test was developed, (b) be aware of known floor or ceiling effects (*i.e.*, the inability of the least robust participants to score lower and the most robust to score higher on the performance test), and (c) understand the context (*i.e.*, the sample, age, health status, and intervention) in which change scores or predictive capabilities are attributed.

TABLE 6.3 • Commonly Used Physical Performance Tests

Measure and Description	Administration Time	Cutpoint Indicative of Lower Function
Senior Fitness Test (103)		
Seven items: 30-s chair stand, 30-s arm curls, 8 ft up and go, 6-min walk, 2-min step test, sit and reach, and back scratch with normative scales for each test	30 min total Individual items range from 2 to 10 min each.	≤25th percentile of age-based norms
Short Physical Performance Battery (104)		
A test of lower extremity functioning that combines scores from usual gait speed and timed tests of balance and chair stands; scores range from 0 to 12 with higher score indicating better functioning.	10 min	10 points
Usual Gait Speed		
Usually assessed as the better of two trials of time to walk a short distance (3–10 m) at a usual pace	<2 min	$1\ m \cdot s^{-1}$
6-Min Walk Test		
Widely used as an indicator of cardiorespiratory endurance; assessed as the	<10 min	≤25th percentile of age-based norms

most distance an individual can walk in 6 min. A change of 50 m is considered a substantial change) (105).		
Continuous Scale Physical Performance Test (106)		
Two versions — long and short — are available. Each consists of serial performance of daily living tasks, such as carrying a weighted pot of water, donning and removing a jacket, getting down and up from the floor, climbing stairs, carrying groceries, and others, performed within an environmental context that represent underlying physical domains. Scores range from 0 to 100 with higher scores representing better functioning.	60 min	57 points

The *Senior Fitness Test* was developed using a large, healthy, community-dwelling sample and has published normative data for men and women aged 60–94 yr for items representing upper and lower body strength, upper and lower body flexibility, CRF, agility, and dynamic balance (103). Senior Fitness investigators have now published thresholds for each test item that define for adults ages 65–85 yr the level of capacity needed at their current age, within each domain of functional fitness, to remain independent to age 90 yr (107). The Short Physical Performance Battery (SPPB) (104), a test of lower extremity functioning, is best known for its predictive capabilities for disability, institutionalization, and death, but it also has known ceiling effects that limit its use as an outcome for exercise interventions in generally healthy older adults. A change of 0.5 point in the SPPB is considered a small meaningful change, whereas a change of 1.0 point is considered a substantial change (105). Usual gait speed, widely considered the simplest test of walking ability, has comparable predictive validity to the SPPB (108), but its sensitivity to change with exercise interventions has not been consistent. A change in usual gait speed of 0.05 $m \cdot s^{-1}$ is considered a small meaningful change, and a change of 0.10 $m \cdot s^{-1}$ is considered a substantial change (105). In fact, predicted 10-yr survival at age 75 yr varies between 19% and 87% and between 35% and 91% in women across a range of gait speeds, with significant increases in mortality risk per 0.10 $m \cdot s^{-1}$ increment in gait speed (109). The 400-m usual-pace walk test has also been proven reliable as an assessment of mobility status in older adults with functional limitations (110). More recently, there is an interest in measuring the rate of force development in older adults as a means of determining muscle power (111). See *Table 6.4* for additional criterion-referenced fitness standards for maintaining physical independence in older adults.

TABLE 6.4 • Criterion-Referenced Fitness Standards for Maintaining Physical Independence in Older Adults

	Age Groups							% of Decline Reflected over 30 yr
	60–64	65–69	70–74	75–79	80–84	85–89	90–94	
Lower body strength (number of chair stands in 30 s)								
Women	15	15	14	13	12	11	9	**40.0**
Men	17	16	15	14	13	11	9	**47.1**
Upper body strength (number of arm curls in 30 s)								
Women	17	17	16	15	14	13	11	**35.3**
Men	19	18	17	16	15	13	11	**42.1**
Aerobic endurance (yards walked in 6 min)								
Women	625	605	580	550	510	460	400	

								36.0
Men	680	650	620	580	530	470	400	41.2
Alternate aerobic endurance (number of steps in 2 min)								
Women	97	93	89	84	78	70	60	38.1
Men	106	101	95	88	80	71	60	43.4
Agility/dynamic balance (8-foot up-and-go, s)								
Women	5.0	5.3	5.6	6.0	6.5	7.1	8.0	37.5
Men	4.8	5.1	5.5	5.9	6.4	7.1	8.0	40.0
Mean decline = 40.1								

NOTE: The proposed fitness standards were developed for use with the Senior Fitness Test (SFT) battery.

Exercise Prescription

The general principles of Ex R_x apply to adults of all ages (see *Chapter 5*). The relative adaptations to exercise and the percentage of improvement in the components of physical fitness among older adults are comparable with those reported in younger adults and are important for maintaining health and functional ability and attenuating many of the physiologic changes that are associated with aging (see *Table 6.2*). Low aerobic capacity, muscle weakness, and deconditioning are more common in older adults than in any other age group and contribute to loss of independence (112,113). Therefore, an appropriate Ex R_x should be a multicomponent program that combines aerobic exercise, resistance training, balance, and flexibility exercises. The *2018 Physical Activity Guidelines Advisory Committee Scientific Report* highlighted strong evidence from numerous randomized controlled trials (RCTs) and cohort studies that aerobic, muscle-strengthening, balance, and/or multicomponent PA programs improved physical function and reduced risk of age-related loss of physical function in the general aging population, as well as in older people with specific chronic conditions (1). In fact, the evidence suggests that the benefits of multicomponent exercise to physical function in older age are greater, compared with single-component exercise. Moreover, multicomponent activities that can be incorporated into the daily routine may be a promising alternative to structured, single-task exercise programs for older adults.

For Ex R_x, an important distinction between older adults and their younger counterparts should be made relative to intensity. For apparently healthy adults, moderate and vigorous intensity PAs are defined relative to METs, with moderate intensity activities defined as 3–5.9 METs and vigorous intensity activities as ≥6 METs. In contrast for older adults, activities should be defined relative to an individual's physical fitness within the context of a perceived 10-point physical exertion scale, which ranges from 0 (an effort equivalent to sitting) to 10 (an all-out effort), with moderate intensity defined as 5 or 6 and vigorous intensity as ≥7. A moderate intensity PA should produce a noticeable increase in heart rate (HR) and breathing, whereas a vigorous intensity PA should produce a large increase in HR or breathing (114). More recently, the Lifestyle Interventions and Independence for Elders (LIFE) study (113) used the Borg scale of self-perceived exertion (115) to assess intensity of activity. The Borg scale ranges from 6 to 20, and LIFE participants were asked to walk at a self-perceived intensity of 13 (“somewhat hard”), whereas lower extremity muscle strengthening exercises were performed at an intensity of 15–16 (113).

FITT RECOMMENDATIONS FOR OLDER ADULTS (112,114,116)

	Aerobic	Resistance	Flexibility
Frequency	≥5 d · wk^{-1} for moderate intensity; ≥3 d · wk^{-1} for vigorous intensity; 3–5 d · wk^{-1} for a combination of moderate and vigorous intensity	≥2 d · wk^{-1}	≥2 d · wk^{-1}
Intensity	On a scale of 0–10 for level of physical exertion, 5–6 for moderate intensity and 7–8 for vigorous intensity	*Progressive weight training:* Light intensity (*i.e.*, 40%–50% 1-RM) for beginners; progress to moderate-to-vigorous intensity (60%–80% 1-RM); alternatively, moderate (5–6) to vigorous (7–8) intensity on a 0–10 scale *Power training*: light-to-moderate	Stretch to the point of feeling tightness or slight discomfort.

		loading (30%–60% of 1-RM)	
Time	30–60 min · d^{-1} of moderate intensity exercise; 20–30 min · d^{-1} of vigorous intensity exercise; or an equivalent combination of moderate and vigorous intensity exercise; may be accumulated over the course of the day	*Progressive weight training*: 8–10 exercises involving the major muscle groups; ≥1 set of 10–15 repetitions for beginners; progress to 1–3 sets of 8–12 repetitions for each exercise *Power training*: 6–10 repetitions with high velocity	Hold stretch for 30–60 s.
Type	Any modality that does not impose excessive orthopedic stress such as walking. Aquatic exercise and stationary cycle exercise may be advantageous for those with limited tolerance	Progressive or power weight-training programs or weight-bearing calisthenics, stair climbing, and other strengthening activities that use the major muscle groups	Any physical activities that maintain or increase flexibility using slow movements that terminate in static stretches for each muscle group rather than rapid ballistic movements

	for weight-bearing activity.	
1-RM, one repetition maximum.		

Neuromotor (Balance) Exercises and Power Weight Training for Frequent Fallers or Individuals with Mobility Limitations

One in four individuals ≥65 yr falls in the United States every year (117). Furthermore, falls are the leading cause of fatal injury and the most common cause of nonfatal trauma–related hospital admissions among older adults (117). Neuromotor exercise training, which combines balance, agility, and proprioceptive training, is effective in reducing and preventing falls, if performed 2–3 d · wk^{-1} (112,116). The *2018 PAGAC Scientific Report* (1) cited strong and consistent evidence demonstrating that multicomponent PA that includes two or more components of strength, balance, endurance, or flexibility significantly reduced the risk of fall-related injuries by about 32%–40%, including severe falls that result in bone fracture, head trauma, open wound soft tissue injury, or any other injury requiring medical care or admission to hospital (118–121), with similar benefits observed between older adults who were at high risk of falling versus those who were at an unspecified risk (118). Also, fall prevention programs using multicomponent activity reduced the risk of fall-related bone fractures by 40%–66% among older adults in community and home settings (118–121).

General recommendations for balance training include using the following: (a) progressively difficult postures that gradually reduce the base of support (*e.g.*, two-legged stand, semitandem stand, tandem stand, one-legged stand), (b) dynamic movements that perturb the center of gravity (*e.g.*, tandem walk, circle turns), (c) stressing postural muscle groups (*e.g.*, heel, toe stands), (d) reducing sensory input (*e.g.*, standing with eyes closed), and (e) tai chi (112). Exercise done in supervised groups, such as tai chi, or individually prescribed home programs, have all been shown to be effective at reducing fall risk (1,119); however, there may be times when supervision of these activities is warranted (112).

"Functional exercises" are slightly different and designed to improve lower body strength, balance, and motor performance, as well as for increasing daily levels of PA (122,123). Examples of such include postures or walking with gradual reduction in the base of support (*e.g.*, upgrading tandem stand to one-leg stand over time) and dynamic movements that perturb the center of gravity (stepping over obstacles). Balance training interventions examined the effects of four different types of balance training interventions (multidimensional [activities such as functional exercises, tai chi, and ball games], control center of mass [COM], mobility, and reaching) on several different dimensions of balance performance (124). Overall, balance training interventions report significant benefits from programs that included any of these four types of balance training versus interventions that did not involve any balance training (124). Multitask activities with high levels of physical (speed, coordination, balance), mental, and social demands (*e.g.*, dancing, team sports, handball) appeared particularly effective in improving functional performance and balance (125), whereas Nordic walking is significantly effective in improving dynamic balance, functional balance, muscle strength of lower limbs, and aerobic capacity in healthy older people (126). Active computer gaming (ACG) also has a significantly beneficial effect on balance and on functional exercise capacity when the volume of the ACG was >120 min $\cdot$ wk^{-1} (127).

Older adults also may benefit from power weight training because this element of muscle fitness declines most rapidly with aging, and insufficient power has been associated with a greater risk of functional decline and falls (128–130). Increasing muscle power in healthy older adults should include both single- and multiple-joint exercises (1–3 sets) using light-to-moderate loading (30%–60% of one repetition maximum [1-RM]) for 6–10 repetitions with high velocity (131).

Special Considerations for Exercise Programming

There are numerous considerations that should be considered to maximize the effective development of an exercise program, including the following:

- Intensity and duration of PA should be light at the beginning, in particular for older adults who are highly deconditioned, functionally limited, or have chronic conditions that affect their ability to perform physical tasks.
- Progression of PA should be individualized and tailored to tolerance and preference; a conservative approach may be necessary for the older adults who are highly deconditioned or physically limited.
- Muscular strength decreases rapidly with age, especially for those aged >50 yr. Although resistance training is important across the lifespan, it becomes more important with increasing age (114,116,131).
- For strength training involving use of selectorized machines or free weights, initial training sessions should be supervised and monitored by personnel who are sensitive to the special needs of older adults.
- Individuals with sarcopenia, a marker of frailty, need to increase muscular strength before they are physiologically capable of engaging in aerobic training.
- If chronic conditions preclude activity at the recommended minimum amount, older adults should perform PA as tolerated to avoid being sedentary.
- Older adults should gradually exceed the recommended minimum amounts of PA and attempt continued progression if they desire to improve and/or maintain their physical fitness.
- Older adults should consider exceeding the recommended minimum amounts of PA to improve management of chronic diseases and health conditions for which a higher level of PA is known to confer a therapeutic benefit.
- Moderate intensity aerobic PA (especially those that combine a cognitive and physical task, such as counting backward while walking) (1) should be encouraged for individuals with cognitive decline given the known

benefits of PA on cognition. Individuals with significant cognitive impairment can engage in PA but may require individualized assistance.

- Structured PA sessions should end with an appropriate cool-down, particularly among individuals with CVD. The cool-down should include a gradual reduction of effort and intensity and, optimally, flexibility exercises.
- Incorporation of behavioral strategies such as social support, self-efficacy, the ability to make healthy choices, and perceived safety all may enhance participation in a regular exercise program (see *Chapter 12*).
- The exercise professional should also provide regular feedback, positive reinforcement, and other behavioral/programmatic strategies to enhance adherence.

ONLINE RESOURCES

Alliance for Aging Research: https://www.agingresearch.org/

Canadian Society for Exercise Physiology. *Canadian Physical Activity Guidelines for Older Adults (65 years and older)* [Internet]. Ottawa, Ontario (Canada): Canadian Society for Exercise Physiology; 2019 [cited 2019 Apr 24]. Available from: https://csepguidelines.ca/adults-65/#resourceshttps

National Council on Aging; Healthy Living: https://www.ncoa.org/healthy-aging/

U.S. Department of Health and Human Services; Healthy Aging: https://www.hhs.gov/aging/healthy-aging/index.html

PREGNANCY

In consultation with their health care provider, healthy pregnant women without contraindications (*Box 6.3*) are encouraged to be physically active throughout pregnancy (132,133,135,136). The health benefits of PA are well recognized and can include prevention of excessive gestational weight gain and gestational diabetes mellitus, decreased risk of preeclampsia and urinary incontinence, improvement of mood, reduced incidence of LBP and caesarean section, reduced length of labor, and maintenance or improvement of CRF (125,132,137–140). In contrast, short- and long-term risks associated with sedentary behavior are of concern (141). It is reasonable to consider that the physical and psychological benefits of PA and negative consequences of sedentary behavior in nonpregnant women generally apply to pregnant women.

Box 6.3 Contraindications for Exercising during Pregnancy (131–134)

Absolute Contraindications

- Hemodynamically significant heart disease
- Incompetent cervix, cervical insufficiency, or cerclage
- Intrauterine growth restriction[a]
- Multiple gestation at risk for premature labor[b]
- Persistent second or third trimester bleeding
- Placenta previa after 26–28 wk of gestation
- Preeclampsia or pregnancy-induced hypertension[c]
- Premature labor during the current pregnancy
- Restrictive lung disease
- Ruptured membranes
- Severe anemia
- Uncontrolled or poorly controlled hypertension[d]
- Uncontrolled thyroid disease[e]
- Uncontrolled Type 1 diabetes
- Unexplained persistent vaginal bleeding, such as in second or third trimester
- Other serious cardiovascular, respiratory, or systemic disorder

Relative Contraindications

- Anemia or symptomatic anemia
- Cervical dilation
- Chronic bronchitis, mild/moderate respiratory disease, or other respiratory disorders
- Eating disorder
- Extreme morbid obesity
- Heavy smoker
- History of extremely sedentary lifestyle
- History of spontaneous preterm birth, premature labor, miscarriage, or fetal growth restriction
- Malnutrition or extreme underweight
- Mild/moderate cardiovascular disease
- Orthopedic limitations
- Poorly controlled seizure disorder
- Poorly controlled Type 1 diabetes
- Recurrent pregnancy loss
- Unevaluated maternal cardiac arrhythmia
- Other significant medical conditions

[a]The American College of Obstetricians and Gynecologists (ACOG) guideline specifies intrauterine growth restriction in current pregnancy as a relative contraindication (132).

[b]The Canadian guideline specifies triplets and higher as an absolute contraindication and a twin pregnancy after the 28th wk as a relative contraindication (135).

[c]The Canadian guideline specifies gestational hypertension as a relative contraindication (135).

[d]The ACOG guideline specifies poorly controlled hypertension as a relative contraindication (132).

[e]The ACOG guideline specifies poorly controlled hyperthyroidism as a relative contraindication (132).

In their respective guidelines, the American College of Obstetricians and Gynecologists (132), the 2018 U.S. Department of Health and Human Services (1), the 2019 Canadian guideline for PA throughout pregnancy (135), and the International Olympic Committee (133,137,138) outlined the importance of exercise during pregnancy and provide evidence-based guidance on Ex R_x for the minimization of risk and promotion of health benefits. With appropriate modifications and progression, pregnancy is an opportunity for sedentary women to adopt PA behavior (135).

Exercise Testing

Maximal exercise testing should not be performed on women during any stage of pregnancy (142,143). If a submaximal exercise test is warranted, the test should be performed with physician supervision after the woman has been medically evaluated for contraindications to exercise (see *Box 6.3*).

The acute physiologic responses normally observed with exercise are magnified during pregnancy compared to nonpregnancy (*Table 6.5*) (145). Because of the physiologic changes that accompany pregnancy, assumptions of submaximal protocols in predicting maximal aerobic capacity may be compromised and are therefore most appropriately used in determining the effectiveness of training rather than accurately estimating maximal aerobic power (137,143,146).

TABLE 6.5 • Physiologic Responses to Acute Exercise during Pregnancy Compared to Nonpregnancy (144)	
Oxygen uptake (during weight-dependent exercise)	Increase
Heart rate	Increase
Stroke volume	Increase
Cardiac output	Increase
Tidal volume	Increase
Minute ventilation	Increase
Ventilatory equivalent for oxygen ($\dot{V}E/\dot{V}O_2$)	Increase
Ventilatory equivalent for carbon dioxide ($\dot{V}E/\dot{V}CO_2$)	Increase
Systolic blood pressure	No change/decrease
Diastolic blood pressure	No change/decrease

Exercise Prescription

In the absence of obstetric or medical complications, the American College of Obstetricians and Gynecologists recommend 20–30 min · d^{-1} of moderate intensity aerobic exercise on most or all days of the week during pregnancy (*Table 6.6*) (132). Exercise recommendations for pregnant women should be modified according to the woman's prior exercise history as well as symptoms, discomforts, and abilities across the pregnancy time course, with consideration of absolute and relative contraindications (see *Box 6.3*). Women should consult with their health care provider (who monitors the progress of the pregnancy) about whether or how to adjust their exercise during and after pregnancy (1). There may be periods when following exercise recommendations is not possible; women should do what they can and return to following the recommendations when they are able under the health care providers care (135). Further guidance specifically for athletes can be found in the evidence summary from the International Olympic Committee (133).

TABLE 6.6 • Physical Activity Recommendations during Pregnancy from Three Guideline Documents

	Canada 2019 (135)	ACOG 2015 (132)	United States 2018 (1)
Duration	≥150 min · wk^{-1}	≥20–30 min · d^{-1}	≥150 min · wk^{-1}
Frequency	Minimum of 3 d · wk^{-1}; being active every day is encouraged.	Most or all days of the week	Spread throughout the week
Intensity	Moderate intensity defined as physical activity intense enough to noticeably increase heart rate; a person can talk but not sing during activities of this intensity. Target heart rate zones for pregnant	Moderate intensity, RPE 13–14 on a scale of 6–20, “talk test” — can talk while exercising	Light to moderate intensity, RPE 5–6 on a scale of 0–10, “talk test” — can talk while exercising; additionally, women who engaged in vigorous intensity aerobic activity can continue these activities if they remain healthy and discuss with their health care provider.

	women based on age, “talk test.”		
Type	Aerobic and resistance training activities including brisk walking, stationary cycling (moderate effort), swimming or aquafit, carrying moderate loads, household chores (*e.g.*, gardening, washing windows)	Aerobic and strength-conditioning exercises including walking, swimming, stationary cycling, low-impact aerobics, modified yoga or Pilates, running, racquet sports	Aerobic and muscle strengthening

ACOG, American College of Obstetricians and Gynecologists; RPE, rating of perceived exertion. From (115).

Health Screening

The Canadian Society for Exercise Physiologists Physical Activity Readiness Medical Examination for Pregnancy (*PARmed-X for Pregnancy*) or the electronic Physical Activity Readiness Medical Examination (*ePARmed-X+*) can be used for the health screening of pregnant women before their participation in exercise programs (*Figure 6.1*). All pregnant women should be educated on the warning signs for when to stop exercise (*Box 6.4*).

Box 6.4 Warning Signs to Stop Exercise during Pregnancy (130,131,133,134)

- Amniotic fluid leakage or other vaginal fluid loss including rupture of the membranes
- Calf pain or swelling
- Chest pain
- Dizziness, syncope, or faintness that does not resolve on rest
- Headache
- Muscle weakness or muscle weakness affecting balance
- Regular painful uterine contractions
- Shortness of breath prior to exertion or that is persistent and excessive that does not resolve on rest
- Vaginal bleeding

PARmed-X FOR PREGNANCY

Physical Activity Readiness Medical Examination

PARmed-X for PREGNANCY is a guideline for health screening prior to participation in a prenatal fitness class or other exercise.

Healthy women with uncomplicated pregnancies can integrate physical activity into their daily living and can participate without significant risks either to themselves or to their unborn child. Postulated benefits of such programs include improved aerobic and muscular fitness, promotion of appropriate weight gain, and facilitation of labour. Regular exercise may also help to prevent gestational glucose intolerance and pregnancy-induced hypertension.

The safety of prenatal exercise programs depends on an adequate level of maternal-fetal physiological reserve. PARmed-X for PREGNANCY is a convenient checklist and prescription for use by health care providers to evaluate pregnant patients who want to enter a prenatal fitness program and for ongoing medical surveillance of exercising pregnant patients.

Instructions for use of the 4-page PARmed-X for PREGNANCY are the following:

1 The patient should fill out the section on PATIENT INFORMATION and the PRE-EXERCISE HEALTH CHECKLIST (PART 1, 2, 3, and 4 on p. 1) and give the form to the health care provider monitoring her pregnancy.

2 The health care provider should check the information provided by the patient for accuracy and fill out SECTION C on CONTRAINDICATIONS (p. 2) based on current medical information.

3 If no exercise contraindications exist, the HEALTH EVALUATION FORM (p. 3) should be completed, signed by the health care provider, and given by the patient to her prenatal fitness professional.

In addition to prudent medical care, participation in appropriate types, intensities and amounts of exercise is recommended to increase the likelihood of a beneficial pregnancy outcome. PARmed-X for PREGNANCY provides recommendations for individualized exercise prescription (p. 3) and program safety (p. 4).

*Note: **Sections A and B** should be completed by the patient before the appointment with the health care provider.*

A PATIENT INFORMATION

NAME ______________________ ADDRESS ______________________

PHONE ______________ BIRTHDATE MM / DD / YEAR HEALTH INSURANCE No. ______________

NAME OF PRENATAL FITNESS PROFESSIONAL ______________ PHONE NUMBER OF PRENATAL FITNESS PROFESSIONAL ______________

B PRE-EXERCISE HEALTH CHECKLIST

PART 1: GENERAL HEALTH STATUS

In the past, have you experienced:	Y	N
1 Miscarriage in an earlier pregnacy?	☐	☐
2 Other pregnancy complications?	☐	☐
3 I have completed a PAR-Q within the last 30 days.	☐	☐

If you answered YES to question 1 or 2, please explain:

____

Number of previous pregnancies: ______________

PART 2: STATUS OF CURRENT PREGNANCY

Due Date: MM / DD / YEAR

During this prenancy, have you experienced:	Y	N
1 Marked fatigue?	☐	☐
2 Bleeding from the vagina ("spotting")?	☐	☐
3 Unexplained faintness or dizziness?	☐	☐
4 Unexplained abdominal pain?	☐	☐
5 Sudden swelling of ankles, hands or face?	☐	☐
6 Persistent headaches or problems with headaches?	☐	☐
7 Swelling, pain or redness in the calf of one leg?	☐	☐
8 Absence of fetal movement after 6th month?	☐	☐
9 Failure to gain weight after 5th month?	☐	☐

If you answered YES to any of the above questions, please explain:

____

PART 3: ACTIVITY HABITS DURING THE PAST MONTH

1 List only regular fitness/recreational activities:

____

INTENSITY	FREQUENCY (times/week)			TIME (minutes/day)		
	1-2	2-4	4+	<20	20-40	40+
Heavy	___	___	___	___	___	___
Medium	___	___	___	___	___	___
Light	___	___	___	___	___	___

2 Does your regular occupation (job/home) activity involve:	Y	N
Heavy lifting?	☐	☐
Frequent walking/stair climbing?	☐	☐
Occasional walking (> once/hr)?	☐	☐
Prolonged standing?	☐	☐
Mainly sitting?	☐	☐
Normal daily activity?	☐	☐
3 Do you currently smoke tobacco?*	☐	☐
4 Do you consume alcohol?*	☐	☐

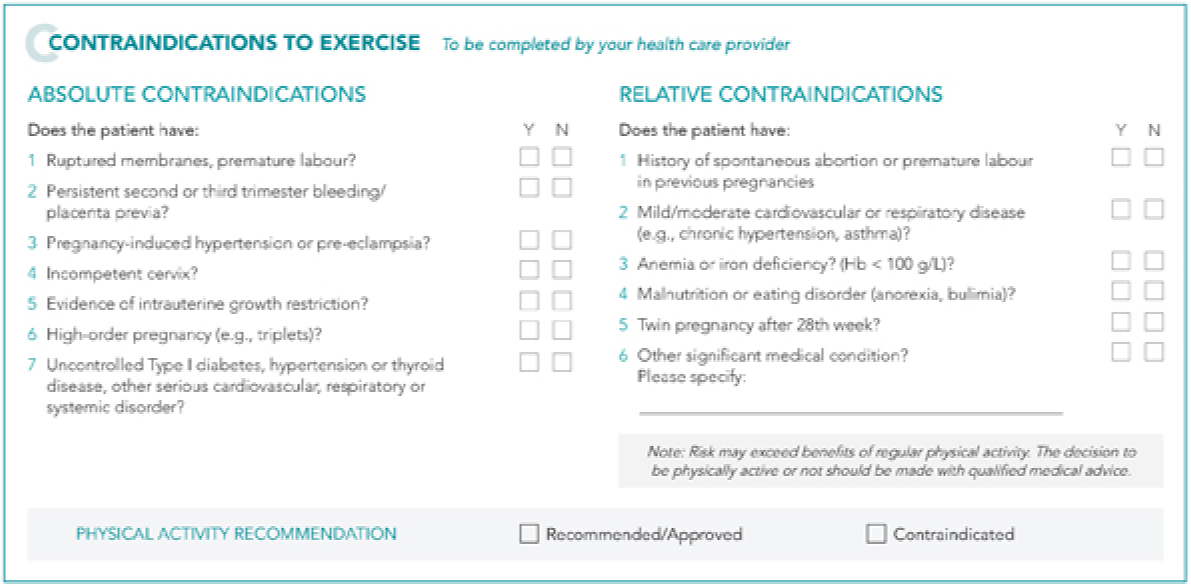
PART 4: PHYSICAL ACTIVITY INTENTIONS

What physical activity do you intend to do?

____

Is this a change from what you currently do? ☐ YES ☐ NO

**Note: Pregnant women are strongly advised not to smoke or consume alcohol during pregnancy and during lactation.*


CONTRAINDICATIONS TO EXERCISE *To be completed by your health care provider*

ABSOLUTE CONTRAINDICATIONS

Does the patient have:	Y	N
1 Ruptured membranes, premature labour?	☐	☐
2 Persistent second or third trimester bleeding/ placenta previa?	☐	☐
3 Pregnancy-induced hypertension or pre-eclampsia?	☐	☐
4 Incompetent cervix?	☐	☐
5 Evidence of intrauterine growth restriction?	☐	☐
6 High-order pregnancy (e.g., triplets)?	☐	☐
7 Uncontrolled Type I diabetes, hypertension or thyroid disease, other serious cardiovascular, respiratory or systemic disorder?	☐	☐

RELATIVE CONTRAINDICATIONS

Does the patient have:	Y	N
1 History of spontaneous abortion or premature labour in previous pregnancies	☐	☐
2 Mild/moderate cardiovascular or respiratory disease (e.g., chronic hypertension, asthma)?	☐	☐
3 Anemia or iron deficiency? (Hb < 100 g/L)?	☐	☐
4 Malnutrition or eating disorder (anorexia, bulimia)?	☐	☐
5 Twin pregnancy after 28th week?	☐	☐
6 Other significant medical condition? Please specify:	☐	☐

Note: Risk may exceed benefits of regular physical activity. The decision to be physically active or not should be made with qualified medical advice.

PHYSICAL ACTIVITY RECOMMENDATION ☐ Recommended/Approved ☐ Contraindicated

FIGURE 6.1 The Canadian Society for Exercise Physiologists Physical Activity Readiness Medical Examination for Pregnancy (*PARmed-X for Pregnancy*). Reprinted with permission from the Canadian Society for Exercise Physiologists. See https://www.csep.ca/en/publications/parmed-x-for-pregnancy for most current update of the form.

Exercise Frequency, Duration, and Intensity

These points assume the absence of obstetric or medical complications during pregnancy.

- Exercise frequency should be regular, occurring throughout the week, and adjusted based on total exercise volume (*i.e.*, number of days may vary based on intensity and duration of exercise). For previously inactive women, lower intensity and/or duration is recommended rather than reduced or irregular frequency.
- Exercise duration for each session should be spread throughout the week, such as in 20–30-min sessions, although bouts of any duration are beneficial (1,132).
- A talk test can be used to monitor exercise intensity. For the talk test, a woman should be able to maintain a conversation during exercise, and reduce the intensity if she cannot talk without being out of breath (135).
- Higher intensity or prolonged exercise may require caloric intake beforehand (132).

- A light intensity warm-up and cool-down is suggested before and after exercise, respectively, in order to lower the chance for injury (135,147).
- Previously inactive women without contraindications are encouraged to start exercise in pregnancy but may need to begin at a lower intensity and duration (135). Exercise goals and progression may vary at different time points during pregnancy, and exercise routines should remain flexible.

Exercise Types to Consider

- Examples of safe exercises including walking, swimming, stationary cycling, low-impact aerobics, and running (132).
- Resistance training can also be performed during pregnancy, but research about safety and risks is limited (133,148–150). Women who habitually participate in resistance training should discuss if and how to adjust their routine with their health care provider.
- Pelvic floor muscle training, such as Kegel exercises, may be performed on a daily basis to decrease the risk of urinary incontinence during and after pregnancy (135,151).
- Substitution of certain activities may be necessary given physiologic changes the woman experiences over the time course of pregnancy (see *Table 6.6*) (137).

Exercise Types to Avoid

- Women who are pregnant should avoid contact and collision sports/activities that may cause loss of balance or trauma to the mother or fetus (1,132,135). Examples of sports/activities to avoid include basketball, downhill snow skiing, gymnastics, horseback riding, ice hockey, off-road bicycling, soccer, Olympic lifts, and water skiing.
- Women should avoid activities that present an increased risk of falling (132,152).
- Activities that require jumping and quick changes in direction are not recommended due to the laxity of joints and ligaments during pregnancy (132).

- Scuba diving during pregnancy should be avoided due to decompression sickness and the inability of the fetal pulmonary circulation to filter bubble formation (132,135).
- Hot Pilates and hot yoga should be avoided due to the risk of rising core temperatures (132).
- PA on the back (*e.g.*, supine) should be avoided after the first trimester (1,133). Exertion or prolonged periods in the supine position may reduce venous return and subsequent cardiac output, restricting blood flow to the uterus and fetus.
- In any PA avoid using the Valsalva maneuver, prolonged isometric contraction, and motionless standing, which may result in decreased venous return and hypotension (132,135).
- During pregnancy, some women experience diastasis recti, indicated by a visible separation of their abdominal muscles (135). These women should seek physical therapy advice and avoid abdominal strengthening exercises because they may worsen the condition.

Special Considerations

- *Heat* — Women who are pregnant should avoid exercising in a hot humid environment, be well hydrated, and dress appropriately to avoid heat stress (132,133). On hot humid days, it may be best to exercise indoors.
- *Hydration* — Drink water before, during, and after PA (135). Further information on fluid replacement is detailed in the *ACSM Exercise and Fluid Replacement* position stand (35).
- *LBP* — For women experiencing LBP during pregnancy, an excellent alternative to land-based exercise may be water exercise (132).
- *Metabolic demand and weight* — During pregnancy, the metabolic demand increases, so women may need to modestly increase caloric intake to meet the additional caloric costs of pregnancy and exercise. PA may help regulate weight gain during pregnancy (1). In order to avoid

excessive weight gain during pregnancy, women should consult with their health care provider regarding appropriate weight gain (153,154).

- *High altitude* — For lowlanders, PA up to an altitude of 6,000 ft (~1,829 m) is safe (132). PA at higher elevations should be discussed with an obstetrician with knowledge of the impact of high altitude on maternal and fetal outcomes (135). Others recommend refraining from high intensity training at altitudes higher than ~5,000 ft (>1,500–2,000 m) during pregnancy for those not acclimated (133).

Exercise during Postpartum

Women should work with their health care provider to determine when PA can be resumed following delivery. Resumption may differ based on the type and intensity of the PA. When starting back, PA should be resumed gradually, as soon as medically safe, because of normal deconditioning in the initial postpartum period (132). Women with higher CRF levels and more rigorous exercise routines prior to and during pregnancy may be able to resume exercise sooner. The health benefits of exercise during postpartum can include improved postpartum recovery, prevention of postpartum weight retention, improvement of mood, and decreased risk of postpartum depressive symptoms (1,132,137,138).

Exercise in the postpartum period is important for return to prepregnancy BMI and does not interfere with breastfeeding, as long as the woman takes in appropriate food and fluid (155,156). For babies that do not breastfeed well immediately after maternal exercise, mothers could feed them or express milk immediately before exercise, which may also make exercise more comfortable for the woman (132,156).

ONLINE RESOURCES

American College of Obstetricians and Gynecologists: guideline (132) and resources: http://www.acog.org

Exercise During Pregnancy and the Postpartum Period: regularly updated literature review (149): https://www.uptodate.com/contents/exercise-during-pregnancy-and-the-postpartum-period

2018 Physical Activity Guidelines for Americans, 2nd edition (1): https://health.gov/paguidelines/second-edition/

2018 Scientific Report supporting the Physical Activity Guidelines for Americans: https://health.gov/paguidelines/second-edition/report/

2019 Canadian Guideline for Physical Activity throughout Pregnancy: guideline (135) and resources: https://csepguidelines.ca/guidelines-for-pregnancy/

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CHAPTER 7

Environmental Considerations for Exercise Prescription

INTRODUCTION

This chapter addresses unique factors associated with environmental effects on exercise, with specific emphasis on altitude, heat, and cold. Aside from describing general considerations for exercising in environmental extremes, this chapter also provides details on common medical environmental illnesses and injuries, prevention strategies, and organizational planning factors that are intended to assist those who train or provide coverage to athletes under these conditions. The sports medicine professional must be familiar with environmental effects on athletes in order to provide effective and safe counseling for exercising in a variety of environments.

EXERCISE IN HIGH-ALTITUDE ENVIRONMENTS

By definition, altitude is broken into the following elevation bands: *low altitude* (0–1,500 m; 0–4,921 ft), *high altitude* (1,500–3,500 m; 4,921–11,483 ft), *very high altitude* (3,500–5,500 m; 11,483–18,045 ft), and *extreme altitude* (5,500–8,850 m; 18,045–29,035 ft) (1). As altitude increases, there is a corresponding reduction in atmospheric pressure, which directly reduces the partial pressure of oxygen inhaled. This drop in partial pressure of oxygen leads to a decrease in arterial oxygen levels and induces physiological compensation. These changes induce several normal physiologic responses as the body attempts to adjust to higher elevations (1). The immediate compensatory responses include increased ventilation and cardiac output, the latter usually through elevated heart rate (HR) (2). These responses then produce a respiratory alkalosis, which leads to renal compensation, and occurs through the elimination of bicarbonate in the urine. Practically, as the athlete exhales greater and greater levels of carbon dioxide (CO_2), the kidneys remove bicarbonate to maintain pH of the blood, which can lead to increased risk of dehydration as a function of increased respiration. Therefore, exercising at altitude requires an increased fluid intake beyond the normal athletic requirements (1).

Physical performance decreases with increasing altitude. In general, the physical performance decrement will be greater as elevation, physical activity duration, and muscle mass increases, but this decrement can be ameliorated with proper altitude acclimatization (1). As a rule of thumb, individuals can expect a decrease in exercise performance of 1.5%–3.5% per 300 m of elevation after 1,500 m (3,4). The most common altitude effect on physical task performance is an increased time for task completion because of reduced pace or the need for more frequent rest breaks. With altitude exposure of ≥1 wk, significant acclimatization occurs (*i.e.*, increased ventilation and arterial oxygen content and restored acid-base balance), and the time to complete a task is reduced, but still longer relative to sea level (3). The estimated increases in performance time to complete tasks of various durations during altitude exposure are given in *Table 7.1* (5).

TABLE 7.1 • Estimated Impact of Increasing Altitude on Time to Complete Physical Tasks at Various Altitudes (5)

Percentage Increase in Time to Complete Physical Tasks Relative to Sea Level

	Tasks Lasting <2 min		Tasks Lasting 2–5 min		Tasks Lasting 10–30 min		Tasks Lasting >3 h	
Altitude	**Initial**	**>1 wk**	**Initial**	**>1 wk**	**Initial**	**>1 wk**	**Initial**	**>1 wk**
High	**0**	**0**	2–7	0–2	4–11	1–3	7–18	3–10
Very high	0–2	**0**	12–18	5–9	20–45	9–20	40–65	20–45
Extreme	**2**	**0**	**50**	**25**	**90**	**60**	**200**	**90**

Altitude Acclimatization

Proper acclimatization is typically more effective, when time allows, than premedication for the prevention of acute altitude illnesses. A detailed description of acute altitude illnesses may be found in the “Medical Considerations: Altitude Illnesses and Preexisting Conditions” section below. With proper acclimatization, individuals can achieve optimal physical and cognitive performance for the altitude at which they will be performing. Altitude acclimatization consists of physiologic adaptations that develop in a time-dependent manner during continuous exposures to high altitudes (1). Breathing low concentrations of oxygen or restricting ventilation using masks, hoods, and other equipment (*i.e.*, normobaric hypoxia) is not as effective as being exposed to the natural-altitude environment (*i.e.*, hypobaric hypoxia) for inducing functionally useful altitude acclimatization (6).

A graded ascent to altitude of 600 $m \cdot d^{-1}$ and a rest day every 600–1,200 m is the most widely advocated method for reduction in risk and prevention of high-altitude illnesses (7). Above 3,000 m, ascent should be limited by a sleeping altitude increase of 500 m per night, with a rest day of every 3–4 d (8). Since this is not always feasible because of terrain, transportation, or accommodations, modifications can be made by averaging the ascent rate for the entire trip (days ascending/total altitude gain) and maintaining it at no more than the 500 $m \cdot d^{-1}$ threshold (8). Additional rest days should be included after nights where the altitude gain exceeded 500 m (8).

For individuals ascending from low altitude, at least partial altitude acclimatization can develop by living at a high-altitude elevation temporarily while leading up to the event or ascending to a higher target elevation, which is termed *staging*. The goal of staged ascents is to gradually promote development of altitude acclimatization while averting the adverse consequences (*e.g.*, altitude sickness) of rapid ascent to high altitudes (6). The first stage of all staged ascent protocols should be ≥3 d of residence at high altitude. At this altitude, individuals will experience small decrements in physical performance and a low incidence of altitude sickness. At any given altitude, almost all of the acclimatization response is attained between 7 and 12 d of residence at that altitude. Short stays of 3–7 d at high altitudes will decrease susceptibility to altitude illness at higher altitudes. Stays of 6–12 d are required to improve physical work performance (6). The magnitude of the acclimatization response is increased with additional higher staging elevations or a longer duration at a given elevation. The final staging elevation should be as close as possible to the target elevation. It should be noted that this method is effective and designed for when there is ample time available before the event. A return to lower elevation during staging will negate or reduce the accumulated benefits of acclimatization (6).

The general staging guideline is as follows (6):

- For every day spent >1,200 m (3,937 ft), an individual is prepared for a subsequent rapid ascent to a higher altitude equal to the number of days at that altitude times 305 m (1,000 ft).
- For example, an athlete stages at 1,829 m (6,000 ft) for 6 d. Therefore, 305 m (1,000 ft) per staged day multiplied by 6 d equals 6,000 ft additional ascent with reduced risk. In this case, the physical performance and altitude sickness risk will be reduced up to altitudes of 3,657 m (12,000 ft) compared to the athlete who does not stage.
- This guideline applies to altitudes up to 4,267 m (14,000 ft).

Rapid Ascent

Many individuals travel directly to high mountainous areas from sea level for skiing or trekking vacations and are unacclimatized when beginning their activities. During this time, physical activity should not be excessive, and endurance exercise training should be stopped, or its intensity greatly reduced to minimize the possibility that acute mountain sickness (AMS) will develop or be exacerbated if already present (7). Beginning within hours of a rapid ascent to a given altitude, AMS may begin to present, and physical and cognitive performances will be at their nadir for these unacclimatized individuals (8). As acclimatization occurs, individuals may gradually resume normal activities and exercise training once the altitude symptoms begin to subside over the subsequent hours to days (7). Classically, acute altitude illnesses are associated with travel above 2,500 m, but cases of AMS have been observed as low as 2,000 m (8).

Assessing Individual Altitude Acclimatization Status

Assessing the acclimation process can allow the fitness professional to provide an exercise prescription (Ex R_x) with informed decisions on activity quantity and intensity in order to reduce risk of altitude illnesses. The best indices of altitude acclimatization over time at a given elevation are improved physical performance, decreased HR (both resting and exercise), an increase in arterial oxygen saturation (SaO_2), and if present, a decrease in AMS symptoms (8). The uncomplicated resolution of AMS or its absence in the first 3–4 d following ascent indicates a normal acclimatization response. After 1–2 wk of acclimatization, physical performance improves such that most tasks can be performed for longer periods of time and with less perceived effort relative to the initial exposure to the same elevation (8). Another early sign of appropriate adaptation to altitude is increased respiratory rate and subsequently increased urine volume, which generally occurs during the first several days at a given elevation. Urine volume will continue to increase with additional ascent and return to normal with subsequent adaptation after acclimatization is complete (1).

The response to acclimatization and possibility of an acute altitude illness can be roughly predicted by measuring an individual's maximal heart rate (HR_{max}) at their normal altitude. To minimize the risk of AMS, the goal should be to maintain an HR below 85% of the individual's HR_{max}. Doing so reduces the incidence of AMS in unacclimatized/acclimatizing individuals to only 20%. This is in contrast to an incidence of over 60% for those who exceed 85% of max threshold (9). HR_{max} estimation formulas have been found to be less accurate at altitude than at sea level when predicting athletes' capacities (10). Therefore, it is recommended that direct/real-time HR monitoring or pulse oximetry be used during any training while in the acclimatization process, and that this should be limited to 85% of previous measured HR_{max}.

Indirect measurement of SaO_2 by noninvasive pulse oximetry (SpO_2) is a very good indicator of acclimatization. Pulse oximetry should be performed under nonstimulating, resting conditions (11). From its nadir on the first day at a given altitude, SpO_2 should progressively increase over the next 3–7 d before stabilizing. For example, with initial exposure to an altitude of 4,300 m (14,107 ft), resting SpO_2 is 81%; after a week of continuous residence at the same elevations, resting SpO_2 progressively rises to ~88% (11). Pulse oximetry often reveals pronounced hypoxia and should be utilized as soon as there are any concerns for acute altitude illness. While continuous pulse oximetry is typically not necessary, frequent checks of asymptomatic personnel may be helpful for situational awareness (12).

Medical Considerations: Altitude Illnesses and Preexisting Conditions

Rapid ascent to high and very high altitude increases individual susceptibility to altitude illness. The primary altitude illnesses are AMS, high-altitude cerebral edema (HACE), and high-altitude pulmonary edema (HAPE). Additionally, many individuals may develop a sore throat and bronchitis from drier air that may produce disabling, severe coughing spasms at high altitudes. Susceptibility to altitude illnesses is increased in individuals who rapidly ascend without acclimatization, by immediate prolonged physical exertion, dehydration early in the altitude exposure, and with a prior history of acute altitude illnesses (12).

AMS is the most common form of altitude sickness. Symptoms include headache, nausea, vomiting, decreased appetite, fatigue or weakness, dizziness or light-headedness, and poor sleep. The Lake Louise Scoring system is used to determine severity of AMS (12), and the assessment should be performed by personnel trained in this scoring system (*e.g.*, Wilderness First Responder). AMS typically develops within the first 24 h of altitude exposure, and its incidence and severity increase in direct proportion to ascent rate and altitude (13). The estimated incidence of AMS in unacclimatized individuals rapidly ascending directly to high altitudes is ≤15%; to very high altitudes, 15%–70%; and to extreme altitudes, 70%–85% (13). In most individuals, if ascent is stopped and physical exertion is limited, AMS symptoms peak at about 18–22 h, and recovery occurs over the next 24–48 h (13).

HACE is a potentially fatal, although uncommon illness that occurs in <2% of individuals ascending >3,658 m (12,000 ft) (12). HACE may begin with or without AMS; symptoms may start with headache or nausea and progresses to ataxia, altered consciousness (confusion, drowsiness, impaired decisions), and then coma. HACE most often occurs in individuals who have AMS, yet continue to ascend without treatment; deterioration to coma may occur in as little as 12 h (12). HACE alone, without concomitant HAPE, is more common at very high altitudes such as cases in Tibet. Whereas cases at high altitude often have both HACE and HAPE present (1).

HAPE is a potentially fatal illness that occurs in <0.6% of individuals ascending >3,658 m (12,000 ft) (12). Initial symptoms include shortness of breath with exertion, progressing to shortness of breath at rest, and cough which may be productive of blood-tinged sputum. Individuals making repeated ascents and descents >3,658 m (12,000 ft), and who exercise strenuously early in the exposure, have an increased susceptibility to HAPE. Half of those with HAPE have preceding AMS that was untreated. Of those diagnosed with HAPE, 16% have concurrent HACE at presentation, whereas upon autopsy, 50% of those with HAPE also demonstrate HACE. The presence of crackles (*i.e.*, rales) in the lungs, severe dyspnea, and elevated respiratory and HRs may indicate impending HAPE. Most HAPE presentations begin during the night or early morning, between the first and third days of ascent (12).

Altitude can affect preexisting conditions in a variety of ways such as predisposing individuals to acute altitude illnesses, interfering with training regimens, or by exacerbating (or in some cases alleviating) symptoms from preexisting conditions. Examples of this variability include coronary artery disease, where the altitude outcome depends on how well the disease is controlled; sickle cell disease, where the individual should avoid altitude training altogether; and asthma, where the symptoms may actually improve with altitude (12). Individuals with conditions present prior to ascent should discuss their planned ascent with their health care team in order to prepare for altitude and make any necessary accommodations or restrictions (12).

Prevention and Treatment of Altitude Sickness

Altitude acclimatization is the best countermeasure to all altitude sickness. Minimizing initial sustained physical activity while maintaining adequate hydration and food intake will reduce susceptibility to altitude sickness during the acclimatization process, the duration of which will vary considerably based on individual health and behaviors. Medications may play a role in reducing altitude sickness, even when acclimatization is possible, and should be prescribed by a licensed health care provider if used. The most common medication used is acetazolamide (*i.e.*, Diamox) and is used as prophylaxis at a dosage of 125 mg twice a day to speed the elimination of urine bicarbonate, which hastens acclimatization (8). In situations requiring a rapid ascent above 3,500 m with expectation of immediate moderate-to-strenuous physical activity, acetazolamide should be augmented with 4 mg of dexamethasone every 12 h orally as prescribed by a licensed health care provider (8).

When moderate-to-severe symptoms and signs of an altitude-related sickness develop, the most effective treatment is to descend to a lower altitude. Descents of 300–1,000 m (985–3,280 ft) with an overnight stay can be effective in prevention and recovery of all altitude illnesses, but vary by individual, and further descent may be necessary (8). If no medical provider is readily available for evaluation, the symptomatic individual should seek out medical evaluation as soon as possible.

AMS may be treated with therapeutic use of acetazolamide 250 mg twice a day, which should be prescribed by a licensed health care provider. Headaches are most effectively treated with ibuprofen, which has additional evidence supporting overall AMS symptom reduction (8). Oxygen therapy or a portable hyperbaric chamber (*i.e.*, Gamow Bag) therapy can relieve AMS symptoms and the associated poor sleep. Dexamethasone (*i.e.*, Decadron, Hexadrol) is taken orally and may be used for prevention; it can also be delivered as an intravenous (IV) or intramuscular (IM) for acute treatment (14). Dexamethasone may be used in combination with or in place of other treatments such as acetazolamide. Note that dexamethasone should not be used in pediatric individuals because of the systemic suppression effects on children (14). An important distinction is that while medications are considered first-line treatment for AMS (in conjunction with descent), the most critical treatment for individuals diagnosed with HACE or HAPE is urgent, rapid, controlled descent, oxygen therapy, and/or hyperbaric bag therapy (8).

Exercise Prescription

During the first few days at high altitudes, individuals should minimize their exercise and physical activity to reduce susceptibility to altitude illness. After this period, if their Ex R_x specifies a target heart rate (THR), the individual may utilize the same THR used at sea level. The personalized number of weekly training sessions and the duration of each session at altitude can remain similar to those used at sea level for a given individual. This approach reduces the risk of altitude illness and excessive physiologic strain. For example, at high altitudes, reduced speed, distance, or resistance will achieve the same THR as at lower altitudes. As altitude acclimatization develops, the THR will be achieved at progressively higher exercise intensity (7). Monitoring exercise HR provides a safe, easy, and objective means to quantify exercise intensity at altitude, as it does at sea level. Therefore, using any HR-based Ex R_x model at altitude will provide a similar training stimulus to sea level as long as the quantity and duration of training sessions are maintained. Be mindful that for the same perceived effort, the individuals jogging or running pace will be reduced at altitude compared to sea level, independent of altitude acclimatization status.

Special Considerations

Active individuals who are acclimatized to altitude, adequately rested, nourished, and hydrated, minimize the risk for developing altitude sickness and maximize their physical performance capabilities for the altitude to which they are acclimatized. The following factors should be considered to further minimize the negative effects of high altitude:

- Prepare for the environment: High-altitude regions are often associated with more daily extremes of temperature, humidity, wind, and solar radiation. Follow appropriate guidelines for hot (15) and cold environments (16).
- Monitor the weather: A drop in barometric pressure with worsening weather can more directly exacerbate altitude changes with increased elevation. Sudden swings in weather can also radically change the environmental protection needed in accordance with the mentioned guidelines. Remember mountains may generate or change their own weather (8).
- Modify activity at high altitudes: Activity levels should be based on altitude acclimatization status, physical fitness, nutrition, sleep quality and quantity, age, exercise time and intensity, and availability of fluids. Longer or more frequent rest breaks and shortened activity times should be incorporated to facilitate rest and recovery. Longer duration activities are affected more by high altitude than shorter duration activities (7,8).

- Hydration: Reasonably increase hydration beyond the normal expected amount for exertion. This is to offset fluid loss from the acclimatization process and the water loss through respiration due to the lower humidity with increased elevation. Overhydration with hypotonic fluids (*e.g.*, water), while rare, can pose a risk for life-threatening hyponatremia (15).
- Clothing: Individual clothing and equipment need to provide protection over a greater range of temperature, wind conditions, and solar radiation.
- Education: The training of personal trainers, coaches, and community emergency response teams enhances the reduction, recognition, and treatment of altitude-related illnesses.

Organizational Planning

When individuals exercise in high-altitude locations, physical fitness facilities and organizations should formulate a standardized management plan that includes the following procedures:

- Screening and surveillance of at-risk individuals.
- Using altitude acclimatization procedures to minimize the risk of altitude sickness and enhance physical performance.
- Consideration of the hazards of mountainous terrain when designing exercise programs and activities.
- Planning proper ascent profiles or staging methods to allow acclimatization
- Awareness of the signs and symptoms of altitude illness.
- Development of organizational procedures for emergency medical care of altitude illnesses.
- Team physicians should consider maintaining a supply of oxygen and pharmaceuticals for preventing and treating altitude sickness.

EXERCISE IN COLD ENVIRONMENTS

Individuals exercise and work in many cold weather environments, and although unpleasant at times, cold temperatures are not necessarily a barrier to performing physical activity (17). Many factors, including the environment, clothing, body composition, health status, nutrition, age, and exercise intensity, interact to determine if exercising in the cold elicits additional physiologic strain and injury risk beyond that associated with the same exercise done under temperate conditions (16). In most cases, the body is able to balance heat production with environmental heat loss and exercise in the cold does not increase cold injury risk (16). However, there are scenarios (*i.e.*, immersion, rain, prolonged exposure, and low-ambient temperature with wind) where whole body or local thermal balance cannot be maintained during exercise-related cold stress, which in turn contributes to hypothermia, frostbite, and diminished exercise capability and performance (16). Furthermore, exercise-related cold stress may increase the risk of morbidity and mortality in at-risk populations such as those with cardiovascular disease or asthmatic conditions, and inhalation of cold air may also exacerbate these conditions (18). It is prudent for the exercise professional to understand the different predisposing factors that may lead to a cold-related injury (*Table 7.2*).

TABLE 7.2 • Predisposing Factors for Cold Injury

Decreased Heat Production	Increased Heat Loss	Impaired Thermoregulation	Conditions Aggravated by Cold Exposure	Others
Low energy Low caloric intake Inactivity Endocrine Hypopituitarism Hypoadrenalism Hypoglycemia Diabetes Age Children Age >60 yr	Immersion Rain Wind Fatigue Low body fat Age (young and old) Skin changes Sunburn Dermatitis Psoriasis Open wound	Neuropathies Multiple sclerosis Parkinson disease Stroke Illicit drug abuse Alcohol abuse Vascular Raynaud syndrome Diabetes Peripheral artery disease Inadequate clothing Constrictive clothing/boots	Asthma Exercise-induced bronchoconstriction Coronary artery disease Raynaud disease Chronic obstructive pulmonary disease	Infection Renal failure Previous cold injury

Adapted from (16,19).

Medical Considerations: Cold Injuries

Hypothermia develops when heat loss exceeds heat production, causing the body heat content to decrease (20), entailing a core body temperature below 35° C (<95° F) (18). The environment, individual characteristics, and clothing all impact the development of hypothermia, with some specific hypothermia risk factors being immersion, rain, wet clothing, low body fat, older age (*i.e.*, ≥60 yr), and hypoglycemia (16). Exercise in wet and windy environments markedly increases heat losses and can increase risk of hypothermia (18).

Frostbite occurs when tissue temperature falls lower than 0° C (32° F) (21,22). Frostbite is most common in exposed skin (*i.e.*, nose, ears, cheeks, and exposed wrists) but also occurs in the hands and feet (16). Contact frostbite may occur by touching cold objects with bare skin, particularly highly conductive metal or stone that causes rapid heat loss (16). Risk factors for frostbite include inadequate clothing, advanced age, and prior cold injury (23).

The principal cold stress determinants for frostbite are air temperature, wind speed, and wetness. Wind exacerbates heat loss by facilitating convective heat loss and reducing the insulative value of clothing (16). The Wind Chill Temperature Index (WCT) (*Figure 7.1*) integrates wind speed and air temperature to provide an estimate of the cooling power of the environment. WCT is specific in that its correct application only estimates the danger of cooling for the exposed skin of individuals walking at 1.3 $m \cdot s^{-1}$ (3 $mi \cdot h^{-1}$) (16). Important information about wind and the WCT incorporates the following considerations:

- Wind does not cause an exposed object to become cooler than the ambient temperature (16).
- Wind speeds obtained from weather reports do not take into account self-made wind (*e.g.*, running, skiing) (16). Athletes participating in sport are almost always moving and creating self-made wind, which must be accounted for in WCT.
- The WCT presents the relative risk of frostbite and predicted times to freezing (see *Figure 7.1*) of exposed facial skin. Facial skin was chosen because this area of the body is typically not protected (16).
- Frostbite cannot occur if the air temperature is >0° C (32° F) (16).
- Wet skin exposed to the wind cools faster. If the skin is wet and exposed to wind, the ambient temperature used for the WCT table should be 10° C lower than the actual ambient temperature (24).
- A reminder that ambient temperature is never adequate to determine frostbite risk except for stationary personnel (*e.g.*, spectators). For planning purposes, the risk of frostbite is <5% when the ambient temperature is greater than −15° C (5° F), but increased safety surveillance of exercisers is warranted when the WCT falls lower than −27° C (−8° F). In those conditions, frostbite can occur in 30 min or less in exposed skin (16).

Wind Speed (mph) ↓ \ Air Temperature (°F)	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite times:
- Frostbite could occur in 30 min
- Frostbite could occur in 10 min
- Frostbite could occur in 5 min

FIGURE 7.1 Wind Chill Temperature Index and frostbite times for exposed facial skin. From *NWS Windchill Chart* [Internet]. Silver Spring (MD): National Oceanic and Atmospheric Administration, National Weather Service; 2009 [cited 2015 Aug 18]. Available from: https://www.weather.gov/safety/winter; *Canada's Windchill Index: Windchill Hazards and What to Do* [Internet]. Gatineau, Quebec (Canada): Environment Canada; 2011 [cited 2015 Aug 18]. Available from: http://www.ec.gc.ca/meteo-weather/default.asp?lang=En&n=5FBF816A-1.

Nonfreezing cold injuries (NFCIs) typically occur when tissues are exposed to cold-wet temperatures between 0° and 15° C (32° and 60° F) for prolonged periods of time (25). These injuries may occur due to actual immersion or by the creation of a damp environment inside boots or gloves, as often seen during heavy sweating (16). Diagnosing NFCI involves observation of clinical symptoms over time as different, distinct stages emerge days to months after the initial injury (25). The most common NFCIs are trench foot and chilblains, although NFCIs have also been observed in the hands (26).

NFCIs initially appear as swollen and edematous with a feeling of numbness. The initial color is red but soon becomes pale and cyanotic if the injury is more severe (16). Trench foot is accompanied by aches, increased pain, and infections, making peripheral pulses hard to detect (16). The exposure time needed to develop trench foot is quite variable, with estimates ranging from 12 h to 3–4 d in cold-wet environments (25–27). Most commonly, trench foot develops when wet socks and shoes are worn continuously over many days (23). The likelihood of trench foot in most sporting activities is low, except in winter hiking, camping, and expeditions (16).

Prevention of NFCIs can be achieved by encouraging individuals to remain active and increase blood flow to the feet and keeping feet dry by continually changing socks (26). Changing socks two to three times throughout the day is highly recommended in cold-wet environments during long-term exposure (16). Prophylactic treatment with antiperspirants containing aluminum hydroxide may also decrease sweating in the foot (16). Vapor barrier boots (some hiking boots, ski boots) and liners do not allow sweat from the foot to evaporate, so sock changing becomes more important (16). Also, boots and liners should be taken off each day, wiped out, and allowed to dry. If regular boots are worn, these boots need time to dry to avoid getting moisture in the insulation (16).

Cardiac and Respiratory Considerations

Exercise in cold environments appears to increase risk of exercise-induced bronchoconstriction (EIB) in both asthmatic and non-asthmatic individuals (28). These effects can reduce athletic performance (28). Additionally, the incidence of acute upper respiratory tract viral infections is directly correlated with cold weather (29). Acute upper respiratory tract viral infections can also exacerbate underlying EIB, leading to compounded reduction in athletic performance. Appropriate asthma preventive and rescue medications should be provided to cold-weather athletes (28). Most of the common asthma treatment medications are permitted in athletic competition, but providers should refer to World Anti-Doping Agency (WADA) Prohibited List prior to prescribing medications to athletes' subject to antidoping regulations (30).

Two strategies that may limit the effects of cold air inhalation in athletes with known EIB include face masks and specific warm-up routines. Masks that provide heat and moisture exchange have been shown in small studies to significantly reduce the effects of cold weather EIB (31). The reduction in EIB symptoms appears to persist when a mask is utilized only in warm-up and rest periods, but without using the mask during actual sport activity (32). Additionally, athletes with known EIB may benefit from a specific warm-up routine in order to trigger a refractory period that reduces hyperresponsiveness. While evidence for several variations exist, broadly speaking, a warm-up strategy should include some exercise near peak oxygen consumption or HR_{max} (*i.e.*, sprints) approximately 20–30 min before the event or competition (see "Exercise Prescription" below) (33). The duration of this protective effect from an induced refractory period should be considered short-term, potentially lasting between 2 and 4 h (34).

Typically, as detailed above, land-based athletes can safely exercise in the cold with proper attire and equipment; however, exercising in cold water deserves special mention due to two conditions unique to this environment. Swimming-induced pulmonary edema (SIPE) is a rare cause of acute breathlessness in swimmers. SIPE occurs during swimming in the absence of aspiration when fluid accumulates in the lungs causing acute dyspnea and hemoptysis (35). Affecting roughly 0.01%–0.5% of competitors in open water-based events, SIPE may occur in tropical waters but there appears to be a higher incidence in cold water, presumably due to increased central venous pooling and subsequent increase in cardiac preload (35). Of note, recurrences are unpredictable yet fairly common, with recurrence rates between 13% and 22% (36). Swimming in cold water also increases the risk for cardiac arrhythmias, which are seen in about 2% of cold water immersions. Cold water immersion activates two powerful reflexes in the human body. The diving response when the face is immersed in cold water stimulates the parasympathetic system causing bradycardia, and the cold shock response when the skin is immersed in cold water stimulates the sympathetic system causing tachycardia (37). Under most normal conditions, these two reflexes coexist without difficulty; however, with breath holding and the addition of other predisposing factors (*e.g.*, ischemic heart disease, channelopathies), this "autonomic conflict" may pose a risk for more serious arrhythmias (37).

While widespread screening for these conditions may not be warranted, it would be prudent to counsel those who have experienced SIPE of the high rate of recurrence. Likewise, it is critical for those providing medical coverage to open water events to be aware of the elevated risk of SIPE and arrhythmias with cold water immersion.

Clothing Considerations

Cold weather clothing protects against hypothermia and frostbite by reducing heat loss through the insulation provided by the clothing and trapped air within and between clothing layers (16). Typical cold weather clothing consists of three layers: (a) an inner layer (*i.e.*, lightweight polyester or polypropylene), (b) a middle layer (*i.e.*, polyester fleece or wool) that provides the primary insulation, and (c) an outer layer designed to allow moisture transfer to the air while repelling wind and rain. Recommendations for clothing wear include the following considerations (16,38):

- Adjust clothing insulation to minimize sweating.
- Use clothing vents to reduce sweat accumulation.
- Do not wear an outer layer unless rainy or very windy.
- Reduce clothing insulation as exercise intensity increases.
- Do not impose a single clothing standard on an entire group of exercisers.
- Wear appropriate footwear to minimize the risks of slipping and falling in snowy or icy conditions.
- Emollients applied to exposed skin do not protect against cold injuries and may increase risk.
- Chemical or electric hand/foot warmers may be considered (these should not constrict blood flow).

Exercise Prescription

For athletes at higher risk for injury with exercise in cold, the following should be considered:

- Individuals with known coronary artery disease should use caution when exercising in cold environments. Angina symptoms may be masked by cold water immersion. Additionally, cold exposure increases incidence of cardiovascular events and angina likely due to increase in arterial pressure, total peripheral resistance, and cardiac work/myocardial oxygen demand (17).
- Endocrine conditions should be well controlled prior to cold weather athletics (26). Hypoglycemia and other endocrine abnormalities can impair the shivering response (18).
- Athletes should avoid vasoconstrictive medications, smoking, drugs, alcohol, and central nervous system depressant medications. Vasoconstrictive medications and cigarette smoking can impair peripheral circulation increasing risk of cold injury (26).
- Individuals with asthma or EIB should have appropriate medical management prior to exercise and should have β-2 agonist medication readily available during exercise (19).

Preexercise warm-up can protect against bronchoconstriction. Intermittent high intensity preexercise warm-up consisting of 10–15 min of exercise approximately 20–30 min prior to event can provide protection against bronchoconstriction for between 2 and 4 h (33).

EXERCISE IN HOT ENVIRONMENTS

The body's mechanisms for thermoregulation occur through a balance of heat production and heat loss. Significant shifts in this fragile balance can result in heat illness (39). Muscular contractions produce metabolic heat that is transferred from the active muscles to the blood stream, which in turn raises the body's core temperature (40). Subsequent body temperature elevations elicit heat loss responses of increased skin blood flow and increased sweat secretion so that heat can be dissipated to the environment via evaporation (41). As a result of elevated skin blood flow, the cardiovascular system plays an essential role in temperature regulation (41). Heat exchange between skin and environment via sweating and dry heat exchange is governed by biophysical properties dictated by surrounding temperature, humidity and air motion, sky and ground radiation, and clothing (42). However, when the amount of metabolic heat exceeds heat loss, hyperthermia (*i.e.*, elevated internal body temperature) may develop (40). Sweat that drips from the body or clothing provides no cooling benefit. In fact, if secreted sweat drips from the body and is not evaporated, a higher sweating rate will be needed to achieve the evaporative cooling requirements (41). Sweat losses vary widely among individuals and depend on the amount and intensity of exercise, clothing, protective equipment, and environmental conditions. Other factors such as hydration state, body composition, and level of aerobic fitness can alter sweat rates and ultimately fluid needs (42). For example, heat acclimatization results in higher and more sustained sweating rates, whereas aerobic exercise training has a modest effect on enhancing sweating rate responses (41). When properly controlled and compared, the differences in thermoregulation (*e.g.*, sweating) between men and women are minimal (43,44).

During exercise-induced heat stress, dehydration increases physiologic strain as measured by core temperature, HR, and perceived exertion responses (45). The greater the body water deficit, the greater the increase in physiologic strain for a given exercise task (46). Dehydration can exacerbate core temperature elevations during exercise in temperate (47) as well as in hot environments (48,49), with typical increases of 0.1° to 0.2° C (0.2° to 0.4° F) with each 1% of dehydration (50). The greater heat storage with dehydration is associated with a proportionate decrease in heat loss; thus, decreased sweating rate (*i.e.*, evaporative heat loss) and decreased cutaneous blood flow (*i.e.*, dry heat loss) are responsible for greater heat storage observed during exercise when hypohydrated (51).

Counteracting Dehydration

Mechanisms by which dehydration might impair strength or power are presently unclear.

A nonconventional analysis of the exercise performance literature revealed that the majority of studies support the concept that dehydration of ≥2% loss in body mass negatively impacts endurance exercise performance and thermoregulation, whereas strength and power are negatively affected to a smaller degree (43). This is true whether individuals commence exercise in a dehydrated state or accumulate fluid loss during the course of exercise (52).

The critical water deficit (*i.e.*, >2% body mass for most individuals) and magnitude of performance decrement are likely related to environmental temperature, exercise task, and the individual's unique biological characteristics (*e.g.*, tolerance to dehydration) (52). Acute dehydration impairs endurance performance regardless of whole-body hyperthermia or environmental temperature, and endurance capacity (*i.e.*, time to exhaustion) is reduced more in a hot environment than in a temperate or cold one (53).

Individuals have varying sweat rates, and as such, fluid needs for individuals performing similar tasks under identical conditions can be different. Determining sweat rate ($L \cdot h^{-1}$) by measuring body weight before and after exercise provides a fluid replacement guide. Active individuals should drink 0.5 L (1 pint) of fluid for each pound of body weight lost. Meals can help stimulate thirst resulting in restoration of fluid balance. Snack breaks during longer training sessions can help replenish fluids and be important in replacing sodium and other electrolytes (54). There is presently no scientific consensus for how to best assess hydration status in a field setting (49). However, in most field settings, the additive use of first morning body mass measurements in combination with some measure of first morning urine concentration and gross thirst perception provides a simple and inexpensive way to dichotomize euhydration from gross dehydration resulting from sweat loss and poor fluid intakes (*Figure 7.2*) (55,56). When assessing first morning urine, a paler color indicates adequate hydration; a darker yellow/brown color indicates a greater degree of dehydration (57). *Box 7.1* provides recommendations for hydration prior to, during, and following exercise or physical activity (15).

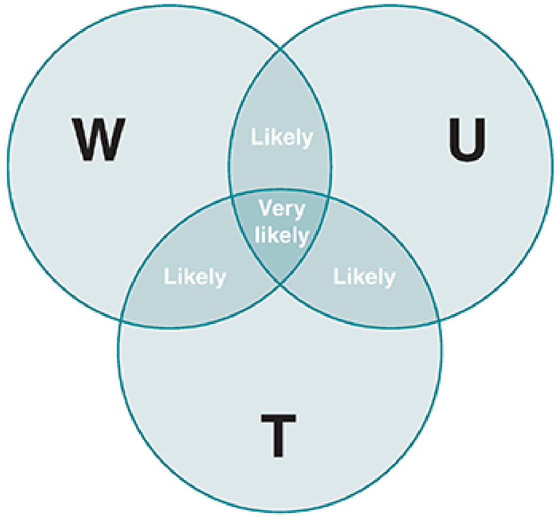

FIGURE 7.2 W stands for “weight.” U stands for “urine.” T stands for “thirst.” When two or more simple markers are present, dehydration is likely. If all three markers are present, dehydration is very likely. Reprinted with permission from (55).

Box 7.1 Fluid Replacement Recommendations before, during, and after Exercise

	Fluid	Comments
Before exercise	• Drink 5–7 mL · kg^{-1} (0.08–0.11 oz · lb^{-1}) at least 4 h before exercise (12–17 oz for 154-lb individual).	• If urine is not produced or very dark, drink another 3–5 mL · kg^{-1} (0.05–0.08 oz · lb^{-1}) 2 h before exercise. • Sodium-containing beverages or salted snacks will help retain fluid.
During exercise	• Monitor individual body weight changes during exercise to estimate sweat loss. • Composition of fluid should include 20–30 mEq · L^{-1} of sodium, 2–5 mEq · L^{-1} of potassium, and 5%–10% of carbohydrate.	• Prevent a >2% loss in body weight. • Amount and rate of fluid replacement depends on individual sweating rate, environment, and exercise duration.
After exercise	• Consumption of normal meals and beverages will restore euhydration. • If rapid recovery is needed, drink 1.5 L · kg^{-1} (23 oz · lb^{-1}) of body weight lost.	• Goal is to fully replace fluid and electrolyte deficits. • Consuming sodium will help recovery by stimulating thirst and fluid retention.

Adapted from (15,58).

Overdrinking hypotonic fluid (*e.g.*, water) can lead to exercise-associated hyponatremia, a state of lower-than-normal blood sodium concentration (typically <135 mEq · L^{-1}) accompanied by nausea, vomiting, headache, extremity edema, and severe symptoms such as pulmonary edema and altered cognitive status (59). Hyponatremia tends to be more common in long duration physical activities and is precipitated by consumption of hypotonic fluid in excess of sweat losses (typified by body mass gains) (60). When participating in exercise events that result in many hours of continuous or near-continuous sweating, hyponatremia can be prevented by practices such as having an individualized hydration plan, not drinking in excess of sweat rate, and consuming salt-containing fluids or foods (15). For additional information, see the American College of Sports Medicine (ACSM) position stand on fluid replacement (15).

Medical Considerations: Exertional Heat Illnesses

Heat illnesses lie on a continuum ranging from muscle cramps to life-threatening heat stroke, and are described in *Table 7.3*. Dehydration may be either a direct (*i.e.*, heat cramps and heat exhaustion) (61) or indirect (*i.e.*, heatstroke) (62) factor in heat illness.

TABLE 7.3 • A Comparison of the Signs and Symptoms of Illnesses that Occur in Hot Environments (58)

Disorder	Prominent Signs and Symptoms	Mental Status Changes	Core Temperature Elevation
Exertional heatstroke	Disorientation, dizziness, irrational behavior, apathy, headache, nausea, vomiting, hyperventilation, wet skin	Marked (disoriented, unresponsive)	Marked (>40° C [>104° F])
Exertional heat exhaustion	Low blood pressure, elevated heart rate and respiratory rates, skin is wet and pale, headache, weakness, dizziness, decreased muscle coordination, chills, nausea, vomiting, diarrhea	Little or none, agitated	None to moderate (37° to 40° C [98.6° to 104° F])
Heat syncope	Heart rate and breathing rates are slow; skin is pale; individual may experience sensations of weakness, tunnel vision, vertigo, or nausea before syncope.	Brief fainting episode	Little or none
Exertional heat cramps	Begins as feeble, localized, wandering spasms that may progress	None	Moderate (37° to 40° C [98.6° to 104° F])

	to debilitating cramps	

Exercise-associated muscle cramps (EAMCs) are painful involuntary muscle contractions or spasms most often in the abdomen, arms, or legs that may occur during or after strenuous activity (63). The term *heat cramps* is often used interchangeably but technically is an inappropriate term because EAMCs present during exercise in hot and cold environments unassociated with elevated core temperatures (49). Some controversy exists regarding the etiology of EAMCs; the cause is likely multifactorial and possibly unique to each athlete (63). Evidence suggests that EAMCs may be more related to muscle fatigue and neuronal excitability compared to hydration status or electrolyte concentrations (64). However, water loss and significant sweat sodium have been proposed as contributing factors and may play a role in cramping in individuals identified as "heavy sweaters" (*e.g.*, $>2\ L \cdot h^{-1}$) or those who lose appreciable amounts of body fluid and sodium. One treatment or prevention strategy is not likely to work for every individual (49). However, EAMCs have been shown to respond to rest, prolonged stretching, and dietary sodium chloride (*i.e.*, 1/8–1/4 tsp of table salt or one to two salt tablets added to 300–500 mL of fluid, bullion broth, or salty snacks). There is limited anecdotal evidence for IV fluid use. Oral hydration remains the best practice for the majority of athletes (65).

Heat syncope, or orthostatic dizziness, is a temporary circulatory failure caused by the pooling of blood in the peripheral veins, particularly of the lower extremities. Heat syncope tends to occur more often among physically unfit, sedentary, and nonacclimatized individuals. Heat syncope is caused by standing erect for a long period or at the cessation of strenuous, prolonged, upright exercise, because maximal cutaneous vessel dilation results in a decline of blood pressure (BP) and insufficient oxygen delivery to the brain. Symptoms range from light-headedness to loss of consciousness; however, recovery is rapid once individuals lay supine. Complete recovery of stable BP and HR may take a few hours (49). See the ACSM position stand on heat illness during exercise for additional information (58).

Heat exhaustion is the most common form of serious heat illness (66). Heat exhaustion is the incapacity to perform exercise in the heat, due to a combination of factors to include cardiovascular insufficiency, hypotension, energy depletion, and central fatigue (67). Heat exhaustion manifests with an elevated core body temperature (usually <40.5° C) when the body cannot sustain the level of volume needed to support skin blood flow for thermoregulation and blood flow for metabolic requirements of exercise (68). Heat exhaustion is characterized by prominent fatigue and progressive weakness without end-organ damage (*e.g.*, renal insufficiency, rhabdomyolysis, altered mental status, or liver injury) (49). Oral fluids are preferred for rehydration in individuals who are conscious, able to swallow, and not losing fluid (*i.e.*, vomiting and diarrhea). IV fluid administration facilitates recovery in those unable to ingest oral fluids or who have severe dehydration (65). With elite athlete care both in and out of competition, providers are reminded that the use of IV fluid administration outside of a hospital setting is strictly regulated by some governing bodies (*e.g.*, WADA, United States Anti-Doping Agency [USADA]) and may require a therapeutic use exemption (TUE) (69).

Exertional heatstroke is caused by hyperthermia and is characterized by elevated body temperature (>40° C or 104° F) (70), profound central nervous system dysfunction, and multiple organ system failure that can result in delirium, convulsions, or coma. The greatest risk for heatstroke exists during very high intensity exercise of short duration or prolonged exercise when the ambient wet-bulb globe temperature (WBGT) exceeds 28° C (82° F) (58). Heat stroke is a life-threatening medical emergency that requires immediate and effective whole-body cooling with cold water and ice water immersion therapy (49). Inadequate physical fitness, excess adiposity, improper clothing, protective pads, incomplete heat acclimatization, illness, and medications or dietary supplements that contain stimulants (*e.g.*, ephedra; synephrine) also increase the risk of heat stroke (70).

Exercise Prescription

Exercise professionals may use standards established by the National Institute for Occupational Safety and Health to define WBGT levels at which the risk of heat injury is increased. Exercise may be performed, however, if preventive steps are taken (71), including required rest breaks in shaded or air-conditioned areas between exercise periods.

If an Ex R_x specifies a THR, it will be achieved at a lower absolute workload when exercising in a warm/hot versus a cooler environment. For example, in hot or humid weather, an individual will achieve their THR with a reduced running speed. Reducing one's workload to maintain the same THR in the heat will help to reduce the risk of heat illness during acclimatization. As heat acclimatization develops, progressively higher exercise intensity will be required to elicit the THR. The first exercise session in the heat may last as little as 5–10 min for safety reasons, but can be increased gradually as tolerated (72).

Special Considerations

Adults and children who are adequately rested, nourished, hydrated, and acclimatized to heat are at less risk for exertional heat illnesses. However, when individuals exercise in fitness or recreational settings while in hot/humid conditions, staff (coaches, trainers, educators, etc.) should formulate a standardized heat stress management plan that incorporates the following considerations in order to minimize the effects of hyperthermia and dehydration, along with the questions in *Box 7.2* (49,55):

- Monitor the environment: Use the WBGT index to determine appropriate action and based on established criteria for modifying or canceling exercise/events.
- Allow at least 3 h, and preferably 6 h, of recovery and rehydration time between exercise sessions.

- Modify activity in extreme environments: Enable access to ample fluid and bathroom facilities, provide longer and/or more rest breaks to facilitate heat dissipation, and shorten or delay playing times. Perform exercise at times of the day when conditions will be cooler compared to midday (early morning, later evening). Children and older adults should modify activities in conditions of high-ambient temperatures accompanied by high humidity.
- Optimize but do not maximize fluid intake that (a) matches the volume of fluid consumed to the volume of sweat lost and (b) limits body weight change to <2% of body weight.
- Screen and monitor at-risk individuals and establish specific emergency procedures.
- Consider heat acclimatization status, physical fitness, nutrition, sleep deprivation, previous illness (especially vomiting and/or diarrhea), age of individuals; intensity, time/duration, and time of day for exercise; availability of fluids; and playing surface heat reflection (*i.e.*, grass vs. asphalt).
- Heat acclimatization adaptations include a 10%–20% increase in plasma volume, which allows the body to store more heat with minimal impact to its core temperature. Acclimatization results in the earlier onset of sweating, reduced sodium loss in sweat, decreased skin blood flow, and increase synthesis of heat shock proteins to prevent cellular damage. Additional adaptations include decreased rectal temperature, HR, and rating of perceived exertion (RPE); increased exercise tolerance time; and an increased sweating rate.
- Acclimatization results in the following: (a) improved heat transfer from the body's core to the external environment, (b) improved cardiovascular function, (c) more effective sweating, and (d) improved exercise performance and heat tolerance. Seasonal acclimatization will occur gradually during late spring and early summer months with sedentary exposure to the heat. However, this process can be facilitated with a structured program of moderate exercise in the heat across 10–14 d to stimulate adaptations to warmer ambient temperatures.
- Clothing: Clothes that have a high wicking capacity may assist in evaporative heat loss. Athletes should remove as much clothing and equipment (especially headgear) as possible to permit heat loss and reduce the risks of hyperthermia, especially during the initial days of acclimatization.
- Diet/nutrition: The body loses 0.58 kcal of heat per milliliter of water that evaporates. If an athlete evaporates 1 L (1,000 mL), he or she has lost 580 kcal of heat.
- Education: The training of individuals, fitness specialists, coaches, and community emergency response teams enhances the reduction, recognition, and treatment of heat-related illness. Such programs should emphasize the importance of recognizing signs/symptoms of heat intolerance, being hydrated, fed, rested, and acclimatized to heat. Educating individuals about dehydration, assessing hydration state, and using a fluid replacement program can help maintain hydration.

Box 7.2 **Questions to Evaluate Readiness to Exercise in a Hot Environment (72)**

Adults should ask the following questions to evaluate readiness to exercise in a hot environment. Corrective action should be taken if any question is answered “no.”

- Have I developed a plan to avoid dehydration and hyperthermia?
- Have I acclimatized by gradually increasing exercise duration and intensity for 10–14 d?
- Do I limit intense exercise to the cooler hours of the day (early morning)?
- Do I avoid lengthy warm-up periods on hot, humid days?
- When training outdoors, do I know where fluids are available, or do I carry water bottles in a belt or a backpack?
- Do I know my sweat rate and the amount of fluid that I should drink to replace body weight loss?
- Was my body weight this morning within 1% of my average body weight?
- Is my 24-h urine volume plentiful?
- Is my urine color “pale yellow” or “straw colored”?
- When heat and humidity are high, do I reduce my expectations, my exercise pace, the distance, and/or duration of my workout or race?
- Do I wear loose-fitting, porous, lightweight clothing?
- Do I know the signs and symptoms of heat exhaustion, exertional heatstroke, heat syncope, and heat cramps (see *Table 7.3*)?
- Do I exercise with a partner and provide feedback about his or her physical appearance?
- Do I consume adequate salt in my diet?
- Do I avoid or reduce exercise in the heat if I experience sleep loss, infectious illness, fever, diarrhea, vomiting, carbohydrate depletion, some medications, alcohol, or drug abuse?

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CHAPTER 8

Exercise Prescription for Individuals with Cardiovascular and Pulmonary Diseases

INTRODUCTION

This chapter will present the guidelines as well as the supporting evidence for developing an exercise prescription (Ex R_x)/program for individuals with various cardiovascular and pulmonary disease. *Box 8.1* contains a listing of several of the common manifestations of cardiovascular and pulmonary diseases. As a reminder, *Chapter 5* presented the general principles of Ex R_x for aerobic, resistance, and flexibility training for apparently healthy individuals.

Box 8.1 Manifestations of Cardiovascular Disease and Pulmonary Disease

- Cardiovascular disease: diseases that involve the heart and/or blood vessels; includes but not limited to hypertension, coronary heart disease, heart failure, coronary valvular disease, cerebrovascular disease, etc.; it includes but not limited to atherosclerotic (ischemic) disease

- Peripheral arterial disease: diseases of arterial blood vessels outside the heart and brain
- Cerebrovascular disease: diseases of the blood vessels that supply the brain, resulting in stroke
- Coronary heart disease: disease of the arteries of the heart (usually atherosclerotic); also known as coronary artery disease
- Acute coronary syndrome: the acute manifestation of coronary heart disease with increasing symptoms of angina pectoris, myocardial infarction (heart attack), or sudden death
- Myocardial ischemia: temporary lack of adequate coronary blood flow relative to myocardial oxygen demands; often manifested as angina pectoris (chest pain)
- Myocardial infarction: injury/death of the muscular tissue of the heart (heart attack)

- Pulmonary disease: diseases that involve the lungs including but not limited to chronic obstructive pulmonary disease and asthma. Acute manifestations of pulmonary disease include shortness of breath or difficult or rapid or labored breathing, chest tightness, bouts of coughing (with mucus/phlegm), wheezing, and more frequent colds/flu/pneumonia.

CARDIOVASCULAR, PERIPHERAL ARTERIAL, AND PULMONARY DISEASES

Cardiac rehabilitation (CR) is commonly used to deliver exercise and other lifestyle interventions and consists of a coordinated, multifaceted intervention designed to reduce risk, foster healthy behaviors and adherence to these behaviors, reduce disability, and promote an active lifestyle for individuals with several forms of cardiovascular disease (CVD) (1). CR is typically delivered in outpatient (previously termed *phase II–III CR*) settings and reduces the rate of mortality and morbidity in individuals with various forms of disease by stabilizing, slowing, or even reversing the progression of the atherosclerotic process (2). Some inpatient (previously termed *phase I CR*) settings also exist (2). The benefits provided by CR are important to the individual and to society as subsequent health care costs may be reduced following participation (3), with cost-effectiveness greater in individuals with a higher risk for subsequent cardiac events (4). Currently, Medicare and most other commercial and private insurance companies provide outpatient CR as a benefit for those with a recent myocardial infarction (MI)/acute coronary syndrome (within the past 12 mo), coronary revascularization (coronary artery bypass graft [CABG] [surgery] or percutaneous coronary intervention [PCI] with or without stent placement), stable angina pectoris, heart valve repair or replacement (open surgery or transcutaneous procedure), heart failure with reduced ejection fraction (HFrEF), and heart transplant. Pulmonary rehabilitation (PR) is often provided for those with various chronic obstructive pulmonary diseases (COPDs) including emphysema and bronchitis. In addition, individuals with peripheral artery disease (PAD) have recently been covered for reimbursement for exercise therapy. The following sections provide general inpatient and outpatient CR and PR program information followed by specific exercise testing and Ex R_x information on various cardiovascular and pulmonary diseases and procedures. Stroke rehabilitation using exercise is becoming an important therapy for those with cerebrovascular disease and also is addressed in this chapter.

Inpatient Cardiac Rehabilitation Programs

Inpatient CR refers to an in-hospital, multidisciplinary, systematic approach to applying secondary therapies of known benefit through assessment, early mobilization, education regarding lifestyle behaviors in controlling CVD risk factors, evaluation of the individual’s level of readiness for physical activity (PA), and comprehensive discharge planning following hospitalization for an acute cardiac event, procedure, or other cardiovascular-related pathology (5).

Currently, a documented physician referral is required for individuals to begin participating in an inpatient CR program that focuses on preventive and rehabilitative services (5,6). The American Association of Cardiovascular and Pulmonary Rehabilitation (AACVPR) Guidelines for the Inpatient CR Program, which are frequently cited as a standard by the American College of Cardiology (ACC), the American Heart Association (AHA), and the American College of Sports Medicine (ACSM), states that CR should be conducted by a competent CR specialist and focus on:

- Clinical assessment via chart review and individual interview
- Physical ambulation and mobilization
- Identification and education regarding modifiable risk factors and self-care
- Discharge planning for transitional care and a home program for activities of daily living (ADL)/PA
- Referral to outpatient CR (7)

Clinical assessments should note diagnosis, current medical status, comorbidities, CVD risk factors, personalized goals, as well as readiness for PA and learning. An inpatient's CVD risk stratification should be performed as early as possible following an acute cardiac event or procedure in preparation for the initiation and progression of PA. A risk stratification tool, such as the one developed by the AACVPR for outpatients with known CVD may be utilized for inpatients because it considers the overall prognosis of the individual and their potential for rehabilitation (7).

Supervised daily ambulation may be initiated pursuant to all of the conditions in *Box 8.2* being met and the consideration of the indications/contraindications for CR in *Box 8.3*. These recommendations may be superseded by the clinical judgment of the supervising physician in consultation with the CR Team. *Box 8.4* provides a list of possible adverse responses for which discontinuing an exercise session would be warranted. In general, the criteria for terminating an inpatient exercise session are similar to, or slightly more conservative than, those for terminating a low intensity exercise test (7). Each PA session should include assessment and documentation of vital signs (*i.e.*, heart rate [HR], blood pressure [BP], heart and lung sounds) and provide feedback on the individual's overall ability to perform the PA.

Box 8.2 American Association of Cardiovascular and Pulmonary Rehabilitation (AACVPR) Parameters for Inpatient Cardiac Rehabilitation Daily Ambulation (7)

- No new or recurrent chest pain in previous 8 h
- Stable or falling creatine kinase and troponin values
- No indication of decompensated heart failure (*e.g.*, resting dyspnea and bibasilar rales)
- Normal cardiac rhythm and stable electrocardiogram for previous 8 h

Box 8.3 Indications and Contraindications for Inpatient and Outpatient Cardiac Rehabilitation

Indications

- Medically stable postmyocardial infarction
- Stable angina
- Coronary artery bypass graft (surgery)
- Percutaneous transluminal coronary angioplasty
- Stable heart failure caused by either systolic or diastolic dysfunction (cardiomyopathy)
- Heart transplantation
- Valvular heart disease/surgery
- Peripheral arterial disease

- At risk for coronary artery disease with diagnoses of diabetes mellitus, dyslipidemia, hypertension, or obesity
- Other individuals who may benefit from structured exercise and/or individual education based on physician referral and consensus of the rehabilitation team

Contraindications

- Unstable angina
- Uncontrolled hypertension (resting systolic blood pressure >180 mm Hg and/or resting diastolic blood pressure >110 mm Hg)
- Orthostatic blood pressure drop of >20 mm Hg with symptoms
- Significant aortic stenosis (aortic valve area <1.0 cm^2)
- Uncontrolled atrial or ventricular arrhythmias
- Uncontrolled sinus tachycardia (>120 beats · min^{-1})
- Uncompensated heart failure
- Third-degree atrioventricular block without pacemaker
- Active pericarditis or myocarditis
- Recent embolism (pulmonary or systemic)
- Acute thrombophlebitis
- Aortic dissection
- Acute systemic illness or fever
- Uncontrolled diabetes mellitus
- Severe orthopedic conditions that would prohibit exercise
- Other metabolic conditions, such as acute thyroiditis, hypokalemia, hyperkalemia, or hypovolemia (until adequately treated)
- Severe psychological disorder

Information from (1).

Box 8.4 Adverse Responses to Inpatient Exercise Leading to Exercise Discontinuation

- Diastolic blood pressure (DBP) ≥110 mm Hg

- Decrease in systolic blood pressure (SBP) >10 mm Hg during exercise with increasing workload
- Significant ventricular or atrial arrhythmias with or without associated signs/symptoms
- Second- or third-degree heart block
- Signs/symptoms of exercise intolerance including angina, marked dyspnea, and electrocardiogram (ECG) changes suggestive of ischemia

Used with permission from (7).

During the hospital stay, simple exposure to orthostatic or gravitational stress, such as intermittent sitting or standing, within the initial 12–24 h after an MI may prevent deterioration in exercise performance that often follows an acute cardiac event and subsequent bed rest (8,9). The optimal dose of exercise for inpatients has not been defined and should progress from self-care activities (*e.g.*, sitting, toileting), arm and leg range of motion (ROM), and postural changes, to limited supervised walking short-to-moderate distances with minimal or no assistance three to four times per day on the hospital floor. Other activities may include upper body movement exercises and minimal stair climbing in preparation for returning home (7). Although there are no specific inpatient guidelines for the volume and rate of progression of PA, an individual assessment performed daily by a qualified staff member (*e.g.*, ACSM Certified Clinical Exercise Physiologist [ACSM-CEP]), along with a conservative use of the FITT recommendations may be used as a guide for the initiation and progression of the dose of inpatient PA. During progressive phases of PA, the individual should be monitored for appropriate hemodynamic responses (HR, systolic blood pressure [SBP]), electrocardiogram (ECG) rhythm, or ST changes), and/or new cardiovascular signs or symptoms (*i.e.*, chest pain [CP], shortness of breath [SOB], palpitations, fatigue) (7). Although not all individuals may be suitable candidates for inpatient exercise, virtually all will benefit from some level of inpatient intervention including the assessment of CVD risk factors (see *Table 2.2*), PA counseling, and/or individual and family education.

FITT — FITT RECOMMENDATIONS FOR INPATIENT CARDIAC REHABILITATION PROGRAMS[a] (7,10)

	Aerobic	Flexibility
Frequency	2–4 sessions · d^{-1} for the first 3 d of the hospital stay.	Minimally once per day but as often as tolerated.
Intensity	Seated or standing resting heart rate (HR_{rest}) +20 beats · min^{-1} for individuals with an MI and +30 beats · min^{-1} for individuals recovering from heart surgery Upper limit ≤120 beats · min^{-1} that corresponds to an RPE ≤13 on a scale of 6–20 (11).	Very mild stretch discomfort.
Time	Begin with intermittent walking bouts lasting 3–5 min as tolerated; progressively increase duration. The rest period may be a slower walk (or complete rest) that is shorter than the duration of the exercise bout. Attempt to achieve a 2:1 exercise/rest ratio; progress to 10–15 min of continuous walking.	All major joints with at least 30 s per joint appropriate with sternal precautions.
Type	Walking. Other aerobic	Focus on ROM and

	modes are useful in inpatient facilities that have accommodations (*e.g.*, treadmill, cycle).	dynamic movement. Pay particular attention to lower back and posterior thigh regions. Bed-bound individuals may benefit from passive stretching provided by an allied health care professional (*e.g.*, ACSM-CEP, PT).

[a]Resistance training is not recommended in the inpatient setting.
ACSM-CEP, ACSM Certified Clinical Exercise Physiologist; MI, myocardial infarction; PT, physical therapist; ROM, range of motion; RPE, rating of perceived exertion.

Individual education on modifiable risk factors, lifestyle changes, and self-care should not be attempted until the individual's physical ability and psychological willingness to learn is assessed (7). Once this is established, individual education is best accomplished with a medical team approach and should begin with each encounter. Assess the individuals' knowledge of their disease and treatment by having them explain it to you; determine the individuals' preferred learning style; communicate in lay terms and make corrections to misperceptions; expand their knowledge of their disease, signs and symptoms, and treatments with the use of technology, visual aids, and family involvement.

At *hospital discharge*, the individual should have a comprehensive plan of care and educational materials that address issues such as medication compliance, timely follow-up, dietary interventions, surgical wound care, appropriate levels of physical and sexual activities, and participation in CR. The medical team should pay close attention to psychosocial and socioeconomic issues, including access to care, risk of depression, social isolation, and health care disparities (12). Moreover, a safe, progressive plan of exercise should be formulated before leaving the hospital. Until evaluated with an exercise test or entry into a clinically supervised outpatient CR program, the upper limit of HR or rating of perceived exertion (RPE) noted during exercise should not exceed those levels observed during the inpatient program (7). Individuals should be counseled to identify abnormal signs and symptoms suggesting exercise intolerance and the need for medical evaluation.

All eligible individuals should be strongly encouraged, and if possible, given an appointment, to participate in a clinically supervised *Outpatient Cardiac Rehabilitation* program for enhancement of quality of life and functional capacity, and reduction in risk of morbidity and mortality. *Table 8.1* lists strategies that may be utilized to increase the percentage of individuals with cardiac disease participating in outpatient CR.

TABLE 8.1 • Strategies that Influence Referral and Enrollment to Cardiac Rehabilitation (13)

Strategy	Brief Description
Automatic inpatient CR referral system	CR referral is carried out as an automatic EMR order for all eligible individuals.
Inpatient "liaison" to help educate and refer individuals to outpatient CR	A liaison meets with inpatients who are eligible for CR, educating and guiding them in the CR enrollment process.
Combination of automatic CR referral system and "liaison"	Combination of the two strategies listed above
Limit or eliminate out-of-pocket expenses to individuals for CR services	Negotiate with insurance companies to limit or eliminate copayments and other out-of-pocket expenses for individuals enrolled in CR
Inclusion of home-based CR option for individuals who are not able to attend a center-based CR program	Protocol-driven, home-based approaches to CR delivery provide CR services to individuals at home for low- to moderate-risk individuals may be nurse-managed.
Flexible hours of operation	Increased flexibility of CR center hours to include early morning, noontime, after work, and weekend hours
Early outpatient appointment	Inpatient staff members work and

established before hospital discharge	EMR set up an outpatient CR enrollment appointment for each eligible individual within 12 d of hospital discharge.
Use of CR referral performance measures in a quality improvement system	CR referral is assessed, reported, and acted on in a systematic quality improvement program

CR, cardiac rehabilitation; EMR, electronic medical record.

Outpatient Cardiac Rehabilitation

There is strong evidence that outpatient CR, or secondary prevention, is a useful and effective treatment for individuals after heart surgery, MI, coronary intervention, and for those with stable angina, PAD, or HFrEF. CR also is recommended, although with moderate evidence, for stable systolic heart failure (HF) (5,14,15). Outpatient CR may include a traditional center-based CR program or may include other alternative models (*e.g.*, home-based CR models, remote monitoring, or mobile health strategies that link individuals with CR professionals, either alone or in combination with center-based CR) that meet all criteria for a safe and effective CR program. CR programs also may incorporate the core clinical and operational components of an industry-standard service that provides, tracks, and reports on safe and effective exercise (5). Lastly, CR programs provide individual-centered disease management education aimed to progress individuals toward improved outcomes in the clinical, functional, and behavioral domains. The goals of outpatient CR are listed in *Box 8.5*, and the components of CR are listed in *Box 8.6*.

Box 8.5 **Goals for Outpatient Cardiac Rehabilitation**

- Develop and assist the individual to implement a safe and effective formal exercise and lifestyle physical activity program.
- Provide appropriate supervision and monitoring to detect change in clinical status.
- Provide ongoing surveillance to the individual's health care providers in order to enhance medical management.
- Return the individual to vocational and recreational activities or modify these activities based on the individual's clinical status.
- Provide individual and spouse/partner/family education to optimize secondary prevention (*e.g.*, risk factor modification) through aggressive lifestyle management and judicious use of cardioprotective medications.

Box 8.6 **Components of Outpatient Cardiac Rehabilitation**

- Cardiovascular risk factor assessment and counseling on aggressive lifestyle management
- Education and support to make healthy lifestyle changes to reduce the risk of a secondary cardiac event
- Development and implementation/supervision of a safe and effective personalized exercise plan
- Monitoring with a goal of improving blood pressure, lipids/cholesterol, and diabetes mellitus
- Psychological/stress assessment and counseling
- Communication with each individual's physician and other health care providers regarding progress and relevant medical management issues
- Return to appropriate vocational and recreational activities

At the time of CR program entry, the following assessments should be performed (7):

- Medical and surgical history including the most recent cardiovascular event, comorbidities, and other pertinent medical history
- Review of recent cardiovascular tests and procedures including 12-lead ECG, coronary angiogram, echocardiogram, stress test (exercise or pharmacologic studies), cardiac surgeries or percutaneous interventions, and pacemaker/implantable defibrillator implantation.
- CVD risk factors (see *Table 2.2*)
- Current medications including dose, route of administration, and frequency
- Physical examination with an emphasis on the cardiopulmonary and musculoskeletal systems

Exercise training is safe and effective for most individuals with cardiac disease; however, all individuals should be evaluated on their risk for occurrence of a cardiac-related event during exercise training (see *Box 2.2*). Routine assessment of risk for exercise (see *Chapters 2* and *4*) should be performed before, during, and after each CR session, as deemed appropriate by the rehabilitation staff, and include the following (7):

- HR
- BP
- Bodyweight
- Symptoms or evidence of change in clinical status not necessarily related to activity (*e.g.*, dyspnea at rest, light-headedness or dizziness, palpitations or irregular pulse, chest discomfort, sudden weight gain)
- Symptoms and evidence of exercise intolerance
- Change in medications and adherence to the prescribed medication regimen
- Consideration of ECG and HR surveillance that may consist of telemetry, Bluetooth, or hardwire monitoring for periodic rhythm strips, depending on the risk status of the individual and the need for accurate rhythm detection

Exercise Prescription

Prescriptive techniques for determining exercise dosage or the FITT principle of Ex R_x for the general apparently healthy population are detailed in *Chapter 5*. The Ex R_x techniques used for the apparently healthy adult population may be applied to many individuals with CVD. This section provides specific considerations and modifications of the Ex R_x for individuals with known CVD.

FITT — FITT RECOMMENDATIONS FOR INDIVIDUALS WITH CARDIOVASCULAR DISEASE PARTICIPATING IN OUTPATIENT CARDIAC REHABILITATION (7,10,16)

	Aerobic	Resistance	Flexibility
Frequency	Minimally 3 d · wk^{-1} preferably up to 5 d · wk^{-1}	2–3 nonconsecutive d · wk^{-1}	≥2–3 d · wk^{-1} with daily being most effective.
Intensity	With an exercise test, use 40%–80% of exercise capacity using HRR, $\dot{V}O_2R$, or $\dot{V}O_{2peak}$. Without an exercise test, use seated or standing resting heart rate (HR_{rest}) +20 to +30 beats · min^{-1} or an RPE of 12–16 on a scale of 6–20 (11).	Perform 10–15 repetitions of each exercise without significant fatigue; RPE 11–13 on a 6–20 scale or 40%–60% of 1-RM.	To the point of feeling tightness or slight discomfort.
Time	20–60 min.	1–3 sets; 8–10 different exercises focused on major muscle groups.	10–30 s hold for static stretching; ≥4 repetitions of each exercise.
Type	Arm ergometer, combination of	Select equipment that	Static and dynamic

	upper and lower (dual action) extremity cycle ergometer, upright and recumbent cycle ergometer, recumbent stepper, rower, elliptical, stair climber, treadmill.	is safe and comfortable for the individual to use.	stretching focused on the major joints of the limbs and the lower back Consider PNF technique.

1-RM, one repetition maximum; HRR, heart rate reserve; PNF, proprioceptive neuromuscular facilitation; RPE, rating of exertion; $\dot{V}O_{2peak}$, peak oxygen uptake; $\dot{V}O_2R$, oxygen uptake reserve.

Exercise Training Considerations

- During each exercise session, warm-up and cool-down activities of 5–10 min, including dynamic and static stretching, and light or very light (see *Table 5.2*) aerobic activities should be performed (17).
- The aerobic exercise portion of the session should include rhythmic, large muscle group activities with an emphasis on increased caloric expenditure for maintenance of a healthy bodyweight and its many other associated health benefits (see *Chapters 1*,*5*, and 9).
- Conditioning that includes the upper and lower extremities and multiple forms of aerobic activities and exercise equipment should be incorporated into the exercise program.
- Safety factors that should be considered include the individual's clinical status, risk stratification category, exercise capacity, adverse event/ischemic/angina threshold, musculoskeletal limitations, and cognitive/psychological impairment.
- The presence of classic angina pectoris that is induced with exercise training and relieved with rest or nitroglycerin is sufficient evidence for

the presence of myocardial ischemia.

- If an adverse event threshold in an individual has been identified (*i.e.*, ischemic threshold determined by angina and/or >1 mm ischemic ST-segment depression, compromised hemodynamic response, etc., on an exercise test), the exercise intensity should be prescribed at an HR of 10 beats · min^{-1} below the HR at which the event was initially identified (16).
- If peak HR is unknown, the individual may be trained to use the RPE method to guide exercise intensity utilizing the following relationships (16):
    - <12 is light or less than 40% of heart rate reserve (HRR)
    - 12–13 is somewhat hard or 40%–59% of HRR
    - 14–16 is hard or 60%–80% of HRR
- High intensity aerobic interval training (HIIT) may be beneficial for this population; however, there are no universally accepted guidelines for HIIT at this time in the cardiac population (17). Therefore, HIIT may be best shifted to "maintenance" or community-based programs after the successful completion of 12–18 sessions of a supervised early CR program (10).
- Individuals should take their prescribed medications at their usual time, as recommended by their health care providers. Individuals on a β-adrenergic blocking agent (*i.e.*, β-blocker) may have an attenuated HR response to exercise and an increased or decreased maximal exercise capacity. For individuals whose β-blocker dose was altered after an exercise test or during the course of CR, a new graded exercise test (GXT) may be helpful (7).
- For individuals who have had a β-blocker dose change but have not had an exercise test since this change, the following recommendations for guiding exercise intensity may be used: (a) monitor signs and symptoms and (b) note the RPE and HR responses at the workload most recently

used in CR. The HR and RPE observed may serve as the individual's new target for exercise intensity.

- Individuals on diuretic therapy are at an elevated risk of volume depletion, hypokalemia, or orthostatic hypotension, particularly after bouts of exercise. For these individuals, the BP response to exercise, symptoms of dizziness or light-headedness, and arrhythmias should be monitored while providing education regarding proper hydration (18). See *Appendix A* for other common medications that may influence the hemodynamic response during and after exercise.
- Current exercise guidelines suggest any amount of exercise is better than none (17), and for individuals with very limited exercise capacities, multiple shorter daily sessions (*i.e.*, <10 min) may be considered as a starting point, with gradual progression toward increased aerobic exercise time suggested (19). Individuals should be encouraged to perform some exercise sessions independently (*i.e.*, without direct supervision).
- It is recommended that an exercise test be performed any time there is a change in symptoms or other clinical changes that may indicate compromised ability to exercise (7).
- Associated factors to consider when guiding those exercising in CR include premorbid activity level, vocational and avocational goals and requirements, and personal health/fitness goals.

Continuous Electrocardiographic Monitoring

ECG monitoring during supervised exercise sessions may be helpful during the first several weeks of CR. The following recommendations for ECG monitoring are related to individual-associated risks of exercise training (16).

- Individuals with known stable CVD and low risk for complications may begin with continuous ECG monitoring and decrease to intermittent or no ECG monitoring after 6–12 sessions or sooner, as deemed appropriate by the medical team.

- Individuals with known CVD and at moderate-to-high risk for cardiac complications should begin with continuous ECG monitoring and decrease to intermittent or no ECG monitoring after 12 sessions, as deemed appropriate by the medical team.
- When considering removing or reducing ECG monitoring, the individuals should understand their personal exercise level that is safe.

Exercise Prescription without a Preparticipation Exercise Test

Although a symptom-limited GXT prior to starting CR is ideal in the development of an exercise program, it is less common for individuals referred to CR to have a preparticipation GXT in clinical practice. Ex R_x procedures can be based on the recommendations of these *Guidelines* and what was accomplished during the inpatient phase and home exercise activities. In lieu of a GXT, a 6-min walk test (6-MWT) or other forms of submaximal exercise tests can be performed as a measurement of exercise tolerance and capacity (7). Use of RPE also can be a practical method for prescribing both aerobic and resistance exercises in the absence of a GXT (10). Each individual should be educated on and closely monitored for signs and symptoms of intolerance such as excessive fatigue, dizziness or light-headedness, chronotropic incompetence, and signs/symptoms of ischemia.

Lifestyle Physical Activity

Based on recommendations of the *2018 Physical Activity Guidelines Advisory Committee*, increasing moderate-to-vigorous PA levels by even small amounts has the potential to have a substantial impact on the outcomes for all-cause mortality due to atherosclerotic CVDs of coronary heart disease, ischemic stroke, and HF (17). It is important to encourage individuals to perform regular physical activities and exercise outside of and after completion of the CR program participation.

Individuals with Heart Failure

Chronic HF is characterized by exertional dyspnea and fatigue in the setting of HFrEF (*i.e.*, systolic dysfunction), a preserved left ventricular ejection fraction (heart failure with preserved ejection fraction [HFpEF], *i.e.*, diastolic dysfunction), or a combination of the two. Due partly to the aging of the population and to improved survival of CVD, the prevalence of HF is increasing. HF currently affects an estimated 6.5 million American adults and is estimated to increase 46% by 2030 (20). In spite of this increasing prevalence, hospitalization for acute decompensated HF has decreased (20). Among individuals admitted for acute HF, 53% have HFrEF and 47% have HFpEF; and 1-yr mortality is nearly 30% (20).

Exercise training is broadly recognized as a valuable adjunct in the therapeutic approach to the care of individuals with stable chronic HF and is recommended by the ACC and the AHA (21). The benefits of exercise training in individuals with HFrEF have been previously described (22) and include improved clinical outcomes (*e.g.*, hospitalizations) and health-related quality of life (23–27). Exercise training also improves exercise capacity (10%–30%), central hemodynamic function, autonomic nervous system function, and peripheral vascular and skeletal muscle function in individuals with HFrEF (13). In total, these adaptations allow individuals to exercise to a higher peak work rate or exercise at a submaximal level with a lower HR, less perceived effort, and less dyspnea and fatigue. A meta-analysis of 57 studies that directly measured peak oxygen uptake ($\dot{V}O_{2peak}$) reported an average 17% improvement (28). Emerging data indicate that individuals with HFpEF also benefit from exercise training, as evidenced by improved skeletal muscle function, quality of life, and exercise capacity; however, it is not a CR-covered population as of this writing (29). There is moderate supporting evidence for exercise for stable HF (5,14,15).

Exercise Testing

Symptom-limited exercise testing is safe in individuals with HFrEF, and when combined with the indirect measurement of expired gases provides useful information pertaining to ECG, hemodynamic responses to exercise, and prognostic information as well (16).

- Compared to age-matched healthy individuals, individuals with HFrEF exhibit a lower peak HR, peak stroke volume, and peak cardiac output response to exercise.
- Vasodilation of the large vessels (*e.g.*, brachial artery) and resistance vasculature are attenuated, limiting regional and local blood flow (30).
- Abnormalities in skeletal muscle histochemistry limit oxidative capacity of the more metabolically active cells.
- Impaired HR, stroke volume, and cardiac output response to exercise contribute to the reduced exercise capacity observed in individuals with HFpEF.
- Exercise tolerance in individuals with HF being considered for cardiac transplant may be <50% of age-predicted normal or a volume of oxygen consumed per minute ($\dot{V}O_2$) <12 mL/kg/min (31,32). Because of this limitation, an exercise protocol that starts at a lower work rate and imposes smaller increases in work rate per stage, such as the modified Naughton treadmill protocol or a 10 W $\cdot$ min^{-1} ramp ergometer protocol (see *Chapter 5*), are commonly used.
- Both $\dot{V}O_{2peak}$ and the slope relationship between change in minute ventilation and to change in carbon dioxide production during incremental exercise (*e.g.*, $\Delta\dot{V}E/\Delta\dot{V}CO_2$ slope, $\dot{V}E/\dot{V}CO_2$ slope) are related to prognosis and can be used to help guide when to refer an individual to an advanced HF specialist or when to further evaluate for advanced therapies such as a continuous flow left ventricular assist device (LVAD) or cardiac transplant (16,32).

Exercise Prescription

Because two of the main goals for exercise training in individuals with HF are to reverse exercise intolerance and decrease subsequent risk for a clinical event, the principle of specificity of training dictates the use of exercise modalities that were used in trials that reported improved functional and clinical benefits. Therefore, exercise regimens should always include aerobic activities.

FITT — FITT RECOMMENDATIONS FOR INDIVIDUALS WITH HEART FAILURE (25,33)

	Aerobic	Resistance	Flexibility
Frequency	Minimally 3 $d \cdot wk^{-1}$; preferably up to 5 $d \cdot wk^{-1}$	1–2 nonconsecutive $d \cdot wk^{-1}$	≥2–3 $d \cdot wk^{-1}$ with daily being most effective.
Intensity	Start at 40%–50% and progress to 70%–80% of $\dot{V}O_2$ reserve (or HRR); titrate based on perceived exertion. If atrial fibrillation is present, use perceived exertion only, such as RPE (11–14 on a 6–20 scale) or talk test.	Begin at 40% 1-RM for upper body and 50% 1-RM for lower body exercises. Gradually increase to 70% 1-RM over several weeks to months.	Stretch to the point of feeling tightness or slight discomfort.
Time	Progressively increase to 20–60 $min \cdot d^{-1}$.	1–2 sets of 10–15 repetitions focusing on major muscle groups.	10–30 s hold for static stretching; 2–4 repetitions of each exercise.
Type	Aerobic exercise, focusing on treadmill- or free-walking and stationary cycling as capable.	Weight machines, dumbbells, elastic bands, and/or body	Static, dynamic, and/or PNF stretching.

		weight can be used.

1-RM, one-repetition maximum; HRR, heart rate reserve; PNF, proprioceptive neuromuscular facilitation; RPE, rating of perceived exertion; $\dot{V}O_2$, volume of oxygen consumed per unit time.

Exercise Training Considerations

- A target HR range should be determined based on peak HR measured during a symptom-limited, maximal exercise test. There are no data to support the use of estimated peak HR in individuals with HF. If measured peak HR is not available, then target HR should be set at rest HR + 20–30 beats and an RPE of 11–14 (6–20 scale). Resting HR should be established in a stable, upright position and need not be recalculated each day unless there is a change in β-blockade.
- For those individuals who have completed a maximal exercise test, higher intensity aerobic interval training may be considered, with work intervals of 30 s to 4 min at an intensity up to 85%–90% of HRR interspersed with 1–3 min rest intervals at 50%–70% HRR (10,34). HIIT improved $\dot{V}O_{2peak}$ by 46% in stable individuals with HFrEF and was associated with reverse remodeling of the left ventricle (35,36). However, the evidence on the impact of HIIT training across several clinical populations is still limited (10).
- The exercise program should be designed to gradually increase the volume of exercise performed over time, with duration and frequency of effort increased before intensity. Individuals who regularly exercise can tolerate weekly adjustments in either intensity or duration. For individuals with HF, the goal volume of exercise is 3–7+ metabolic equivalent (MET)-h · wk^{-1} (37).
- After individuals have adjusted to and are tolerating aerobic training, which usually requires at least 4 wk, resistance training activities can be added.

Special Considerations

- Approximately 40% of individuals with HF are compliant with prescribed exercise at the end of 1 yr, which is not different than long-term adherence for individuals with established coronary artery disease (24,38,39).
- Because numerous barriers to exercise adoption and adherence exist in this population, factors amenable to interventions such as treating anxiety and depression, improving motivation, seeking additional social support (see *Chapter 12*), and managing logistical problems such as transportation should be addressed.

Special Considerations for Individuals with a Left Ventricular Assist Device

- Regular exercise training improves exercise tolerance and quality of life in patents with LVAD (40).
- Exercise training and testing of individuals that received an LVAD for either bridge-to-transplant or as a destination therapy for end-stage disease is becoming increasingly more common. These individuals have a low functional capacity with a $\dot{V}O_{2peak}$ in the range of 7–23 mL · kg^{-1} · min^{-1} (41).
- Due to the continuous flow of the LVAD (*i.e.*, lacking pulsatile flow), BP (*i.e.*, mean arterial pressure [MAP]) must be measured by Doppler instead of auscultation with a stethoscope. Resting mean pressure should be controlled to between 70 and 80 mm Hg (42). In general, MAP should mildly increase with increasing work rates. Studies have shown safe performance of exercise in inpatient settings with MAP maintained between 70 and 90 mm Hg (43).
- HR during exercise increases in a manner that is generally linear with an increase in work rate.
- Individuals with LVAD typically have modest increases in blood flow rate (as high as 10 L · min^{-1}) during progressive intensity exercise.

- Early-onset fatigue is common with exercise. When starting an exercise training program, fatigue later in the day may be reported. If fatigue occurs, intermittent exercise may reduce the level of fatigue experienced from subsequent exercise training sessions.
- Until more definitive information describing the relationship between HR and exercise intensity are available, using an RPE of 11–13 to prescribe exercise intensity is appropriate.

Individuals with a Sternotomy

The median sternotomy is the standard incision to provide optimal access for cardiovascular surgeries such as CABG, LVAD, or heart valve replacement. Although most individuals heal without complications and achieve adequate sternal stability in approximately 8–10 wk, sternal instability has been observed in up to 16% of cases (33,44). Several factors such as diabetes, age, certain drugs, and obesity can predispose an individual to such a complication and associated effect on exercise training.

Special Considerations for Sternotomy

For individuals who have had a sternotomy, there are no evidence-based precautions or restrictions on arm movement and the vast majority of individuals can initiative arm movement immediately after surgery with little or no risk of dehiscence (45). Other considerations include:

- Individuals should be encouraged to move arms freely immediately after surgery, keeping arms close to the body to reduce stress on the sternum (46).
- Recent expert opinion supports teaching individuals how to use the upper body to perform activities that avoid excessive stress on the sternum and recommend an individualized activity progression strategy (46,47).
- The rate of dehiscence is 1.5%–3% of all individuals with sternotomy. The highest risks of dehiscence are from excess coughing, osteoporosis, or infection (45).

- While in outpatient CR, rhythmic upper limb activities (*e.g.*, arm ergometry, dual-action ergometer) can be performed.
- The referring physician or surgeon should be notified of clinically meaningful observations in regard to any rare sternal complications.

Pacemaker and Implantable Cardioverter Defibrillator

Implanted cardiac pacemakers are used to restore an optimal HR at rest and during exercise, to synchronize atrial and ventricular filling and contraction in the setting of abnormal rhythms, and to synchronize right and left ventricular contraction in the setting of left bundle-branch block (LBBB). Specific indications for pacemakers include sick sinus syndrome with symptomatic bradycardia, acquired atrioventricular (AV) block, and persistent advanced AV block after MI. The different types of pacemakers include the following:

- Rate-responsive (*i.e.*, rate-adaptive or rate-modulated) pacemakers that are programmed to increase or decrease HR to match the level of PA (*e.g.*, sitting rest or walking).
- Single-chambered pacemakers that have only one lead placed into the right atrium or the right ventricle; generally indicated for individuals with chronic atrial fibrillation with concomitant symptomatic bradycardia such as seen with a high-grade AV block or after creation of complete heart block for definitive rate control measure.
- Dual-chambered pacemakers that have two leads: one placed in the right atrium and one in the right ventricle; indicated for physiologic pacing to reestablish a normal sequence and timing of contractions between the upper and lower chambers of the heart.
- Cardiac resynchronization therapy pacemakers that have three leads: one in right atrium, one in right ventricle, and one in coronary sinus or, less

commonly, the left ventricular myocardium via an external surgical approach; indicated in select individuals with HFrEF.

The type of pacemaker, regardless of manufacturer, is identified by a four-letter code:

- The first letter of the code describes the chamber paced (*e.g.*, atria [A], ventricle [V], dual [D]).
- The second letter of the code describes the chamber sensed.
- The third letter of the code describes the pacemaker's response to a sensed event (*e.g.*, triggered [T], inhibited [I], dual [D], no response [O]).
- The fourth letter of the code describes the rate modulation availability of the pacemaker (*e.g.*, rate modulation/responsive available [R], rate modulation not available or disabled [O]).

For example, a VVIR code pacemaker means (a) the ventricle is paced (V) and sensed (V); (b) when the pacemaker senses a normal ventricular contraction, it is inhibited (I); and (c) the pulse generator is rate responsive (R).

Exercise testing is strongly recommended for the assessment of rate-responsive pacemakers in those contemplating increased PA or competitive sports (16). In these cases, exercise testing can help to optimize the HR response and thus may increase the exercise capacity of an individual.

The implantable cardioverter defibrillator (ICD) is a device that monitors the heart rhythm and delivers an electrical shock if life-threatening rhythms are detected. ICDs are used for high-rate ventricular tachycardia or ventricular fibrillation in individuals who are at risk for these conditions as a result of previous cardiac arrest, cardiomyopathy, HF, or ineffective drug therapy for abnormal heart rhythms. When ICDs detect an excessively rapid or irregular heartbeat, they may first attempt to pace the heart into a normal rate and rhythm (*i.e.*, antitachycardia pacing). If unsuccessful, they can then deliver an electrical shock (*i.e.*, electrical cardioversion, defibrillation) in an attempt to reset the heart to a normal HR and electrical pattern. ICDs protect against sudden cardiac death from ventricular tachycardia and ventricular fibrillation. Exercise is safe for individuals with an ICD (48).

Exercise Training Considerations

- Programmed pacemaker modes, HR limits, and ICD rhythm detection algorithms should be obtained prior to exercise testing or training.
- Exercise testing should be used to evaluate HR and rhythm responses prior to beginning an exercise program. Exercise training should not begin in individual's whose HR does not increase during the exercise test. In these cases, the exercise sensing mechanism (*i.e.*, movement or respiration) needs adjustment to allow the HR to increase with PA.
- When an ICD is present, the peak heart rate (HR_{peak}) during the exercise test and exercise training program should be maintained at least 10–15 beats · min^{-1} below the programmed HR threshold for defibrillation (16).
- After the first 24 h following the device implantation, mild upper extremity ROM activities can be performed and may be useful to avoid subsequent joint complications.
- Rigorous upper extremity activities such as swimming, bowling, lifting weights, elliptical machines, and golfing should be avoided for at least 3–4 wk after device implant. However, lower extremity activities are allowable.
- In the United States, isolated pacemaker and ICD implantation are not indications for CR. However, supervised exercise can be important for these individuals, particularly those with a long history of sedentary living.

Individuals after Cardiac Transplantation

In individuals with end-stage HF for whom prognosis is poor and standard medical therapy fails to control symptoms, cardiac (heart) transplant may be a surgical option for those who are eligible. In 2016, 3,209 heart transplants were performed in the United States and 30,622 people were living with a heart transplant. Survival after a heart transplant varies by age and race. Between 2009 and 2011, the 3-yr posttransplant survival rate was 83.5% in the United States (49). Following surgery, both aerobic and resistance training programs are strongly recommended to improve exercise capacity and quality of life, help restore bone mineral density, reverse sarcopenia, and help modify cardiovascular risk factors such as obesity, hypertension, and glucose intolerance (50). According to the International Society of Heart and Lung Transplant, strong evidence exists to support the efficacy of CR (aerobic exercise training) and resistance exercise after heart transplant (50).

In general, the improvement in exercise capacity ranges between 15% and 30% for exercise programs between 2 and 6 mo in duration (51). Such improvement is due, in part, to improved chronotropic response and improved peripheral effects, such as oxidative capacity of the metabolically more active skeletal muscle. Additionally, resistance training leads to improved muscle strength and endurance (52). Following cardiac transplant, individuals are at risk for several complications including cardiac allograft vasculopathy, graft failure, cancer, hyperlipidemia, hypertension, and diabetes mellitus.

Exercise Testing

Although there is some evidence of reinnervation of cardiac autonomic function a year or more after heart transplant surgery, in the absence of direct cardiac sympathetic efferent innervation, peak cardiac output is reduced 20%–35%. The skeletal muscle and peripheral abnormalities (*e.g.*, endothelial dysfunction) present before surgery are not normalized by the surgery per se and, therefore, also contribute to the reduction in exercise capacity observed in transplant individuals when compared to age-matched healthy individuals (53).

- Resting HR is often elevated, and the HR response to exercise is attenuated. In the absence of parasympathetic innervation, increases in HR are dependent on circulating catecholamines. As a result, increases in

HR to the presence of increases in workload are delayed, the highest HRs may occur after the exercise test or training session, and recovery HR is slow to return to preexercise levels.

- BP is often elevated at rest, with a slightly attenuated response to peak exercise.
- Given the HR and BP responses and the previously mentioned reduction in exercise capacity, a more gradual exercise testing protocol should be employed, similar to those recommended for individuals with HF.
- Other testing issues such as test endpoints remain the same as those used for individuals with other forms of CVD except for detection of angina, which is not possible due to the denervated heart.

Exercise Prescription

Prescribing exercise in individuals having undergone cardiac transplant is, for the most part, quite similar to that of other individuals with CVD. However, because of the denervated myocardium, setting an HR-based training range is not appropriate and subjective methods should be used to guide exercise intensity. Because of the negative effects of immunosuppressive drugs on the musculoskeletal system, resistance training should be performed regularly and engage all major muscle groups.

FITT — FITT Recommendations for Individuals with Cardiac Transplant (52,54,55)

	Aerobic	Resistance	Flexibility
Frequency	Minimally 3 $d \cdot wk^{-1}$; preferably up to 5 $d \cdot wk^{-1}$	1–2 nonconsecutive $d \cdot wk^{-1}$	≥2–3 $d \cdot wk^{-1}$ with daily being most effective.
Intensity	Use perceived only such as RPE (11–14 on a 6–20 scale) or talk test.	Begin at 40% 1-RM for upper body and 50% 1-RM for lower body exercises; gradually increase to 70% 1-RM over several weeks to months.	Stretch to the point of feeling tightness or slight discomfort.
Time	Progressively increase to 20–60 $min \cdot d^{-1}$	1–2 sets of 10–15 repetitions focusing on major muscle groups.	10–30 s hold for static stretching; 2–4 repetitions of each exercise.
Type	Aerobic exercise, focusing on treadmill- or free-walking and stationary cycling as capable.	Weight machines, dumbbells, elastic bands, and/or body weight can be used.	Static, dynamic, and/or PNF stretching.

1-RM, one repetition maximum; PNF, proprioceptive neuromuscular facilitation; RPE, rating of perceived exertion.

Special Considerations

- Due to the delayed HR response, longer warm-up and cool-down periods should be considered.
- Immunosuppression therapy used to prevent graft rejection can lead to bone loss, diabetes, and hypertension, and both regular aerobic and resistance training exercise can play an important role in helping manage these metabolic disorders.
- HIIT has been used in individuals with cardiac transplant with positive results. Work/rest intervals are similar to those recommended for individuals with HF with the exception that HR will not be a useful guide of intensity (51).
- Due to median sternotomy, ROM and the work rate of activities and exercises involving upper limbs should be modified for up to 12 wk. See “Individuals with a Sternotomy” section in this chapter.

INDIVIDUALS WITH PERIPHERAL ARTERY DISEASE

Atherosclerotic plaque leading to significant stenosis and limitations of vasodilation resulting in the reduction of blood flow to regions distal to the area of occlusion is the most common cause of PAD. This reduction in blood flow creates a mismatch between oxygen supply and demand causing ischemia to develop in the affected areas (56). PAD severity can be ranked based on the presence of signs and symptoms (*Table 8.2*) (57) and/or by the ankle/brachial pressure index (ABI) (*Table 8.3*) (58). The recommended treatments for PAD include an initially conservative approach of cardiovascular risk reduction and exercise training, followed by medications (*e.g.*, cilostazol). When there is an inadequate response to exercise or pharmacological therapy, peripheral revascularization may be indicated (58).

TABLE 8.2 • Fontaine Classification of Peripheral Artery Disease (57)

Stage	Symptoms
1	Asymptomatic
2	Intermittent claudication
2a	Distance to pain onset >200 m
	Distance to pain onset <200 m

2b	
3	Pain at rest
4	Gangrene, tissue loss

TABLE 8.3 • Ankle/Brachial Pressure Index Scale for Peripheral Arterial Disease

Supine, Resting ABI	Interpretation
>0.90	Normal
≤0.90	Threshold for PAD confirmation
Decrease of >0.15 over time	Significant PAD progression
Postexercise ABI	**Interpretation**
No change	Normal
Decrease of >30 mm Hg or >20% from resting ABI	Reasonable to consider as threshold for PAD confirmation, whether ABI is normal or abnormal at rest
Decrease of >0.15 over time	Significant PAD progression

ABI, ankle/brachial pressure index; PAD, peripheral arterial disease.
Information from (58).

Intermittent claudication, the major symptom of PAD, is characterized by a reproducible aching, cramping sensation or fatigue usually affecting the muscles of the calf in one or both legs, that is typically triggered by weight-bearing exercise such as walking, and is often relieved with rest (59). Depending on disease severity and lesion location, claudication may also occur in the thigh and buttock regions. On initial clinical presentation, up to 35% of individuals with PAD have typical claudication, and up to 50% have atypical leg pain that does not resolve quickly with rest (58). As the symptoms worsen, they may become severe enough to limit the individual from performing ADL and can greatly impact quality of life (60).

Symptomatic PAD prevalence increases with age, with approximately 2% of those aged 50–54 yr affected, increasing to 6% in those aged ≥60 yr (61). Major risk factors for PAD include diabetes, hypertension, smoking, dyslipidemia, hyperhomocysteinemia, non-Caucasian race, male gender, age, inflammatory markers, and chronic renal insufficiency (61). Individuals with PAD have a 20%–60% increased risk for MI and a two- to sixfold increased risk of dying from CVD compared with individuals without PAD (61).

Exercise Testing

Exercise testing can be performed in individuals with PAD to determine functional capacity, to assess exercise limitations, to determine the time of onset of claudication pain and total walking time before and following therapeutic intervention, and to diagnose the presence of CVD and assess for other exercise safety factors (58,62):

- Medication dose and timing should be noted and repeated in an identical manner in subsequent exercise tests assessing potential therapeutic changes.
- Ankle and brachial artery SBP should be measured bilaterally after 5–10 min of rest in the supine position following standardized ABI procedures (63). The ABI is calculated by dividing the highest ankle SBP reading by

the highest brachial artery SBP reading. Note there are multiple diagnostic criteria using the ABI at rest and during exercise (61).

- A standardized motorized treadmill protocol should be used to ensure reproducibility of pain free maximal walking time (58). Claudication pain perception may be monitored using a numerical rating scale (see *Figure 4.3*) (64).
- The exercise test should begin with a slow speed and have gradual increments in grade (59) (see *Chapter 4*).
- Following the completion of the exercise test, individuals should recover in the seated position.
- The 6-MWT may be used to objectively assess ambulatory functional limitations in those not amenable to treadmill testing (58).

FITT Recommendations for Individuals with Peripheral Artery Disease

Supervised exercise therapy has strong evidence of efficacy in individuals with PAD, as noted in the 2016 AHA/ACC guideline for the management of lower extremity PAD (65). Multiple studies have shown exercise training to be a safe and effective treatment for individuals with PAD. Proposed mechanisms for these improvements are many and still investigational (66). Interval exercise training leads to increases in the time and distance an individual with PAD is able to walk until the initial onset of pain or to a point of maximal tolerable pain (60). Increases in pain-free walking time and distance of 106%–177% and in absolute walking ability of 64%–85% have occurred following exercise training programs (67). The following FITT guidelines for Ex R_x are recommended for individuals with PAD.

FITT — FITT RECOMMENDATIONS FOR INDIVIDUALS WITH LOWER EXTREMITY, SYMPTOMATIC PERIPHERAL ARTERIAL DISEASE (58,59,67)

	Aerobic	Resistance	Flexibility
Frequency	Minimally 3 d · wk^{-1}; preferably up to 5 d · wk^{-1}	At least 2 d · wk^{-1} performed on nonconsecutive days.	≥2–3 d · wk^{-1} with daily being most effective.
Intensity	Moderate intensity (*i.e.*, 40%–59% $\dot{V}O_2R$) to the point of moderate pain (*i.e.*, 3 out of 4 on the claudication pain scale) or from 50%–80% of maximum walking speed.	60%–80% 1-RM	Stretch to the point of feeling tightness or slight discomfort.
Time	30–45 min · d^{-1} (excluding rest periods) for a minimum of 12 wk; may progress to 60 min · d^{-1}	2–3 sets of 8–12 repetitions; 6–8 exercises targeting major muscle groups.	10–30 s hold for static stretching; 2–4 repetitions of each exercise.
Type	Weight-bearing (*i.e.*, free or treadmill walking) intermittent exercise	Whole body focusing on large muscle groups;	Static, dynamic, and/or PNF stretching.

	with seated rest when moderate pain is reached and resumption when pain is *completely* alleviated.	emphasis on lower limbs if time limited.

1-RM, one repetition maximum; PNF, proprioceptive neuromuscular facilitation; $\dot{V}O_2R$, oxygen uptake reserve.

Exercise Training Considerations

- Studies have shown that improvement in PAD with exercise rehabilitation may be most noticeable in the initial 2–3 mo of therapy (67).
- Unsupervised exercise training may be as beneficial, although is not as well established, as a supervised exercise training program (65).
- Some individuals may need to begin exercise by accumulating only 15 min $\cdot$ d^{-1}, gradually increasing time by 5 min $\cdot$ d^{-1} biweekly.
- Although the focus of an exercise training program in individuals with PAD should be walking, non-weight-bearing exercise may provide additional benefits (67).
- Resistance training has not consistently been shown to improve pain-free walking ability in individuals with PAD (67).
- Cycling or other non-weight-bearing exercise modalities may be used as a warm-up but should not be the primary type of activity.
- The optimal work-to-rest ratio has not been determined for individuals with PAD and may need to be adjusted for each individual.
- A cold environment may aggravate the symptoms of intermittent claudication; therefore, a longer warm-up may be necessary (68).
- Encourage individuals to manage all known CVD risk factors.

INDIVIDUALS WITH A CEREBROVASCULAR ACCIDENT (STROKE)

When blood flow to a region of the brain is obstructed (*i.e.*, cerebrovascular accident, CVA, or stroke), brain function deteriorates quickly and leads to neuronal cell death. This can result in motor (functional), sensory, emotional, and cognitive impairments, the extent of which are greatly influenced by the size and location of the affected area and presence or absence of collateral blood flow. The etiology of a stroke is most often ischemic (87%, due to either thrombosis or embolism) or hemorrhagic. Each year, nearly 800,000 U.S. residents suffer a stroke, with women having a higher lifetime risk of stroke than men (69).

Physical and occupational therapy are typically utilized for up to 3–6 mo following a stroke to improve/restore functional mobility, balance, and return to ADL. The AHA/American Stroke Association recommend PA and exercise for stroke survivors across all stages of recovery (70). Loss of physical stamina, mood disturbance, and adoption of sedentary behaviors are common in stroke survivors, which may result in several complications including increased frequency of falls and balance issues. Although the Ex R_x is often adapted to the functional abilities of the individuals, exercise training improves exercise capacity (10%–20%, as measured by $\dot{V}O_{2peak}$) and may improve overall quality of life and help manage risk for a secondary event (71).

Exercise Testing

Compared to those who have not suffered a stroke, oxygen uptake is higher at a fixed submaximal level and reduced at peak effort among stroke survivors. In addition, the functional capacity of stroke survivors is significantly reduced. During exercise testing, both chronotropic incompetence and early-onset fatigue are common.

- Exercise testing should employ a mode of testing that accommodates an individual's physical impairment.
- Cycle ergometry (work rate increase of 5–10 W · min^{-1} or 20 W per stage) and dual action semirecumbent seated steppers may be preferred if sitting is needed to mitigate any balance deficiencies. In each case, modifications of the device (*e.g.*, pedal type, swivel seated, seated back, flip up arm rest) may be needed to facilitate safety and ease of use (71).
- Treadmill testing protocols should increase work rate by 0.5 to 1–2 METs · 2–3 min^{-1} stage and only be considered if the individual can stand and demonstrate sufficient balance and ambulate with very minimal or no assist. Balance impairments demand caution, including dual sided handrails on treadmills and/or a body-weigh support system.

Exercise Prescription

Strong evidence exists to support exercise therapy for individuals with history of stroke, as reported in the review done for the Public Health Agency of Canada in 2013 (72). The majority of individuals suffering a stroke are elderly and many have multiple comorbidities including other CVDs, arthritis, and metabolic disorders. All comorbidities and their associated medications should be considered when performing exercise testing and prescribing exercise. After an individual suffers a stroke, a main objective is to restore ability to return to ADL. Exercise therapy should occur in each of the three phases of recovery; acute (in-hospital), subacute (rehab facility/home), and maintenance (home). After the acute phase of rehabilitation, aerobic, neuromuscular, and muscle-strengthening exercises can be engaged to further improve function, facilitate secondary prevention, and improve fitness in the prolonged maintenance phase of stroke recovery. Future guidelines may need to address the continuum of care in stroke rehabilitation. The following FITT guidelines for Ex R_x are general recommendations for individuals with cerebrovascular disease.

FITT	FITT RECOMMENDATIONS FOR INDIVIDUALS SUFFERING A CEREBROVASCULAR ACCIDENT (70)		
	Aerobic	**Resistance**	**Flexibility**
Frequency	Minimally 3 d · wk^{-1}; preferably up to 5 d · wk^{-1}	At least 2 d · wk^{-1} performed on nonconsecutive days.	≥2–3 d · wk^{-1} with daily being most effective.
Intensity	If HR data are available from a recent GXT, use 40%–70% of HRR. In the absence of a GXT or if atrial fibrillation is present, use RPE of 11–14 on a 6–20 scale.	50%–70% of 1-RM.	Stretch to the point of feeling tightness or slight discomfort.
Time	Progressively increase from 20 to 60 min · d^{-1}. Consider multiple 10-min sessions.	1–3 sets of 8–15 repetitions.	10–30 s hold for static stretching; 2–4 repetitions of each exercise.
Type	Cycle ergometry and semirecumbent seated steppers; may need modification based on functional and cognitive	Use equipment and exercises that improve safety in those with deficits (*e.g.*, strength,	Static, dynamic, and/or PNF stretching.

	deficiencies. Treadmill walking can be considered if individual has sufficient balance and ambulation with very minimal or no assist.	endurance, movement, balance): machine vs. free-weight, bar vs. hand weights; seated vs. standing as indicated.	

1-RM, one repetition maximum; GXT, graded exercise test; HR, heart rate; HRR, heart rate reserve; PNF, proprioceptive neuromuscular facilitation; RPE, rating of perceived exertion.

Exercise Training Considerations

- Avoid the Valsalva maneuver during resistance training to avoid excessive elevations in BP.
- Treadmill should begin at a slow speed (0.8 mph) and provide harness apparatus for individual safety or, if needed, partially unloaded walking.
- Careful use of the HR for intensity monitoring is recommended, as age predicted maximal HR is rarely achieved by the stroke individual during a maximal exercise test.

All components of exercise training (aerobic, muscle strengthening, and balance training) are important to stroke exercise therapy.

Other Considerations

- Comprehensive stroke care involves being attentive to affective issues such as mood, motivation, frustration, and confusion. Correctly managing affective issues can favorably influence how an individual conducts, adheres to, and responds to a prescribed exercise regimen. Strategies aimed at minimizing negative influences include close supervision, individualized instruction until independence is established, involvement of family members, repetition of instructions, and alternate teaching methods. In addition, CVD risk factor reduction is essential (70).

- Exercise therapy should be initiated only after the individual is medically stable (70).
- Early-onset local muscle and general fatigue are common and should be considered when setting work rates and rate of progression.

Exercise Training for Return to Work

For individuals desiring to return to their previous vocation, the exercise plan should consider the musculature used and workload required to perform the required occupations tasks. A list of MET levels associated with a wide range of occupational tasks has been published and can be used to estimate the required workload (73). Specificity of training can be employed for both aerobic and resistance training in an attempt to provide an individual with the strength and endurance needed to return to his or her previous occupation. Exercise training leads to an improved ability to perform physical work, an enhanced self-efficacy, and a greater desire and comfort level for returning to work following a stroke (74,75). *Box 8.7* presents specific information regarding alterations to the standard Ex R_x in preparation for return to work.

Box 8.7 Exercise Prescription for Return to Work for Stroke Individuals

- Assessment of individual's work demands and environment
  - Nature of work.
  - Muscle groups used at work.
  - Work demands that primarily involve muscular strength and endurance

- Primary movements performed during work.
- Periods of high metabolic demands vs. periods of low metabolic demands
- Environmental factors including temperature, humidity, and altitude.

- Exercise prescription
  - Emphasize exercise modalities that use muscle groups involved in work tasks.
  - If possible, use exercises that mimic movement patterns used during work tasks.
  - Balance resistance vs. aerobic training relative to work tasks.
  - If environmental stress occurs at work, educate the individual about appropriate precautions including avoidance if need be, and, if possible, expose them to similar environmental conditions while performing activities similar to work tasks (see the *ACSM Position Stands* and *Chapter 7* for additional information on environmental precautions).
  - If possible, monitor the physiologic responses to a simulated work environment.

PULMONARY DISEASES

Chronic pulmonary disease is a significant cause of morbidity and mortality. There is strong evidence that PR improves exercise tolerance, reduces symptoms, and improves quality of life. For individuals with COPD, evidence-based recommendations (76–78) and clinical practice guidelines (79–85) indicate that exercise training should be a mandatory component of PR. Scientific rationale strongly supports exercise training in people with non-COPD respiratory diseases (*i.e.*, cystic fibrosis [CF], pulmonary hypertension, idiopathic pulmonary fibrosis [IPF]), and confirms similar benefits as those seen in COPD (77,86–88). A key focus of exercise in PR is long-term behavior change to achieve continued participation in PA and exercise. Long-term participation in hospital or home-based PR (*i.e.*, >3 mo) may provide greater and longer lasting physiologic and behavioral benefits than traditional, shorter duration PR programs (89–98). Adjuncts that have the potential to improve exercise performance and quality of life in appropriate individuals include supplemental oxygen, bronchodilation techniques, breathing retraining techniques such as pursed lips breathing, and use of rollators (rolling walkers) or other assisted devices (99). Individuals whose physical limitations prevent them from exercising at higher intensities can achieve significant improvement in aerobic conditioning with lower intensity endurance training (100). Resistance exercise training has been shown to be essential to improve upper and lower body strength and muscle mass, ADL, and health-related quality of life in individuals with chronic obstructive lung diseases (77,100–106). More research is needed on the effect of both aerobic and resistive exercise training in individuals with restrictive and interstitial lung diseases such as pulmonary fibrosis, although recent trials have shown encouraging results (77,107–111). A list of respiratory diseases in which exercise is of potential benefit is shown in *Box 8.8*.

Box 8.8 Individuals with Pulmonary Disease Benefiting from Pulmonary Rehabilitation and Exercise

- Chronic obstructive pulmonary disease — a mostly irreversible airflow limitation consisting of the following:
  - Chronic bronchitis — a chronic productive cough for 3 mo in each of 2 successive yr in an individual in whom other causes of productive chronic cough have been excluded
  - Emphysema — the presence of permanent enlargement of the airspaces distal to the terminal bronchioles, accompanied by destruction of their walls and without obvious fibrosis
  - Asthma — airway obstruction because of inflammation and bronchospasm that is mostly reversible

- Cystic fibrosis — a genetic disease causing excessive, thick mucus that obstructs the airways (and other ducts) and promotes recurrent and ultimately chronic respiratory infection
- Bronchiectasis — abnormal chronic enlargement of the airways with impaired mucus clearance

- Restrictive lung diseases — extrapulmonary respiratory diseases that interfere with normal lung expansion. Examples include the following:
  - Interstitial lung disease/pulmonary fibrosis — scarring and thickening of the parenchyma of the lungs
  - Sarcoidosis — lymph node enlargement throughout the body with widespread appearance of granulomas
  - Pneumoconiosis or occupational lung disease — long-term exposure to dusts, especially asbestos
  - Restrictive chest wall disease, (*e.g.*, scoliosis or kyphosis)
  - Ankylosing spondylitis — a form of spinal arthritis that eventually causes deformities in the vertebral and sacroiliac joints
- Lung cancer — one of the deadliest cancers with cigarette smoking being a common etiology
- Pulmonary arterial hypertension (PAH) — increased blood pressure in the pulmonary artery due to narrowing, blockage, or destruction
- Before and/or after lung transplantation or lung volume reduction surgery
- Obesity-related respiratory disease

Asthma

Asthma is a heterogeneous chronic inflammatory disorder of the airways that is characterized by a history of episodic bronchial hyperresponsiveness; variable airflow limitation; and recurring wheeze, dyspnea, chest tightness, and coughing that occur particularly at night or early morning. These symptoms are variable and often reversible (112). Asthma symptoms can be provoked or worsened by exercise, which may contribute to reduced participation in sports and PA and ultimately to deconditioning and lower cardiorespiratory fitness (CRF). With deconditioning, the downward cycle or "spiral" continues with asthma symptoms being triggered by less intense PA and subsequent worsening of exercise tolerance.

The conclusive evidence for exercise training as an effective therapy for asthma is lacking, and at present, there are no specific evidence-based guidelines for exercise training in these individuals. However, strong evidence is available for recommending regular PA because of its general health benefits (112) and reduced incidence of exacerbations (113). Some (114–116) but not all (117) systematic reviews and meta-analyses have suggested that exercise training can be beneficial for individuals with asthma. The data examined from these reviews are limited by small numbers of randomized controlled trials and heterogeneity of trial methods and individuals. Significant improvements in days without asthma symptoms, aerobic capacity, maximal work rate, exercise endurance, and pulmonary $\dot{V}E$ have been noted. Overall, exercise training is well tolerated and should be encouraged in people with stable asthma (114,118,119).

Exercise-induced bronchoconstriction (EIB), defined as airway narrowing that occurs as a result of exercise, is experienced in a substantial proportion of people with asthma (120), but people without a diagnosis of asthma may also experience EIB. For athletes, environmental triggers such as cold or dry air and air pollution including particulate matter, allergens, and trichloramines in swimming pool areas may stimulate a bout of EIB. EIB can be successfully managed with pharmacotherapy (120). Strong recommendations have also been made for 10–15 min of vigorous intensity or variable intensity (combination of light and vigorous intensity) warm-up exercise to induce a "refractory period" in which EIB occurrence is attenuated (120,121).

Exercise Testing

- Assessment of physiologic function should include evaluations of cardiopulmonary capacity, pulmonary function (before and after exercise), and oxyhemoglobin saturation via noninvasive methods.
- Administration of an inhaled bronchodilator (*i.e.*, β_2-agonists) (see *Appendix A*) prior to testing may be indicated to prevent EIB, thus providing optimal assessment of cardiopulmonary capacity.
- Exercise testing is typically performed on a motor-driven treadmill or an electronically braked cycle ergometer. Targets for high ventilation and HRs are better achieved using the treadmill. For athletes, a sports-specific mode may be more relevant.
- The degree of EIB should be assessed using vigorous intensity exercise achieved within 2–4 min and lasting 4–6 min with the individual breathing relatively dry air. The testing should be accompanied by a spirometric evaluation of the change in forced expiratory volume in one second ($FEV_{1.0}$) from baseline and the value measured at 5, 10, 15, and 30 min following the exercise test (120). The criterion for a diagnosis of EIB varies, but many laboratories use a decrease in $FEV_{1.0}$ from baseline of ≥15% because of its greater specificity (120).
- Appropriately trained staff should supervise exercise tests for EIB, and physician supervision may be warranted when testing higher risk individuals because severe bronchoconstriction is a potential hazard following testing. Immediate administration of nebulized bronchodilators with oxygen is usually successful for relief of bronchoconstriction (122,123).
- Although exercise testing is considered highly specific for detecting EIB, when it is unavailable or unfeasible, surrogate tests to evaluate airway's hyperresponsiveness include eucapnic voluntary hyperventilation of dry air, inhalation of hyperosmolar aerosols of 4.5% saline, dry powder mannitol, or methacholine (122). These tests should be administered by appropriately trained individuals with medical supervision.
- Procedural details for EIB diagnostic testing have been described (120,122). Although none of these surrogate tests are 100% sensitive or

specific for EIB, they are useful in identifying airway hyperresponsiveness.

- Evidence of oxyhemoglobin desaturation ≤80% should be used as test termination criteria in addition to standard criteria (124).
- The 6-MWT may be used in individuals with moderate-to-severe persistent asthma when other testing equipment is not available (83,125,126).

Exercise Prescription

Exercise training is generally well tolerated in asthmatic individuals successfully managed with pharmacotherapy when triggers to bronchoconstriction (*e.g.*, cold; dry, dusty air; inhaled pollutants) are removed to bring about symptom relief (114). As such, the general FITT recommendations for comprehensive exercise in healthy adults, adjusted to individual capabilities, are suitable (see *Chapter 5*). Position statements on exercise in asthma (119) and systematic reviews (114) support this recommendation.

FITT RECOMMENDATIONS FOR INDIVIDUALS WITH ASTHMA (114,119)

	Aerobic	Resistance	Flexibility
Frequency	Minimally 3 d · wk^{-1}; preferably up to 5 d · wk^{-1}	At least 2 d · wk^{-1} performed on nonconsecutive days.	≥2–3 d · wk^{-1} with daily being most effective.
Intensity	Begin with moderate intensity (40%–59% HRR or $\dot{V}O_2R$). If well tolerated, progress to 60%–70% HRR or $\dot{V}O_2R$ after 1 mo.	Strength: 60%–70% of 1-RM for beginners; ≥80% for experienced weight trainers. Endurance: <50% of 1-RM.	Stretch to the point of feeling tightness or slight discomfort.
Time	Progressively increase to at least 30–40 min · d^{-1}.	Strength: 2–4 sets, 8–12 repetitions. Endurance: ≤2 sets, 15–20 repetitions.	10–30 s hold for static stretching; 2–4 repetitions of each exercise.
Type	Aerobic activities using large muscle groups such as walking, running, cycling, swimming, or pool exercises.	Weight machines, free weight, or body weight exercises.	Static, dynamic, and/or PNF stretching.

1-RM, one repetition maximum; HRR, heart rate reserve; PNF, proprioceptive neuromuscular facilitation; $\dot{V}O_2R$, oxygen uptake reserve.

Special Considerations

- Caution is suggested in using target HR based on prediction of maximal heart rate (HR_{max}) because of the wide variability in its association with ventilation and the potential HR effects of asthma control medications.
- Individuals experiencing exacerbations of their asthma should not exercise until symptoms and airway function have improved.
- Use of short-acting bronchodilators may be necessary before or after exercise to prevent or treat EIB (see *Appendix A*).
- Individuals on prolonged treatment with oral corticosteroids may experience peripheral muscle wasting and may therefore benefit from resistance training.
- Exercise in cold environments or in the presence of airborne allergens or pollutants should be limited to avoid triggering bronchoconstriction in susceptible individuals. EIB can also be triggered by prolonged exercise durations or high intensity exercise sessions.
- There is insufficient evidence supporting a clinical benefit from inspiratory muscle training (IMT) in individuals with asthma (116).
- Use of a nonchlorinated pool is preferable because this will be less likely to trigger an asthma event.
- Be aware of the possibility of asthma exacerbation shortly after exercise, particularly in a high-allergen environment.

Chronic Obstructive Pulmonary Disease

COPD is the fourth leading cause of death and a major cause of chronic morbidity throughout the world (80,127). COPD is preventable and treatable and characterized by predisposing risk factors resulting in chronic airway inflammation chiefly due to exposure to noxious gases and particles, especially tobacco smoke and various environmental and occupational exposures. Dyspnea, chronic cough, and sputum production are common symptoms. Significant systemic effects such as weight loss, nutritional abnormalities, sarcopenia, and skeletal muscle dysfunction often accompany COPD (80,127,128). COPD encompasses chronic bronchitis and/or emphysema, and individuals may be categorized according to disease severity based on pulmonary function tests and Global Initiative for Chronic Obstructive Lung Disease (GOLD) criteria (*Table 8.4*) (127).

TABLE 8.4 • Global Initiative for Chronic Obstructive Lung Disease Classification of Disease Severity in Individuals with Chronic Obstructive Pulmonary Disease Based on the $FEV_{1.0}$ Obtained from Pulmonary Function Tests (127)

Disease Severity	Postbronchodilator $FEV_{1.0}/FVC$	Postbronchodilator $FEV_{1.0}$%
Mild	<0.70	$FEV_{1.0}$ ≥80% of predicted
Moderate	<0.70	50% ≤ $FEV_{1.0}$ <80% of predicted
Severe	<0.70	30% ≤ $FEV_{1.0}$ <50% of predicted
Very severe	<0.70	$FEV_{1.0}$ <30% of predicted

$FEV_{1.0}$, forced expiratory volume in 1 s; FVC, forced vital capacity.

Dyspnea or SOB with exertion is a cardinal symptom of COPD resulting in PA limitations and deconditioning. Disuse muscle atrophy is common in individuals with COPD because of the adverse downward spiral of increasing ventilatory limitations, SOB, and further decreases in PA. This contributes to the loss of muscle strength, power, and endurance and decrements in the performance of everyday functional activities. Exercise is an effective and potent intervention that can improve symptoms, lessen the development of functional impairment and disability, and increase quality of life in all individuals with COPD regardless of disease severity (76,80,128). The beneficial effects of exercise occur mainly through adaptations in the musculoskeletal and cardiovascular systems that in turn reduce stress on the pulmonary system during exercise (129).

Exercise Testing

- Exercise testing (*e.g.*, treadmill, cycle ergometer, 6-MWT) has multiple purposes in the assessment of individuals with chronic lung disease. These purposes include quantifying exercise capacity prior to PR entry (77,83,124), establishing a baseline for outcome documentation (82,83), evaluating drug treatment efficacy, assisting in the development of the Ex R_x (77,100), evaluating unexplained dyspnea and exercise intolerance, and prognostic evaluation for individual risk stratification. Ideally, all individuals who enter a PR program should have some form of exercise assessment evaluation prior to PR entry (*e.g.*, cardiopulmonary exercise test, 6-MWT, or shuttle walk test) (82,83,124).
- Evidence-based guidelines confirm the utility of cardiopulmonary exercise testing (CPET) in adults with COPD as well as other chronic lung diseases (*i.e.*, interstitial lung disease, primary pulmonary hypertension, and CF) in providing an objective measure of exercise capacity, mechanisms of exercise intolerance, prognosis, disease progression, and treatment response (123,124,130).
- Incremental exercise tests (*e.g.*, GXT on a treadmill or electronically braked cycle ergometer) may be used to assess cardiopulmonary function and CRF. Modifications of traditional protocols (*e.g.*, smaller work rate increments) may be warranted depending on functional limitations and the onset of dyspnea. A test duration of 8–12 min is optimal in those with mild-to-moderate COPD (131), whereas a test duration of 5–9 min is recommended for individuals with severe and very severe disease (123).

- Individuals with moderate-to-severe COPD may exhibit oxyhemoglobin desaturation with exercise. Therefore, a measure of blood oxygenation, either the partial pressure of arterial oxygen (P_aO_2) or percent saturation of arterial oxygen (SaO_2), should be made periodically during the initial GXT and during any follow-up GXTs to help determine degree of improvement or decline in peripheral blood oxygenation (82).
- Submaximal exercise testing may be used depending on the reason for the test and the clinical status of the individual. However, individuals with pulmonary disease may have ventilatory limitations to exercise; thus, prediction of $\dot{V}O_{2peak}$ based on age-predicted HR_{max} may not be appropriate as criteria for terminating the submaximal GXT.
- A constant work rate (CWR) test using 80%–90% of peak work rate achieved from the GXT is appealing, as it assesses the type of work-related activity levels likely to be encountered in everyday life (132) particularly when performed on a treadmill.
- The measurement of flow volume loops during the GXT using commercially available instruments may help identify individuals with dynamic hyperinflation and increased dyspnea because of expiratory airflow limitations. Use of bronchodilator therapy may be beneficial for such individuals (77).
- Exertional dyspnea is a common symptom in people with many types of pulmonary diseases. The modified Borg Category-Ratio 0–10 (CR10) scale (*Figure 8.1*) (133) has been used extensively to measure dyspnea before, during, and after exercise (134). Individuals should be given specific, standardized instructions on how to relate the wording on the scale to their level of breathlessness (125,126). Because dyspnea scales are subjective, some caution is advised in their interpretation as exercise intolerance may be accompanied by exaggerated dyspnea scores without corresponding physiological confirmation (135).

0	No breathlessness at all
0.5	Very, very slight (just noticeable)
1	Very slight
2	Slight breathlessness
3	Moderate
4	Somewhat severe
5	Severe breathlessness
6	
7	Very severe breathlessness
8	
9	Very, very severe (almost maximal)
10	Maximal

FIGURE 8.1 Borg Category-Ratio 0–10 scale modified for dyspnea.

- The 6-MWT is a widely used exercise assessment tool for cardiorespiratory function in PR (83,125,126,136). The test is safe, easy to administer, involves the use of minimal technical resources, is well tolerated, and accurately reflects walking abilities. To obtain valid and reliable results, it is essential to standardize the test procedure (*i.e.*, staff, exercise track or hallway distance/configuration, individual instructions, verbal reinforcement used during testing, type and flow rate of supplemental oxygen, walking aides, and number of trials) (83,125,126,136,137). The minimal clinically important difference in 6-MWT distance has been reported to be a mean of 30 m (98.42 ft) (83,126).
- Incremental (ISWT) and endurance (ESWT) shuttle walk tests are also used to assess cardiopulmonary function in individuals with chronic lung disease (138–141). The ISWT is an incremental, symptom-limited walk test that simulates a symptom-limited CPET (142). This test measures a symptom-limited walking distance over a marked walking course of 10 m (33 ft). This distance correlates well with $\dot{V}O_{2peak}$ in individuals with

chronic lung disease (83,143) and has been shown to be a reliable, valid, and responsive measure of estimated functional capacity in interstitial lung disease (144) and asthma (145). The ISWT utilizes an audible pacing timer to incrementally increase the pacing frequency. The individual walks according to the pacing timer frequency until they are too breathless to continue or cannot keep pace with the external pacing signal. Like the 6-MWT, the primary test result of the ISWT is the total distance walked. The ESWT is a derivative of the ISWT, where the individual walks as long as possible at a predetermined percentage of maximum walking performance assessed by the ISWT on a subsequent day of testing (141). For this test, the outcome measure is total time walked (minute).

- The exercise testing mode is typically either walking or stationary cycling. Walking protocols may be more suitable for individuals with severe disease who lack the muscle strength to overcome the increasing resistance of cycle leg ergometers.
- Although arm ergometry is a good adjunct to aerobic weight-bearing exercises, it should be used with caution in individuals with COPD because it can result in increased dyspnea that may limit the intensity and duration of the activity.
- In addition to standard termination criteria (77,126) exercise testing may be terminated because of severe arterial oxyhemoglobin desaturation (*i.e.*, SaO_2 ≤80%) (125).

Exercise Prescription

Presently, there are no evidence-based guidelines that describe the specific application of the FITT principle for individuals with COPD, although expert reviews, official statements, and clinical practice guidelines for the components of the FITT principle have been published (76,77,79,80) and tend to be in general agreement.

Aerobic exercise training is recommended for individuals in all stages of COPD who are able to exercise (77,79,82). Pulmonary diseases and their treatments affect both the lungs and skeletal muscles (*i.e.*, limb muscle dysfunction due to atrophy and weakness) (146–150). Resistance training is the most potent intervention to address the muscle dysfunction seen in COPD and should be an integral part of the Ex R_x (77,79,80,151,152). The effects of resistance training on disease outcome and pulmonary function are not yet well understood in individuals with chronic lung diseases. However, limited evidence from a systematic review and meta-analysis on resistance training outcomes in individuals with COPD demonstrated improvements in forced vital capacity (FVC) and peak minute ventilation ($\dot{V}E_{peak}$) but not $FEV_{1.0}$ (153).

Of paramount concern is the common observation of falls in people with COPD (154,155). Because muscle weakness, gait, and balance abnormalities are among the risk factors for falling (156), lower extremity muscle strengthening and balance training are effective countermeasures. As such, functional exercises for balance, posture, and proper gait should be incorporated into PR exercise training sessions (82,88).

Exercise Training Considerations

- Higher intensities yield greater physiologic benefits (*e.g.*, reduced $\dot{V}E$ and HR at a given workload) and should be encouraged when appropriate (76,79).
- For individuals with mild COPD, intensity guidelines for healthy older adults are appropriate (see *Chapter 6*). For those with moderate-to-severe COPD, intensities representing <60% peak work rate have been recommended (77).
- Light intensity aerobic exercise is appropriate for those with severe COPD or very deconditioned individuals. Intensity may be increased as tolerated within the target time window.
- Interval training may be an alternative to standard continuous endurance training for those who have difficulty in achieving their target exercise intensity due to dyspnea, fatigue, or other symptoms (146,157). Interval

training is a modification of endurance training in which higher intensity exercise is interspersed with periods of rest or lower intensity exercise (77). Several randomized, controlled trials (98,157–160) and systematic reviews (161,162) have found no clinically important differences between interval and continuous training protocols in exercise capacity, health-related quality of life, and skeletal muscle adaptations following training. Thus, individual characteristics will warrant the use of either interval or continuous exercise training protocols.

- Supervision at the outset of training allows guidance in correct execution of the exercise program, enhanced safety, and optimizing benefit (163).
- Ventilatory limitation at peak exercise in individuals with severe COPD coincides with significant metabolic reserves during whole body exercise (164). This may allow these individuals to tolerate relatively high work rates that approach peak levels (80) and achieve significant training effects.
- As an alternative to using peak work rate or O_{2peak} to determine exercise intensity, dyspnea ratings of between 3 and 6 on the Borg CR10 scale may be used (see *Figure 8.1*) (77,165). A dyspnea rating between 3 and 6 on the Borg CR10 scale has been shown to correspond with 53% and 80% of O_{2peak}, respectively (165). Most individuals with COPD can accurately and reliably produce a dyspnea rating obtained from an incremental exercise test as a target to regulate/monitor exercise intensity.
- Intensity targets based on percentage of estimated HR_{max} or HRR may be inappropriate (166). Particularly in individuals with severe COPD, resting heart rate (HR_{rest}) is often elevated, and ventilatory limitations as well as the effects of some medications prohibit attainment of the predicted HR_{max} and thus its use in exercise intensity calculations.
- The use of oximetry is recommended for the initial exercise training sessions to evaluate possible exercise-induced oxyhemoglobin desaturation and to identify the workload at which desaturation occurred.

- Flexibility exercises may help overcome the effects of postural impairments that limit thoracic mobility and therefore lung function (77).
- Regardless of the prescribed exercise intensity, the exercise professional should closely monitor initial exercise sessions and adjust exercise intensity and duration according to individual responses and tolerance. In many cases, the presence of symptoms, particularly dyspnea/breathlessness, supersedes objective methods of Ex R_x.

FITT — FITT RECOMMENDATIONS FOR INDIVIDUALS WITH CHRONIC OBSTRUCTIVE PULMONARY DISEASE (76,77,79,80,167)

	Aerobic	Resistance	Flexibility
Frequency	Minimally 3 d · wk^{-1}; preferably up to 5 d · wk^{-1}	At least 2 d · wk^{-1} performed on nonconsecutive days.	≥2–3 d · wk^{-1} with daily being most effective.
Intensity	Moderate-to-vigorous intensity (50%–80% peak work rate or 4–6 on the Borg CR10 scale).	Strength: 60%–70% of 1-RM for beginners; ≥80% for experienced weight trainers. Endurance: <50% of 1-RM.	Stretch to the point of feeling tightness or slight discomfort.
Time	20–60 min · d^{-1} at moderate-to-high intensities as tolerated. If the 20- to 60-min durations are not achievable, accumulate ≥20 min of exercise interspersed with intermittent exercise rest periods of lower	Strength: 2–4 sets, 8–12 repetitions Endurance: ≤2 sets, 15–20 repetitions.	10–30 s hold for static stretching; 2–4 repetitions of each exercise.

	intensity work or rest.		
Type	Common aerobic modes including walking (free or treadmill), stationary cycling, and upper body ergometry.	Weight machines, free weight, or body weight exercises.	Static, dynamic, and/or PNF stretching.

1-RM, one repetition maximum; PNF, proprioceptive neuromuscular facilitation.

Special Considerations

- Peripheral muscle dysfunction contributes to exercise intolerance (146) and is significantly and independently related to increased use of health care resources (168), poorer prognosis (169), and mortality (170), which emphasizes the importance of strength training in these individuals. Maximizing pulmonary function using bronchodilators before exercise training in those with airflow limitation can reduce dyspnea and improve exercise tolerance (77).
- Because individuals with COPD may experience greater dyspnea while performing ADL involving the upper extremities, include resistance exercises for the muscles of the upper body.
- Inspiratory muscle weakness is a contributor to exercise intolerance and dyspnea in those with COPD. In individuals receiving optimal medical therapy who still present with inspiratory muscle weakness and breathlessness, IMT may prove useful in those unable to participate in exercise training or can be used as an adjunct for those who participate in an exercise program (77,79,80,171). IMT improves inspiratory muscle strength and endurance, functional capacity, dyspnea, and quality of life,

which may lead to improvements in exercise tolerance in those with COPD (171) and with asthma (172).

- There are no clear evidenced-based guidelines for IMT for specific chronic lung disease populations, although a training load intensity of ≥30% of maximal inspiratory pressure has been recommended (79).
- Supplemental oxygen is indicated for individuals with a P_aO_2 ≤55 mm Hg or an SaO_2 ≤88% while breathing room air (173). This recommendation applies when considering supplemental oxygen during exercise. In individuals using ambulatory supplemental oxygen, flow rates will likely need to be increased during exercise to maintain SaO_2 levels >88% (77,80,174).
- Individuals suffering from acute exacerbations of their pulmonary disease should limit exercise until symptoms have subsided.

Exercise Training for Pulmonary Diseases Other than Chronic Obstructive Pulmonary Disease

Despite substantially less investigation into the benefits of exercise training in non-COPD chronic lung diseases, strong scientific evidence supports the inclusion of exercise training for many lung diseases and chronic conditions other than COPD with demonstrated clinical and physiologic benefits (81,86,87,107–109,175). Methods for adapting exercise training in individuals with non-COPD chronic lung disease have been published (81), and each program should be modified to include disease-specific strategies based on currently available evidenced-based guidelines.

Pulmonary Arterial Hypertension

Pulmonary arterial hypertension (PAH) is a debilitating and progressive chronic disease that is characterized by pulmonary vascular bed impairment and function. PAH is characterized by elevated pulmonary pressures due to endothelial cell dysfunction and proliferation that contributes to the stiffening, narrowing, and subsequent loss of small pulmonary vessels. This sequence results in signs and symptoms that include fatigue, dyspnea, severe muscle deconditioning, and syncope (77,176). In individuals with PAH, pulmonary arterial stiffness and vasodilatory dysfunction increase vascular resistance during acute exercise, resulting in impaired right ventricular stroke volume and cardiac output, as well as chronotropic incompetence in older individuals (176). In these individuals, pulmonary pressures can increase suddenly and dramatically during exercise, predisposing them to right ventricular decompensation and cardiovascular collapse (177).

Exercise training recommendations have been specifically presented for individuals with stable PAH who are receiving optimal medical management (88,176,178,179). However, the optimal exercise prescription for those with PAH remains unknown (77,85). In general, the following exercise guidelines may be applicable for the individual with PAH (88,176,178,179):

- Due to cardiac remodeling and right ventricular failure often associated with PAH, continuous telemetry ECG monitoring may be useful for detection of high-grade ventricular ectopy or inappropriate bradyarrhythmias.
- Oxygen supplementation may be warranted in many individuals to keep exercise peripheral capillary oxygen saturation (SpO_2) levels >90% due to the potential for hypoxemia, which can further increase pulmonary artery pressures, potentially leading to complex arrhythmias or circulatory collapse.
- Low intensity aerobic exercise consisting of treadmill, level surface walking, recumbent stepper, and arm or cycle ergometry should be employed. The optimal frequency for aerobic exercise sessions is 5 or more $d \cdot wk^{-1}$ (including home exercise) to produce significant gains in overall functional capacity.

- High intensity exercise or activities that may lead to increased intrathoracic pressure or rapid changes in pulmonary hemodynamics such as interval training, heavy weightlifting, or resistive exercise that requires Valsalva effort should be avoided.
- BP, HR, and SaO_2 should be closely monitored during each exercise session.
- Pacing and energy conversation are vitally important for the individual with PAH during PR and home exercise sessions.
- Resistive exercise that utilizes body weight and/or light dumbbells may be sufficient to complement aerobic training regimens. However, machine weights, bands, and tubes have been shown to be safe in those with PAH under proper supervision and may be incorporated on a person-by-person basis.
- Although the 6-MWT is the most common functional capacity assessment technique for those with PAH, CPET provides a wealth of information for individual prognosis and exercise prescription.

Interstitial Lung Disease

Interstitial lung disease (ILD) encompasses a group of disorders characterized by variable degrees of fibrosis and inflammation (or both) in the alveolar compartments of the lung parenchyma. These disorders include IPF, asbestosis, sarcoidosis, and drug-induced pneumonitis, among other related fibrotic lung conditions. Common symptoms of ILD include dry cough, exertional dyspnea, hypoxemia, and exercise intolerance. In contrast to COPD, individuals with ILD typically have low lung volumes and reduced diffusing capacity, resulting in a rapid, shallow breathing pattern. These individuals oftentimes require oxygen supplementation due to impaired gas exchange, as their diffusing capacity diminishes, particularly during exercise. The combination of these detrimental cardiopulmonary changes results in increased dead space ventilation and respiratory rate, peripheral muscle dysfunction, exertional hypoxemia, and an overall diminished health-related quality of life (110,180).

Exercise guidelines have been presented for those with ILD (81,107–109):

- The FITT guidelines are similar to those for COPD, although moderate intensity aerobic exercise should comprise the core component of the exercise program.
- Exercise intensity should be below that which provokes severe dyspnea, oxygen desaturation, or hypertension.
- A high fraction of inspired oxygen (FIO_2) may be required during exercise training due to exertional hypoxemia.
- A strong focus on pacing and energy conservation techniques should be incorporated into the exercise prescription as well as preexercise use of bronchodilators and gradual warm-up.
- As with most chronic lung conditions, CPET is valuable in these individuals due to the complex, multifactorial basis of exercise limitations of ILD.

Cystic Fibrosis

CF is a hereditary disease that affects the lungs and digestive system where the body produces excessively thick, viscous mucus that clogs the lungs and obstructs the pancreas. CF leads to major morbidity with symptoms of cough, sputum production, dyspnea, intermittent hemoptysis, exercise intolerance, functional impairment, and decreased quality of life (88). Although there is no cure for CF, regular exercise and increased levels of PA have been shown to be beneficial for the individual with CF. Higher levels of physical fitness have been associated with better survival rates in individuals with CF (181). Exercise programming used in individuals with COPD is applicable to those with CF before and after lung transplantation (182) when modifications are adapted to the individual's exercise tolerance. Maintenance of adequate nutrition, regular use of airway clearance techniques, pacing/energy conservation, and infection control should be a priority for the individual with CF. Specific CF exercise prescription guidelines for children, adolescents, and adults have been presented (183).

Lung Transplantation

Exercise plays a critical role for lung transplant individuals, both pre- and posttransplant. Exercise capacity is an important predictor of thoracic surgery outcomes and survival (182), thus, increased exercise tolerance has the potential to improve surgical outcomes. Pretransplant PR can help individuals to optimize and maintain functional status before surgery to better tolerate the rigors of the transplant process (77). Although there are currently no evidenced-based published exercise guidelines for lung transplant individuals, exercise recommendations have been presented (77,88):

- Pretransplant, individuals should exercise close to the highest workload that they can tolerate from the standpoint of dyspnea and fatigue.
- Exercise should be closely supervised to ensure that the prescribed workload can be safely tolerated to the level of intensity that will have a beneficial effect.
- Exercise should be continued up to the time of surgery in a PR program, complimented by home exercise.
- Individual education is crucial for the lung transplant person, with topics that include the surgical procedure, posttransplant wound care, potential complications of transplantation, management of anxiety/depression, methods of assisted ventilation, and strategies to optimize nutrition.
- Interval training has been associated with lower levels of dyspnea and fewer untended breaks in lung transplant candidates compared to continuous training while achieving similar improvements in overall exercise capacity (195). Thus, interval training may be a preferred mode of exercise for the PR individual.
- Exercise intolerance and functional disability often persist after lung transplant despite restoration of near-normal lung function dynamics and pulmonary gas exchange.
- Skeletal muscle dysfunction plays a major role in exercise impairment for the lung transplant individual. Postoperative rehabilitation can begin as

early as 24 h after surgery to minimize the detrimental effect of immunosuppressants and bed rest on skeletal muscle.

- Rehabilitation in the early postoperative period should include ROM exercises, transfer activities (*e.g.*, sit to stand), breathing pattern efficiency training, and airway clearance education.
- Poor posture and gait may aggravate incisional discomfort. Balance, posture, and gait should be monitored closely postsurgery, and exercises should be incorporated to improve each, when indicated.
- Intensive aerobic or resistive exercise should be avoided 4–6 wk posttransplant, particularly those activities involving the upper extremities, to assure proper incisional healing.
- Musculoskeletal problems may arise once an individual is exercising at a higher intensity or duration level posttransplant.

Other Tests of Muscular Fitness for Individuals with Chronic Lung Disease

There are a number of validated physical function tests in senior adults that may be used to assess upper and lower muscular strength and endurance in PR populations. Testing is performed at program entry and periodically thereafter for assessment of individual improvement or decline. Upper and lower body muscular power (*e.g.*, watts) may be assessed from some of these tests. These types of tests include, but are not limited to, the following:

- Timed Up and Go (TUG) test (185,186)
- Five-Times-Sit-To-Stand test (187)
- 30-Second Chair Stand test (188)
- 30-Second Arm Curl test (189)
- 6-Minute Pegboard and Ring test (190)
- Handgrip dynamometer test (191–193)
- The seated medicine ball throw test (194)
- The gallon jug shelf transfer test (195)

Although normative data currently do not exist for many of these tests for individuals with chronic lung disease, published normative values may provide a reasonable reference point to determine rate of improvement (or decline) over time. These data may also show the individual how they compare to individuals in their particular age category (189). Consideration must be given to the severity and type of lung disease, comorbidities, musculoskeletal abnormalities, and hypoxemia with regular subjective and objective assessment of these types of tests. Until these (and other) muscular fitness tests have been validated in pulmonary populations, test results should be viewed with caution when comparing normative values to geriatric populations.

ONLINE RESOURCES

American Association for Cardiovascular and Pulmonary Rehabilitation: http://www.aacvpr.org

American Heart Association: https://www.heart.org/en/health-topics/cardiac-rehab

American Lung Association: http://www.lungusa.org/lung-disease/copd/

EPR3: Guidelines for the Diagnosis and Management of Asthma (Expert Panel Report 3): http://www.nhlbi.nih.gov/guidelines/asthma/asthgdln.htm

CTSNet. Goodbye Sternal Precautions, Hello Move in the Tube? https://www.ctsnet.org/article/goodbye-sternal-precautions-hello-move-tube

Global Initiative for Asthma: http://www.ginasthma.org

Global Initiative for Chronic Obstructive Lung Disease: https://goldcopd.org/gold-reports/

Society for Vascular Medicine: http://www.vascularmed.org

American Stroke Association: http://www.strokeassociation.org

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CHAPTER 9

Exercise Prescription for Individuals with Metabolic Disease and Cardiovascular Disease Risk Factors

INTRODUCTION

This chapter contains the exercise prescription (Ex R_x) guidelines and recommendations for individuals with metabolic and cardiovascular disease (CVD) risk factors. The Ex R_x guidelines and recommendations are presented using the *F*requency, *I*ntensity, *T*ime, and *T*ype (*FITT*) principle of Ex R_x based on the available literature. For information relating to volume and progression, exercise professionals are referred to *Chapter 5*. Information is often lacking regarding volume and progression for the chronic diseases and health conditions presented in this chapter. In these instances, the guidelines and recommendations provided in *Chapter 5* for apparently healthy populations should be adapted with good clinical judgment for the chronic disease(s) and health condition(s) being targeted.

DIABETES MELLITUS

Diabetes mellitus (DM) is a group of metabolic diseases characterized by an elevated blood glucose concentration (*i.e.*, hyperglycemia) as a result of defects in insulin secretion and/or an inability to use insulin. Sustained elevated blood glucose levels place individuals at risk for long-term complications such as microvascular diseases (*e.g.*, retinopathy, nephropathy), macrovascular comorbidities (*e.g.*, coronary artery disease [CAD], peripheral artery disease), as well as neuropathies (peripheral and autonomic). Furthermore, those with DM are more likely to have a higher prevalence of other elevated CVD risk factors (*e.g.*, dyslipidemia, inflammatory markers) compared to those without DM. According to the Centers for Disease Control and Prevention, 30.3 million people, or 9.4% of the U.S. population, have diabetes, with 23.8% of those undiagnosed (1). Four types of diabetes are recognized based on etiologic origin: Type 1 diabetes mellitus (T1DM), Type 2 diabetes mellitus (T2DM), gestational (*i.e.*, diagnosed during pregnancy), and other specific origins (*i.e.*, genetic defects and drug induced); however, most individuals have T2DM (90%–95% of all cases) followed by T1DM (5%–10% of all cases) (1).

T1DM is most often caused by the autoimmune destruction of the insulin producing β cells of the pancreas, although some cases are idiopathic in origin (2). The primary characteristics of individuals with T1DM are nearly absolute insulin deficiency and a high tendency for ketoacidosis. T2DM is driven by insulin-resistant skeletal muscle, adipose tissue, and liver combined with an insulin secretory defect. A common feature of T2DM is excess body fat with fat distributed in the upper body (*i.e.*, abdominal or central obesity) (2). Assigning the type of diabetes frequently depends on the circumstances present at the time of diagnosis, with some individuals not necessarily fitting clearly into a single category (such as having T1DM or T2DM) and clinical presentation and disease progression may vary considerably between the various types of diabetes (2). For example, those with T2DM who are on insulin therapy may have similar risks (*e.g.*, hypoglycemia or ketoacidosis) as those with T1DM.

Central obesity and insulin resistance often progress to prediabetes, a condition characterized by (a) elevated blood glucose in response to dietary carbohydrate, termed *impaired glucose tolerance* (IGT), and/or (b) elevated blood glucose in the fasting state, termed *impaired fasting glucose* (IFG) (*Table 9.1*). Individuals with prediabetes are at very high risk to develop diabetes because the capacity of the β cells to hypersecrete insulin diminishes over time and becomes insufficient to restrain elevations in blood glucose.

TABLE 9.1 • Diagnostic Criteria for Prediabetes and Diabetes Mellitus (2)

Normal	Prediabetes	Diabetes Mellitus
HbA1C <5.7% (≤38 mmol · mol^{-1})	HbA1C = 5.7%−6.4% (39–47 mmol · mol^{-1})	HbA1C ≥6.5% (≥48 mmol · mol^{-1})
FPG <100 mg · dL^{-1} (5.6 mmol · L^{-1})	FPG = 100–125 mg · dL^{-1} (5.6−6.9 mmol · L^{-1}) (IFG)	FPG ≥126 mg · dL^{-1} (7.0 mmol · L^{-1})
2-h PG <140 mg · dL^{-1} (7.8 mmol · L^{-1}) during an OGTT	2-h PG = 140–199 mg · dL^{-1} (7.8–11.0 mmol · L^{-1}) during an OGTT (IGT)	2-h PG ≥200 mg · dL^{-1} (11.1 mmol · L^{-1}) during an OGTT
		In an individual with classic symptoms of hyperglycemia or hyperglycemic crisis, a random PG ≥200 mg · dL^{-1} (11.1 mmol · L^{-1})

FPG, fasting plasma glucose (at least 8-h fasting); HbA1C, glycolated hemoglobin; IFG, impaired fasting glucose; IGT, impaired glucose tolerance; OGTT, oral glucose tolerance test (75 g glucose); PG, plasma glucose.

The fundamental goal for the management of DM is glycemic control using diet, exercise, and, in many cases, medications such as insulin or other antidiabetic agents. Intensive treatment to control blood glucose reduces the risk of progression of diabetes complications in anyone with the condition (2). Criteria for diagnosis of DM and prediabetes are presented in *Table 9.1*. The American Diabetes Association (ADA) and World Health Organization now endorse using glycated hemoglobin (HbA1C) ≥6.5%, elevated fasting plasma glucose (FPG) (≥126 mg · dL^{-1} or 7.0 mmol · L^{-1}), and 2-h plasma glucose following a 75-g oral glucose tolerance test (OGTT; ≥200 mg · dL^{-1} or 11.1 mmol · L^{-1}) as being equally appropriate as diagnostic methodologies for diabetes (2,3). Further details on the handling of HbA1C, FPG, and OGTT diagnostic tests are highlighted in the 2018 ADA

Classification and Diagnosis of Diabetes recommendations (2). Beyond glycemic control, management of other comorbidities (*e.g.*, obesity, coronary heart disease) and CVD risk factors (*e.g.*, hypertension) are of importance. The presence of these other factors will affect the approach to both exercise testing and Ex R_x.

Benefits of Regular Physical Activity for Diabetes

Physical activity (PA) is a key management tool for any type of diabetes and can assist in preventing multiple diabetes-related health complications, insulin resistance, and T2DM progression. Regular exercise undertaken by individuals with T2DM results in improved glucose tolerance (4–7). Other important benefits for individuals with T1DM, T2DM, or prediabetes include improvements in multiple CVD risk factors and overall quality of life (8–10). Regular exercise participation may also prevent or delay the transition to T2DM for individuals with prediabetes at high risk for developing the disease (11). In those with T1DM, exercise may improve insulin sensitivity, thus lowering requirements for exogenous insulin despite having no to little impact on pancreatic function (12). A decreased insulin dose has been linked to lower risk of CAD in T1DM (13). Further benefits of regular PA include improved all-cause and CVD mortality risk profile as well as decreased risk for stroke (14,15). Those with diabetes also experience an increased risk for deleterious psychological conditions such as depression (16), which are associated with impaired glucose control among other risk factors. Regular PA has been shown to improve psychological profiles in those with diabetes, which may improve biological markers such as glucose homeostasis (16).

Moderate intensity exercise totaling 150 min · wk^{-1} is associated with reduced morbidity and mortality in observational studies in all populations, including those with DM (17). Prolonged sedentary time has been found to be independently associated with deleterious health outcomes, such as T2DM and all-cause mortality; however, the deleterious outcome effects associated with sedentary time generally decrease with higher levels of PA (17,18). Moreover, the interruption of sedentary time, via increasing overall PA as well as through multiple bouts of activity, is beneficial for glycemic control. Thus, all individuals with DM or prediabetes should be encouraged to be regularly physically active, including more daily physical movement, structured exercise, and decreased overall sedentary time, to improve their health and longevity.

Exercise Testing

The following are special considerations for exercise testing in individuals with DM:

- When beginning an exercise program of light to moderate intensity, exercise testing, is generally not necessary for individuals with DM or prediabetes who are asymptomatic for CVD (8,10,19,20). The American College of Sports Medicine (ACSM) does encourage those with DM who are sedentary, even if asymptomatic for CVD, to receive medical clearance before beginning an exercise program independent of desired intensity. In contrast, the ADA concludes medical clearance is not warranted in those with DM and asymptomatic for CVD wishing to begin an exercise program of light to moderate intensity (10).
- Electrocardiogram (ECG) stress testing may be indicated for individuals with DM (8,10,21), especially anyone who has been sedentary and desires to participate specifically in vigorous intensity activities.
  - If positive or nonspecific ECG changes in response to exercise are noted or nonspecific ST, and T wave changes at rest are observed, follow-up diagnostic testing may be performed. However, the Detection of Ischemia in Asymptomatic Diabetes trial involving 1,123 individuals with T2DM and no symptoms of CAD, found that screening with adenosine-stress radionuclide myocardial perfusion imaging for myocardial ischemia over a 4.8-yr follow-up period did not alter rates of cardiac events (22). Results from the DYNAMIT trial found similar results in which detection of silent ischemia in asymptomatic individuals provided no benefit in predicting risk of future cardiac events (23). Thus, the cost-effectiveness and diagnostic value of more intensive testing remains in question. Furthermore, the most recent statement by the U.S. Preventive Services Task Force suggests against the use of resting or exercise ECG to predict cardiac events in asymptomatic adults (24).
- Silent ischemia in individuals with DM often goes undetected (25); therefore, annual CVD risk factor assessments should be conducted (8,10).

Exercise Prescription

The FITT principle of Ex R_x for healthy adults generally applies to individuals with DM (see *Chapter 5*) without complications. In those with other complications/comorbidities, Ex R_x should be modified as appropriate to these other conditions. Participating in an exercise program confers benefits that are extremely important to individuals with T1DM and T2DM. Thus, maximizing the cardiovascular and metabolic benefits resulting from exercise is a key outcome for both types of diabetes. Healthy weight loss and maintenance of appropriate body weight are often issues for those with T2DM and prediabetes, but excess body weight and fat can be present in those with T1DM as well, and an exercise program can be useful for either (see “Overweight and Obesity” and “Metabolic Syndrome” sections).

A recent systematic review and meta-analysis found no evidence that resistance exercise differs from aerobic exercise in the beneficial impact on multiple cardiovascular risk factors or safety in individuals with T2DM with the exception of HbA1C, with resistance exercise decreasing HbA1C in a greater magnitude although not clinically significant (26). It is important to also note that aerobic exercise significantly increased cardiorespiratory fitness (CRF) in greater magnitude compared to resistance exercise. CRF has been shown to be one of the strongest independent predictors of mortality among those with T2DM (27–29). Thus, it is encouraged that those with T2DM, and those with T1DM, participate in sufficient volumes of both aerobic exercise and resistance exercise. Several studies have provided evidence to suggest a combination of aerobic exercise and resistance exercise is superior to only aerobic or only resistance exercise in the management of glucose homeostasis as well as other risk factors (7,30). Whether the added benefits are caused by a greater overall caloric expenditure (31) or by the combination of aerobic and resistance training (12,30,32) has not yet been fully resolved.

FITT	FITT RECOMMENDATIONS FOR INDIVIDUALS WITH DIABETES (9,10,33,34)		
	Aerobic	**Resistance**	**Flexibility and Balance**
Frequency	3–7 d · wk^{-1} No more than 2 consecutive days without activity	A minimum of 2 nonconsecutive d · wk^{-1}, but preferably 3 d	≥2–3 d · wk^{-1} for both
Intensity	Moderate to vigorous (based on subjective experience of “moderate” to “very hard”)	Moderate (50%–69% of 1-RM) to vigorous (70%–85% of 1-RM) to improve strength	Stretch to the point of tightness or slight discomfort. Balance exercises: light to moderate intensity
Time	T1DM and T2DM: 150 min · wk^{-1} at moderate to vigorous intensity	At least 8–10 exercises with 1–3 sets of 10–15 repetitions to near fatigue per set early in training	Hold static stretch for 10–30 s; 2–4 repetitions of each exercise. Balance for any duration.
Type	Prolonged, rhythmic activities using large muscle groups (*e.g.*, walking, cycling, swimming Continuous activity or HIIT	Resistance machines, free weights, resistance bands, and/or body weight	Static, dynamic, other stretching, yoga

Unstructured activity (errands, housework, yard work) is encouraged in those with diabetes to aid in reducing sedentary time, increasing daily energy expenditure and assisting with weight management (10).
1-RM, one repetition maximum; HIIT, high-intensity interval training; T1DM; Type 1 diabetes mellitus; T2DM, Type 2 diabetes mellitus.

Exercise Training Considerations

- Many people with DM have comorbid conditions; tailor the Ex R_x accordingly. Many individuals with prediabetes or DM are at high risk for or have CVD (see *Chapter 8*).
- Most individuals with T2DM and prediabetes and many with T1DM are overweight or obese (see "Overweight and Obesity" section and the relevant ACSM position stand [35]).
- Due to low initial fitness levels, most individuals with T2DM will require at least 150 min · wk^{-1} of moderate-to-vigorous aerobic exercise to achieve optimal CVD risk reduction and increases CRF (8,10).
- Interspersing very short, high intensity intervals during moderate intensity aerobic exercise may be useful to lessen the decline in blood glucose during the early postexercise recovery period (36,37).
- Given the established importance of CRF, a greater emphasis should eventually be placed on vigorous intensity aerobic exercise if not contraindicated by diabetes-related complications. Better overall blood glucose control may be achieved by engaging in vigorous intensity exercise training as well. Both high-intensity interval training (HIIT) and continuous training are recommended forms of vigorous intensity exercise for individuals with DM (9,10,38). For T2DM, allow no more than two consecutive days without aerobic exercise to prevent a period of excessive decline of insulin action/insulin sensitivity.
- Resistance training should be encouraged for individuals with DM or prediabetes in the absence of contraindications, such as uncontrolled hypertension, severe proliferative retinopathy, and recent treatments using laser surgery. Higher resistance (*i.e.*, heavier weight) may be beneficial for optimization of skeletal muscle strength, insulin action, and blood glucose (34,39,40) control, although moderate resistance may be equally effective in previously sedentary individuals (41).
- Appropriate progression of resistance exercise is important to prevent injury because those with T2DM often have an increased risk for tendinopathy (42) and may have limited joint mobility due to the process of glycation of collagen, especially older adults (43). Beginning training intensity should be moderate, involving 10–15 repetitions per set, with increases in weight or resistance undertaken with a lower number of repetitions (8–10) only after the target number of repetitions per set can consistently be exceeded (10,43). This increase in

resistance can be followed by a greater number of sets and lastly by increased training frequency (44).

- During combined training, completing resistance training prior to aerobic training may lower the risk of postexercise hypoglycemia in individuals with T1DM (37,45,46). HIIT training, combining both anaerobic and aerobic exercise, may have a similar effect (37,46).
- Although flexibility training may be desirable for individuals with all types of diabetes, it should not substitute for other recommended activities (*i.e.*, aerobic and resistance training) because flexibility training does not affect glucose control, body composition, or insulin action.
- Potential complications/contraindications may affect the appropriateness of some types of activities (*e.g.*, diabetic retinopathy, autonomic and peripheral neuropathy, nephropathy). See the following references for more information (10,16).
  - Individuals with DM and retinopathy are at risk for vitreous hemorrhage. However, risk may be minimized by avoiding activities that dramatically elevate blood pressure (BP). Anyone with severe nonproliferative and proliferative diabetic retinopathy should avoid vigorous intensity aerobic and resistance exercise, jumping, jarring, head-down activities and the Valsalva maneuver (10).
- During exercise, autonomic neuropathy may cause chronotropic incompetence (*i.e.*, a blunted heart rate [HR] response), attenuated volume of oxygen consumed per unit of time ($\dot{V}O_{2max}$) kinetics, and anhydrosis (*i.e.*, water deprivation) (10). In the presence of autonomic neuropathy, the following should be considered:
  - Monitor for signs and symptoms of silent ischemia, such as unusual shortness of breath or back pain, because of the inability to perceive angina.
  - Monitor BP before and after exercise to manage hypotension and hypertension associated with vigorous intensity exercise (see "Hypertension" section).
  - HR and BP responses to exercise may be blunted secondary to autonomic dysfunction. Rating of perceived exertion (RPE) should be used to assess exercise intensity (32).
- For individuals with peripheral neuropathy, proper care of the feet is needed to prevent foot ulcers and lower the risk of amputation (10). Special precautions should be taken to prevent blisters on the feet. Feet should be kept dry, and silica gel or air midsoles as well as polyester or blend socks should be used. All

individuals should closely examine their feet on a daily basis to detect and treat sores or ulcers early. Consideration of more non-weight-bearing activities is encouraged

- For individuals with nephropathy, exercise does not appear to accelerate progression of kidney disease even though protein excretion acutely increases after exercise (10,16,47). Both aerobic and resistance training improve physical function and quality of life in individuals with kidney disease, and individuals should be encouraged to be active. Exercise should begin at a low intensity and volume if aerobic capacity and muscle function are substantially reduced (10,48) (see *Chapter 10* for more on exercise and renal disease).

Special Considerations

- Hypoglycemia is the most common, acute concern for individuals taking insulin or certain oral hypoglycemic agents that increase insulin secretion (10).
  - Hypoglycemia, defined as a blood glucose level <70 mg · dL^{-1} (<3.9 mmol · L^{-1}) (49), is a relative contraindication to beginning an acute bout of exercise (8).
  - Rapid decreases in blood glucose may occur with exercise and render individuals symptomatic even when blood glucose is well above 70 mg · dL^{-1}. Conversely, blood glucose levels may decrease in some individuals without generating noticeable symptoms (*i.e.*, *hypoglycemic unawareness*).
  - Common adrenergic symptoms associated with hypoglycemia include shakiness, weakness, abnormal sweating, nervousness, anxiety, tingling of the mouth and fingers, and hunger. More severe neuroglycopenic symptoms may include headache, visual disturbances, mental dullness, confusion, amnesia, seizures, and coma.
- Individuals with DM who take insulin or medications that increase insulin secretion should monitor blood glucose levels before, occasionally during (if needed), and after exercise and compensate with appropriate dietary and/or medication regimen changes (in consultation with their health care provider) as needed to maintain euglycemia (8,10,37) (see [50]). (See [10], p. 2069, *Table 2*, for dose reduction recommendations.)
- For those with diabetes, preexercise optimal blood glucose levels are between 90 and 250 mg · dL^{-1} (5.0 and 13.9 mmol · L^{-1}). The ADA provides guidelines on

carbohydrate ingestion based on preexercise blood glucose levels (10).

- Hypoglycemia risk is higher during and immediately following primarily moderate intensity aerobic exercise but can occur up to 12 h or more postexercise, making food and/or medication adjustments necessary, mostly in insulin users (37,51). However, aerobic exercise at a vigorous intensity has been shown to decrease/lessen the speed in which blood glucose declines following exercise (52). Also, performing resistance exercise before aerobic exercise may elicit similar effects (37). Nonetheless, frequent blood glucose monitoring is the key to detecting and preventing later onset hypoglycemia.
- Sulfonylurea drugs and other compounds that enhance insulin secretion (*e.g.*, glyburide, glipizide, glimepiride, nateglinide, and repaglinide) increase the risk of hypoglycemia because the effects of insulin and muscle contraction on blood glucose uptake are additive (53,54). Blood glucose monitoring is recommended when beginning a program of regular exercise to assess whether changes in these medication doses are necessary.
- The timing of exercise is particularly important in individuals taking insulin. Changing insulin timing, reducing insulin doses, and/or increasing carbohydrate intake are effective strategies to prevent hypoglycemia and hyperglycemia during and after exercise (55). Early morning exercise, in particular, may result in elevations in blood glucose levels instead of the usual decrease with moderate activity (56).
- Prior to planned exercise, rapid- or short-acting insulin doses will likely have to be reduced to prevent hypoglycemia, particularly if exercise occurs during peak insulin times (usually within 2–3 h). Synthetic, rapid-acting insulin analogs (*i.e.*, lispro, aspart, and glulisine) induce more rapid decreases in blood glucose than regular human insulin.
- Longer acting basal insulins (*e.g.*, glargine, detemir, and neutral protamine Hagedorn [NPH]) are less likely to cause exercise-induced hypoglycemia (57), although overall doses may need to be reduced to accommodate regular training.
- For individuals with T1DM using insulin pumps, insulin delivery during exercise can be markedly reduced by decreasing the basal rate or disconnecting the pump for short durations, depending on the intensity and duration of exercise. Reducing basal insulin delivery rates for up to 12 h postexercise may be necessary to avoid later onset hypoglycemia.
- Continuous glucose monitors can be very useful in detecting patterns in blood glucose across multiple days and evaluating both the immediate and delayed

effects of exercise (10,37,58).

- Individuals with DM who have experienced exercise-induced hypoglycemia should ideally exercise with a partner or under supervision to reduce the risk of problems associated with hypoglycemic events. During exercise, carrying medical ID identifying diabetes, a cell phone, and glucose tablets or other rapid carbohydrate treatment for hypoglycemia is recommended.
- Diabetic autonomic neuropathy, long-duration T1DM, and recent antecedent hypoglycemia or exercise contribute to impaired epinephrine and other hormonal responses and hypoglycemia unawareness (59), so frequent blood glucose monitoring is warranted. In older individuals with T2DM, the joint occurrence of hypoglycemia unawareness and deteriorated cognitive function is a critical factor that needs to be considered in their exercise blood glucose management (60).
- Hyperglycemia with or without ketosis is a concern for individuals with T1DM who are not in adequate glycemic control. Common symptoms associated with hyperglycemia include polyuria, fatigue, weakness, increased thirst, and acetone breath. Individuals who present with hyperglycemia (*i.e.*, blood glucose ≥250 mg $\cdot$ dL^{-1} or 16.7 mmol $\cdot$ L^{-1}), provided they feel well and have no ketones present when testing either blood or urine, may exercise up to a moderate intensity; however, they should test blood glucose frequently, refrain from vigorous intensity exercise until glucose levels are declining, and ensure adequate hydration (10).
- It is recommended that individuals with T1DM check for urine ketones when blood glucose levels are ≥250 mg $\cdot$ dL^{-1} (13.9 mmol $\cdot$ L^{-1}) before starting to exercise (10,61). Exercise should be postponed when both hyperglycemia and ketones are evident.
- If blood glucose levels are ≥350 mg $\cdot$ dL^{-1} (≥19.4 mmol $\cdot$ L^{-1}), even without ketones present, conservative corrective insulin therapy is recommended before exercise (10).
- If blood glucose has been elevated for <2–3 h following a meal, individuals with T2DM will likely experience a reduction in blood glucose during aerobic exercise because endogenous insulin levels will be high (53,62). Those with T1DM may experience similar declines in blood glucose levels if injected or pumped levels of insulin are higher during postprandial exercise.
- Regardless of initial blood glucose levels, vigorous activity of any type may cause elevations in glucose due to an exaggerated release of counterregulatory

hormones like epinephrine and glucagon (63). In such cases, individuals with T1DM may need small doses of supplemental insulin to lower postexercise hyperglycemia.

- Dehydration resulting from polyuria secondary to hyperglycemia may contribute to a compromised thermoregulatory response (10,64). Dehydration may also contribute to elevations in blood glucose levels. Anyone with hyperglycemia has an elevated risk for heat illness and should frequently monitor for signs and symptoms (see *Chapter 7* and other relevant ACSM positions stands [65,66]).
- Given the likelihood that thermoregulation in hot and cold environments is impaired (10, p. 2074) in those with DM, additional precautions for heat and cold illness are warranted (see *Chapter 7* and other relevant ACSM positions stands [65–67]).

ONLINE RESOURCES

American College of Sports Medicine position stand on exercise and Type 2 diabetes mellitus: https://www.acsm.org/acsm-positions-policy/official-positions
American Diabetes Association: http://www.diabetes.org
Diabetes Motion (for information about exercising safely with diabetes): http://www.diabetesmotion.com
National Institute of Diabetes and Digestive and Kidney Diseases: https://www.niddk.nih.gov/

DYSLIPIDEMIA

Dyslipidemia is an abnormal amount of lipids (*e.g.*, cholesterol) in the blood. It is further defined by the presence of elevated levels of total cholesterol or low-density lipoprotein (LDL-C), elevated levels of triglycerides (TG), or low levels of high-density lipoprotein (HDL-C). Current definitions for dyslipidemia are found in *Tables 2.4* and *2.5*. Nearly 30% of people in the United States have dyslipidemia (68), a major risk factor for atherosclerotic CVD.

There are many causes of dyslipidemia. The most common contributing cause is poor dietary and lifestyle choices; however, genetics often play a prominent contributing role, and very high levels of cholesterol often cluster within families (both pure familial hypercholesterolemia as well as familial combined hyperlipidemia) (69). Various disease states can also alter blood lipid levels. LDL-C levels are often increased in individuals with hypothyroidism and the nephrotic syndrome. Very high levels of TG are often found in individuals with obesity, insulin resistance, or diabetes. Metabolic syndrome (Metsyn) is partially defined by the presence of high TG levels. Additionally, the use of oral anabolic steroids has been associated with a 20%–70% reduction in HDL-C levels (70).

Lifestyle changes are the foundation for the treatment of dyslipidemia even for individuals who may eventually require medications to treat their dyslipidemia. Exercise is useful to improve dyslipidemia, although the magnitude of effect is often small. Aerobic exercise training consistently reduces LDL-C by 3–6 $mg \cdot dL^{-1}$ (0.17–0.33 $mmol \cdot L^{-1}$) but does not appear to have a consistent effect on HDL-C or TG blood levels (44). Resistance training appears to reduce LDL-C and TG concentrations by 6–9 mg · dL^{-1} (0.33–0.5 mmol · L^{-1}), but results have been less consistent as compared to aerobic exercise (71). Additionally, dietary improvements and weight loss appear to have important beneficial effects on improving dyslipidemia and should be encouraged (72,73).

Statin drugs, also known as hydroxymethylglutaryl-coenzyme A (HMG-CoA) reductase inhibitors, are very effective for the treatment of dyslipidemia (74). When used appropriately, statin therapy consistently improves survival by preventing myocardial infarction and stroke. The four most important groups of people who benefit from statins are (a) individuals with established CVD, (b) individuals with LDL-C levels >190 mg · dL^{-1}, (c) individuals with diabetes who are ≥40 yr, and (d) individuals with an estimated 10-yr risk for CVD of ≥7.5%. The 10-yr risk score is based on the presence and severity of risk markers for heart disease and can be calculated using readily available online calculators (see "Online Resources" at end of this section). Current guidelines for risk stratification for the determination of drug treatment of dyslipidemia are available in the 2013 American College of Cardiology (ACC)/American Heart Association (AHA) reports on the assessment of cardiovascular risk and on the treatment of blood cholesterol to reduce cardiovascular risk in adults (71,74,75). When considering treatment with medication, the use of evidence-based prescribing guidelines and personalized assessment and decision making are strongly recommended in conjunction with the individual's health care provider.

Overall, the population's blood lipid levels are improving (76). This improvement is attributed to improved cholesterol awareness, changes in dietary eating patterns, reduced trans fat consumption, and increased use of medications (76). However, substantial numbers of people throughout the United States and the world still have uncontrolled dyslipidemia, and in the past decade, the population rate of improvement in dyslipidemia appears to have slowed (76).

The ACSM makes the following recommendations regarding exercise testing and training of individuals with dyslipidemia.

Exercise Testing

- In general, an exercise test is not required for asymptomatic individuals prior to beginning an exercise training program at a light to moderate intensity.

- Standard exercise testing methods and protocols are appropriate for use with individuals with dyslipidemia cleared for exercise testing (see *Chapters 3* and *4*).
- Use caution when testing individuals with dyslipidemia because undetected underlying CVD may be present.
- Special consideration should be given to the presence of other chronic diseases and health conditions (*e.g.*, Metsyn, obesity, hypertension) that may require modifications to standard exercise testing protocols and modalities (see the sections of this chapter and other relevant ACSM positions stands on these chronic diseases and health conditions [35,77]).

Exercise Prescription

The FITT principle of Ex R_x for individuals with dyslipidemia without comorbidities is very similar to the Ex R_x for healthy adults (see *Chapter 5*) (44,78). However, an important difference in the FITT principle of Ex R_x for individuals with dyslipidemia compared to healthy adults is that healthy weight maintenance should be highly emphasized. Accordingly, aerobic exercise for the purpose of maximizing energy expenditure (EE) for weight loss becomes the foundation of the Ex R_x, and the FITT recommendations are consistent with the recommendations for healthy weight loss and maintenance of 250–300 min · wk^{-1} (see "Overweight and Obesity" section and the relevant ACSM position stand [35]). Although beneficial for general health, resistance and flexibility exercises should be considered adjuncts to an aerobic training program because these modes of exercise have less consistent beneficial effects in individuals with dyslipidemia (79,80). Flexibility training is recommended for general health benefits only.

FITT	FITT RECOMMENDATIONS FOR INDIVIDUALS WITH DYSLIPIDEMIA (44,79,81)		
	Aerobic	**Resistance**	**Flexibility**
Frequency	≥5 d · wk^{-1} to maximize caloric expenditure	2–3 d · wk^{-1}	≥2–3 d · wk^{-1}
Intensity	40%–75% O_2R or HRR	Moderate (50%–69% of 1-RM) to vigorous (70%–85% of 1-RM) to improve strength	Stretch to the point of tightness or slight discomfort.
Time	30–60 min · d^{-1}. To promote or maintain weight loss, 50–60 min · d^{-1} or more of daily exercise is recommended.	2–4 sets, 8–12 repetitions for strength; ≤2 sets, 12–20 repetitions for muscular endurance	Hold static stretch for 10–30 s; 2–4 repetitions of each exercise
Type	Prolonged, rhythmic activities using large muscle groups (*e.g.*, walking, cycling, swimming)	Resistance machines, free weights, and/or body weight	Static, dynamic, and/or PNF stretching

1-RM, one repetition maximum; HRR, heart rate reserve; O_2R, oxygen uptake reserve; PNF, proprioceptive neuromuscular facilitation.

Exercise Training Considerations

- The FITT principle of Ex R_x may need to be modified should the individuals with dyslipidemia present with other chronic diseases and health conditions such as Metsyn, obesity, and hypertension (see “Metabolic Syndrome,” “Overweight and Obesity,” and “Hypertension” sections and other relevant ACSM position stands on these chronic diseases and health conditions [35,77]).

- Adults older than age 65 yr and with dyslipidemia should follow the ACSM exercise guidelines for older adults (82).
- Performance of intermittent aerobic exercise of at least 10 min in duration to accumulate the duration recommendations appears to be an effective alternative to continuous exercise but should only be performed by those who cannot accumulate 30–60 min of continuous exercise (83).

Special Consideration

- Individuals taking lipid-lowering medications (*i.e.*, statins and fibric acid) may experience muscle weakness and soreness termed *myalgia*. Although rare, these medicines can cause direct and severe muscle injury. A health care provider should be consulted if an individual experiences unusual or persistent muscle soreness when exercising while taking these medications.

ONLINE RESOURCES

American Heart Association:
http://my.americanheart.org/professional/ScienceNews/Clinical-Practice-Guidelines-for-Prevention_UCM_457211_Article.jsp
ASCVD Risk Estimator: http://tools.acc.org/ASCVD-Risk-Estimator-Plus

HYPERTENSION

Chronic primary (essential) hypertension is defined by the ACC/AHA Task Force on Clinical Practice Guidelines recently as having a resting systolic blood pressure (SBP) ≥130 mm Hg or a resting diastolic blood pressure (DBP) ≥80 mm Hg, confirmed by a minimum of two measures taking on at least 2 separate days, or taking antihypertensive mediation for the purpose of BP control (84). Of note, these newly updated thresholds represent a departure from the traditional and long-standing definition of hypertension, defined by the Seventh Report of the Joint National Committee (JNC7) on the Prevention, Detection, Evaluation, and Treatment of High Blood Pressure as having a resting SBP ≥140 mm Hg and/or a resting DBP ≥90 mm Hg, confirmed by a minimum of two measures taken on at least two separate days, or taking antihypertensive medication for the purpose of BP control (85). The JNC7 also previously defined an additional class of individuals with SBP ranging from 120 to 139 mm Hg and/or DBP ranging from 80 to 89 mm Hg as having prehypertension and at heightened risk of developing hypertension in the future (86). It is important to be familiar with both the ACC/AHA and JNC7 BP thresholds and classifications as these changes may result in slight variations in prevalence and control rates and/or influence individual education. See *Table 2.3* for both sets of criteria.

Primary hypertension accounts for 95% of all cases and is a risk factor for the development of CVD and premature mortality (85,87). The known contributors of primary hypertension include genetic and lifestyle factors such as high-fat and high-salt diets and physical inactivity (85,87). Secondary hypertension accounts for the remaining 5%. The principal causes of secondary hypertension are chronic kidney disease, renal artery stenosis, pheochromocytoma, excessive aldosterone secretion, and sleep apnea (85,86). An estimated 78 million U.S. adults ≥20 yr of age and more than 1 billion people worldwide have hypertension (86,88).

Approximately 42 million men and 28 million women (37% of the adult U.S. population) have prehypertension or elevated BP (see *Table 2.3* for all levels of hypertension classification). The 4-yr incidence rate of progression to hypertension is estimated to be 26%–50% among individuals ≥65 yr of age (89). Although the rate of progression from prehypertension to hypertension is positively associated with age, baseline BP, and comorbidities (90), hypertension does not appear to be a fundamental feature of human aging, but the outcome of lifestyle factors (*i.e.*, diets high in salt and fat, excess body weight, and physical inactivity) (90,91).

A variety of medications are available in the treatment of hypertension. Current guidelines for the management of hypertension provide specific instructions on the implementation of pharmacologic therapies (92). Most individuals treated with medication require more than one medication to achieve their targeted BP. Some antihypertensive medications may affect the physiological response to exercise and therefore must be taken into consideration during exercise testing and when prescribing exercise (see *Appendix A*) (77).

Guidelines for the management of hypertension also emphasize lifestyle modifications that include habitual PA as initial therapy to lower BP and to prevent or attenuate progression to hypertension in individuals with prehypertension (77,85,87,92). Other recommended lifestyle changes include smoking cessation, weight management, reduced sodium intake, moderation of alcohol consumption, and an overall health dietary pattern consistent with the Dietary Approaches to Stop Hypertension diet (85,87).

Exercise Testing

Although hypertension is not an indication for exercise testing, the test may be useful to evaluate the BP response to exercise, which may be useful to guide Ex R_x (21). Individuals with hypertension may have an exaggerated BP response to exercise, even if resting BP is controlled (91). Some individuals with prehypertension may also have a similar response (93).

Recommendations regarding exercise testing for individuals with hypertension vary depending on their BP level and the presence of other CVD risk factors (see *Chapter 4*), target organ disease, or clinical CVD (21,77). For most asymptomatic individuals with hypertension and prehypertension, adequate BP management prior to engaging in light-to-moderate intensity exercise programs such as walking is sufficient with no need for medical evaluation or exercise testing (21).

Recommendations include the following:

- Individuals with hypertension whose BP is not controlled (*i.e.*, resting SBP ≥140 mm Hg and/or DBP ≥90 mm Hg) should consult with their physician prior to initiating an exercise program to determine if an exercise test is needed.
- Individuals with stage 2 hypertension (SBP ≥160 mm Hg or DBP ≥100 mm Hg) or with target organ disease (*e.g.*, left ventricular hypertrophy, retinopathy) must not engage in any exercise, including exercise testing, prior to a medical evaluation and adequate BP management. A medically supervised symptom-limited exercise test is recommended prior to engaging in an exercise program for these individuals. Additional evaluations may ensue and vary depending on findings of the exercise test and the clinical status of the individual.
- When exercise testing is performed for the specific purpose of designing the Ex R_x, it is preferred that individuals take their usual antihypertensive medications as recommended (21).
- Individuals on β-blocker therapy are likely to have an attenuated HR response to exercise and reduced maximal exercise capacity. Individuals on diuretic therapy may experience hypokalemia and other electrolyte imbalances, cardiac dysrhythmias, or potentially a false positive exercise test (see *Appendix A*).

Exercise Prescription

- Chronic aerobic exercise of adequate intensity, duration, and volume that promotes an increased exercise capacity leads to reductions in resting SBP and DBP of 5–7 mm Hg and reductions in exercise SBP at submaximal workloads in individuals with hypertension (77,91). Regression of cardiac wall thickness and left ventricular mass in individuals with hypertension who participate in regular aerobic exercise training (93,94) and a lower left ventricular mass in individuals with prehypertension and a moderate-to-high physical fitness status have also been reported (95). Emerging research suggests that dynamic resistance exercise results in BP reductions equal to or greater in magnitude to those experienced following aerobic exercise (96). Therefore, the Ex R_x for individuals with hypertension no longer place an emphasis on aerobic exercise alone but rather encourage a variety of multimodal exercises that reflect personal preference. Individuals with hypertension are recommended to engage in aerobic or resistance exercise alone or aerobic and resistance exercise combined (*i.e.*, concurrent exercise) on most, preferably all, days of the week to total 90–150 min $\cdot$ wk^{-1} (96). In addition, neuromotor exercise should be performed ≥2–3 d $\cdot$ wk^{-1} at low to moderate intensity for ≥20–30 min per session and include exercise involving motor skills and/or functional body weight and flexibility exercise such as yoga, Pilates, and tai chi (96). Flexibility exercise should be performed after a thorough warm-up or during the cool-down period following the guidelines for healthy adults (see *Chapter 5*). Of note, neuromotor functional body weight exercise can be substituted for resistance exercise, and depending on the amount of flexibility exercise integrated into a session, neuromotor flexibility exercise can be substituted for flexibility exercise depending on individual preference.

FITT — FITT RECOMMENDATIONS FOR INDIVIDUALS WITH HYPERTENSION

	Aerobic	Resistance	Flexibility
Frequency	≥5–7 d · wk^{-1}	≥2–3 d · wk^{-1}	≥2–3 d · wk^{-1}
Intensity	Moderate (*i.e.*, 40%–59% O_2R or HRR; RPE 12–13 on a 6–20 scale)	Moderate (*i.e.*, 60%–70% 1-RM; may progress to 80% 1-RM; for older individuals and novice exercisers, begin with 40%–50% 1-RM)	Stretch to the point of feeling tightness or slight discomfort.
Time	≥30 min · d^{-1} of continuous or accumulated exercise	2–4 sets of 8–12 repetitions of each of the major muscle groups per session to total ≥20 min per session with rest days interspersed depending on the muscle groups being exercised	Hold static stretch for 10–30 s with 2–4 repetitions of each exercise targeting the major muscle tendon units to total 60 s of total stretching time for each exercise; ≤10 min per session
Type	Prolonged, rhythmic activities using large muscle groups (*e.g.*, walking, cycling, swimming)	Resistance machines, free weights, resistance bands, and/or functional body weight exercise	Static, dynamic, and/or proprioceptive neuromuscular facilitation

1-RM, one repetition maximum; HRR, heart rate reserve; O_2R, oxygen uptake reserve; RPE, rating of perceived exertion.

Exercise Training Considerations

- Consideration should be given to the level of BP control, recent changes in antihypertensive drug therapy, medication-related adverse effects, the presence of target organ disease, other comorbidities, and age. Adjustments to the Ex R_x should be made accordingly. In general, progression should be gradual, avoiding large increases in any of the FITT components of the Ex R_x, especially intensity for most individuals with hypertension.
- An exaggerated BP response to relatively low exercise intensities and at HR levels <85% of the age-predicted maximal heart rate (HR_{max}) is likely to occur in some individuals, even after resting BP is controlled with antihypertensive medication. In some cases, an exercise test may be beneficial to establish the exercise HR corresponding to the exaggerated BP in these individuals.
- It is prudent to maintain SBP ≤220 mm Hg and/or DBP ≤105 mm Hg when exercising (77).
- Although vigorous intensity aerobic exercise (*i.e.*, ≥60% O_2R) is not necessarily contraindicated in individuals with hypertension, moderate intensity aerobic exercise (*i.e.*, 40%–59% O_2R) is generally recommended to optimize the benefit-to-risk ratio.
- Individuals with hypertension are often overweight or obese. Ex R_x should focus on increasing caloric expenditure coupled with reducing caloric intake to facilitate weight reduction (see "Overweight and Obesity" section and the relevant ACSM position stand [35]).
- Inhaling and breath-holding while engaging in the actual lifting of a weight (*i.e.*, Valsalva maneuver) can result in extremely high BP responses, dizziness, and even fainting. Thus, such practice should be avoided during resistance training.

Special Considerations

- Exercise testing and vigorous intensity exercise training for individuals with hypertension at moderate-to-high risk for cardiac complications should be medically supervised until the safety of the prescribed activity has been established (21).
- β-Blockers and diuretics may adversely affect thermoregulatory function. β-Blockers may also increase the predisposition to hypoglycemia in certain individuals (especially individuals with DM who take insulin or insulin

secretagogue medication that increases pancreas insulin secretion) and mask some of the manifestations of hypoglycemia (particularly tachycardia). In these situations, educate individuals about the signs and symptoms of heat intolerance and hypoglycemia and the precautions that should be taken to avoid these situations (see *Appendix A*).

- β-Blockers, particularly the nonselective types, may reduce submaximal and maximal exercise capacity primarily in individuals without myocardial ischemia (see *Appendix A*). The peak exercise HR achieved during a standardized exercise stress test should then be used to establish the exercise training intensity. If the peak exercise HR is not available, RPE should be used.
- Antihypertensive medications such as α-blockers, calcium channel blockers, and vasodilators may lead to sudden excessive reductions in postexercise BP. Therefore, termination of the exercise should be gradual, and the cool-down period should be extended and carefully monitored until BP and HR return to near resting levels.
- A majority of older individuals are likely to have hypertension. The exercise-related BP reduction is independent of age. Therefore, older individuals experience similar exercise-induced BP reductions as younger individuals (see *Chapter 6* and the relevant ACSM/AHA recommendations [97]).
- The BP-lowering effects of aerobic exercise are immediate, a physiologic response referred to as *postexercise hypotension*. Individuals should be made aware of postexercise hypotension and instructed how to modulate its effects (*e.g.*, continued very light intensity exercise such as slow walking).
- If an individual with hypertension has ischemia during exercise, the Ex R_x recommendations for those with CVD with ischemia should be utilized. See *Chapter 8* for more information.

ONLINE RESOURCES

American College of Sports Medicine position stand on exercise and hypertension: https://www.acsm.org/acsm-positions-policy/official-positions

American Heart Association: http://www.heart.org/HEARTORG/Conditions/HighBloodPressure/PreventionTreatmentofHighBloodPressure/Physical-Activity-and-Blood-Pressure_UCM_301882_Article.jsp

METABOLIC SYNDROME

The Metsyn is characterized by a clustering of risk factors associated with an increased incidence of CVD, DM, and stroke (98). Uncertainty exists as to whether Metsyn is a distinct pathophysiological entity or simply a clinical marker of future untoward events, particularly CVD mortality. Observational research shows a greater risk of CVD death in individuals with Metsyn compared to those without Metsyn (99), yet no evidence exits from prospective studies to confirm these findings.

Until recently, the criteria for defining Metsyn varied by organization (100) and yielded a prevalence rate of 34% and 39% in U.S. adults (101,102). A consensus definition now exists (101), in which each organization includes hyperglycemia (or current blood glucose medication use), elevated BP (or current hypertension medication use), dyslipidemia (or current lipid-lowering medication use), and national or regional cut points for central adiposity based on waist circumference; however, differences in specific value within these criteria remain (*Table 9.2*). It is further agreed that an individual is categorized as having Metsyn when he or she displays at least three of the defining risk factors.

TABLE 9.2 • Metabolic Syndrome Criteria: NCEP/ATP III, IDF, and WHO

Criteria	NCEP/ATP III (103)	IDF (104)	WHO (105)[a]
Body weight	Waist circumference[a,b]	Waist circumference[c]	Waist-to-hip ratio (males >0.90; females >0.85) and/or BMI of >30 $kg \cdot m^{-2}$
Men	>102 cm (>40 in)	≥94 cm (≥37 in)	>0.9 ratio
Women	>88 cm (>35 in)	≥80 cm (≥31.5 in)	>0.85 ratio
Insulin resistance/glucose	≥100 $mg \cdot dL^{-1}$[d] or on drug treatment for elevated blood glucose	≥100 $mg \cdot dL^{-1}$ or previously diagnosed Type 2 diabetes	See footnote.[e]
Dyslipidemia			
HDL	Men: <40 $mg \cdot dL^{-1}$ Women: <50 $mg \cdot dL^{-1}$ Anyone on drug treatment for reduced HDL-C	Men: <40 $mg \cdot dL^{-1}$ Women: <50 $mg \cdot dL^{-1}$ Anyone on drug treatment for reduced HDL-C	Men: <35 $mg \cdot dL^{-1}$ Women: <39 $mg \cdot dL^{-1}$[f]
Triglycerides	≥150 $mg \cdot dL^{-1}$ or on drug treatment for high triglycerides	≥150 $mg \cdot dL^{-1}$ or on drug treatment for high triglycerides	≥150 $mg \cdot dL^{-1}$ or on drug treatment for high triglycerides

Elevated blood pressure	≥130 or ≥85 mm Hg or on drug treatment for hypertension	≥130 or ≥85 mm Hg or treatment of previously diagnosed hypertension	Antihypertensive medication and/or a BP of ≥140 or ≥90 mm Hg
Other	N/A	N/A	Urinary albumin excretion rate ≥20 $\mu g \cdot min^{-1}$ or albumin:creatinine ratio ≥30 $mg \cdot g^{-1}$

[a] Overweight and obesity are associated with insulin resistance and the metabolic syndrome (Metsyn). However, the presence of abdominal obesity is more highly correlated with these metabolic risk factors than is elevated BMI. Therefore, the simple measure of waist circumference is recommended to identify the body weight component of the Metsyn.

[b] Some men develop multiple metabolic risk factors when the waist circumference is only marginally increased (94–102 cm [37–39 in]). Such individuals may have a strong genetic contribution to insulin resistance. They should benefit from changes in life habits, similarly to men with categorical increases in waist circumference.

[c] A required criterion defined as waist circumference ≥94 cm (≥37 in) for Europid men and ≥80 cm (≥31.2 in) for Europid women, with ethnicity-specific values for other groups

[d] The American Diabetes Association has established a cutpoint of ≥100 $mg \cdot dL^{-1}$, above which individuals have either prediabetes (impaired fasting glucose) or diabetes mellitus (2). This cutpoint should be applicable for identifying the lower boundary to define an elevated glucose as one criterion for metabolic syndrome.

[e] A required criterion is one of the following: Type 2 diabetes mellitus, impaired fasting glucose, impaired glucose tolerance, or for individuals with normal fasting glucose levels (<100 $mg \cdot dL^{-1}$), glucose uptake below the lowest quartile for background populations under investigation under hyperinsulinemic and euglycemic conditions. Note this value has been updated to be consistent with current ADA recommendations regarding normal fasting plasma glucose levels (2).

[f] These values have been updated from those originally presented to ensure consistence with ATP III cut points.

NOTE: To convert glucose from $mg \cdot dL^{-1}$ to $mmol \cdot L^{-1}$, multiply by 0.0555. To convert HDL from $mg \cdot dL^{-1}$ to $mmol \cdot L^{-1}$, multiply by 0.0259. To convert triglycerides from $mg \cdot dL^{-1}$ to $mmol \cdot L^{-1}$, multiply by 0.0113.

ATP III, Adult Treatment Panel III; BMI, body mass index; BP, blood pressure; HDL-C, high-density lipoprotein cholesterol; IDF, International Diabetes Federation; NCEP, National Cholesterol Education Program; WHO, World Health Organization.

The treatment guidelines for Metsyn recommended by National Cholesterol Education Program (NCEP) Adult Treatment Panel III (ATP III) focus on three interventions including weight control, PA, and treatment of the associated CVD risk factors that may include pharmacotherapy (106). The International Diabetes Federation (IDF) guidelines for primary intervention include (a) moderate restriction in energy intake (EI) to achieve a 5%–10% weight loss within 1 yr, (b) moderate increases in PA consistent with the consensus public health recommendations of 30 min of moderate intensity PA on most days of the week (78), and (c) change in dietary intake composition consistent with modifying specified CVD risk factors (*i.e.*, decreased simple carbohydrates, increased lean protein, reduced saturated fat) (104). The IDF secondary intervention includes pharmacotherapy for associated CVD risk factors (104,107).

Exercise Testing

- The presence of Metsyn does not result in the requirement of an exercise test prior to beginning a low-to-moderate intensity exercise program.
- If an exercise test is performed, the general recommendations can be followed (see *Boxes 3.1* and *3.2*), with particular consideration for dyslipidemia, hypertension, or hyperglycemia when present.
- Because many individuals with the Metsyn are either overweight or obese, exercise testing considerations specific to those individuals should be followed (see "Overweight and Obesity" section and the relevant ACSM position stand [35]).
- The potential for low exercise capacity in individuals who are overweight or obese may necessitate a low initial workload (*i.e.*, 2–3 metabolic equivalents [METs]) and small increments per testing stage (0.5–1.0 MET) (see *Chapter 5*).
- Because of the potential presence of elevated BP, strict adherence to protocols for assessing BP before and during exercise testing should be followed (see *Chapter 2*) (108).

Exercise Prescription/Special Considerations

The FITT principle of Ex R_x in Metsyn is generally consistent with the recommendations for healthy adults regarding aerobic, resistance, and flexibility exercise (see *Chapter 5*). Similarly, the minimal dose of PA to improve health/fitness outcomes is consistent with the consensus public health recommendations of 150 min · wk^{-1} or 30 min of moderate intensity PA on most days of the week (78,109). However, due to the clustering of CVD and DM risk factors, along with the likely presence of chronic diseases and health conditions that accompany Metsyn, the following Ex R_x special considerations are suggested:

- When developing the Ex R_x for Metsyn, attention should be given to each risk factor/condition present, with the most conservative criteria used to set initial workloads (see other sections of this chapter on the FITT principle Ex R_x for these other chronic diseases and health conditions as well as relevant ACSM position stands [8,35,77]). Over time and as tolerated, longer duration and higher intensities may be necessary to achieve significant health and fitness outcomes.
- To reduce the impact of the Metsyn, variables that are considered risk factors for CVD and DM, initial exercise training should be performed at a moderate intensity (*i.e.*, 40%–59% O_2R or HRR) totaling a minimum of 150 min · wk^{-1} or 30 min · d^{-1} most days of the week to allow for optimal health/fitness improvements. When appropriate, progress to a more vigorous intensity (*i.e.*, ≥60% O_2R or HRR).
- Reduction of body weight is an important goal for individuals with Metsyn (103); therefore, gradually increasing PA levels to approximately 250–300 min · wk^{-1} or 50–60 min on 5 d · wk^{-1} may be necessary when appropriate (35). Daily and weekly amounts of PA may be accumulated in multiple shorter bouts (≥10 min in duration) and can include various forms of moderate intensity lifestyle PAs. For some individuals, progression to 60–90 min · d^{-1} of PA may be necessary to promote or maintain weight loss (see the Ex R_x recommendations for those with overweight and obesity in this chapter and the relevant ACSM position stand [35]).
- Resistance training, when combined with aerobic training, can produce greater decreases in Metsyn prevalence than that of aerobic training alone (110,111). Reported participation in ≥2 d · wk^{-1} of muscle strengthening activity reduces the risk of acquiring dyslipidemia, IFG, prehypertension, and increased waist circumference, all part of the Metsyn cluster (112) (see *Chapter 5* for resistance training guidelines).

ONLINE RESOURCES

American College of Sports Medicine position stand on exercise and hypertension: https://www.acsm.org/acsm-positions-policy/official-positions

American Heart Association, metabolic syndrome: http://www.heart.org/HEARTORG/Conditions/More/MetabolicSyndrome/Metabolic-Syndrome_UCM_002080_SubHomePage.jsp

Mayo Clinic Diseases and Conditions, metabolic syndrome: https://www.mayoclinic.org/diseases-conditions/metabolic-syndrome/symptoms-causes/syc-20351916

National Heart Lung and Blood Institute. What is metabolic syndrome?: http://www.nhlbi.nih.gov/health/health-topics/topics/ms

OVERWEIGHT AND OBESITY

The prevalence of *overweight* and *obesity* has been increasing in the United States and in developed countries around the world. Recent estimates indicate that approximately 70% of the U.S. population are classified as either overweight or obese (body mass index [BMI] $\geq$25.0 kg · m^{-2}), with approximately 40% classified as obese (BMI $\geq$30.0 kg · m^{-2}), including 7% with severe obesity (BMI $\geq$40 kg · m^{-2}) (113). Obesity rates are highest in certain ethnic and gender groups. For example, non-Hispanic Black women have age-adjusted overweight/obesity rates of 82%, followed closely by Hispanic men (78.6%) (114). Although the prevalence of obesity has steadily risen over the last three decades, recent data indicate a plateau in the overall prevalence of obesity (114).

Statistics relating to youth indicate that 32% of children and adolescents are overweight or obese (114). In the United States, the percentage of children 6–11 yr of age who are considered obese increased from 7% in 1980 to 18% in 2012; the percentage of adolescents (12–19 yr of age) who are obese increased from 5% to 21% during the same time period (114). The troubling data on overweight/obesity prevalence among the adult and pediatric populations and its health implications have precipitated an increased awareness in the value of identifying and treating individuals with excess body weight (35,115–117).

For all ages and ethnicities, overweight and obesity are linked to an increased risk of the development of numerous chronic diseases including CVD, DM, some forms of cancer, and musculoskeletal problems (118). It is estimated obesity-related conditions account for more than 7% of total health care costs in the United States, and the direct and indirect costs of obesity are in excess of $190 billion annually (119).

The management of body weight is dependent on energy balance that is determined by EI and EE. For an individual who is overweight or obese, to reduce body weight, EE must exceed EI. Sustained weight loss of 3%–5% is likely to result in clinically meaningful reductions in several CVD risk factors, including TG, blood glucose, and HbA1C levels, and the risk of developing T2DM (120). There is evidence that as little as 2%–3% weight loss can result in similar CVD risk factor improvement (35). These benefits are more likely to be sustained through the maintenance of weight loss, but maintenance is challenging with weight regain averaging approximately 33%–50% of initial weight loss within 1 yr of terminating treatment (121).

Lifestyle interventions for weight loss that combine reductions in EI with increases in EE through exercise and other forms of PA often result in an initial 5%–10% reduction in body weight (122). PA appears to have a modest impact on the magnitude of weight loss observed across the initial weight loss intervention compared with reductions in EI (118). A review of weight loss interventions found that programs, which combined diet and exercise resulted in a 20% (~3 kg) greater weight loss versus diet restriction alone (123); however, this effect is lost when EI is severely reduced (35). PA and diet restriction will provide comparable weight loss if they provide similar levels of negative energy balance (35). Due to low levels of fitness, it may be difficult for overweight/obese individuals to perform a volume of PA required to achieve clinically meaningful weight loss. Therefore, the combination of moderate reductions in EI with adequate levels of PA maximizes weight loss in individuals with overweight and obesity.

There is a dose-response relationship between PA levels and the magnitude of weight loss. The ACSM's position stand on PA and weight loss concluded that (a) $<150 \text{ min} \cdot \text{wk}^{-1}$ of PA promotes minimal weight loss, (b) $>150 \text{ min} \cdot \text{wk}^{-1}$ of PA results in modest weight loss of ~2–3 kg, and (c) $>225–420 \text{ min} \cdot \text{wk}^{-1}$ of PA results in a 5- to 7.5-kg weight loss (35).

PA appears necessary for most individuals to prevent weight regain, but there are no correctly designed, adequately powered, energy balance studies to provide evidence for the amount of PA needed to prevent weight regain after weight loss (35). However, there is literature that suggests it may take more than the consensus public health recommendation for PA of 150 min · wk^{-1} or 30 min of PA on most days of the week (35,78,124). Some studies support the value of ~200–300 min · wk^{-1} of PA during weight maintenance to reduce weight regain after weight loss, and it seems that "more is better" (35).

Based on the existing scientific evidence and practical clinical guidelines (35), the ACSM makes the following recommendations regarding exercise testing and training for individuals with overweight and obesity.

Exercise Testing

- An exercise test is often not necessary in the overweight/obese population prior to beginning a low-to-moderate intensity exercise program.
- Overweight and obese individuals are at risk for other comorbidities (*e.g.*, dyslipidemia, hypertension, hyperinsulinemia, hyperglycemia), which are associated with CVD risk.
- The timing of medications to treat comorbidities relative to exercise testing should be considered, particularly in those who take β-blockers and antidiabetic medications.
- The presence of musculoskeletal and/or orthopedic conditions may necessitate the need for using leg or arm ergometry.
- The potential for low exercise capacity in individuals with overweight and obesity may necessitate a low initial workload (*i.e.*, 2–3 METs) and small increments per testing stage of 0.5–1.0 MET. See *Chapters 3* and *4* for protocol examples.
- Exercise equipment must be adequate to meet the weight specification of individuals with overweight and obesity for safety and calibration purposes.
- The appropriate cuff size should be used to measure BP in individuals who are overweight and obese to minimize the potential for inaccurate measurement.

Exercise Prescription

The goals of exercise during the active weight loss phase are to (a) maximize the amount of caloric expenditure to enhance the amount of weight loss and (b) integrate exercise into the individual's lifestyle to prepare them for a successful weight loss maintenance phase.

FITT	FITT RECOMMENDATIONS FOR INDIVIDUALS WITH OVERWEIGHT AND OBESITY (35,125)		
	Aerobic	**Resistance**	**Flexibility**
Frequency	≥5 d · wk^{-1}	2–3 d · wk^{-1}	≥2–3 d · wk^{-1}
Intensity	Initial intensity should be moderate (40%–59% O_2R or HRR); progress to vigorous (≥60% O_2R or HRR) for greater health benefits.	60%–70% of 1-RM; gradually increase to enhance strength and muscle mass.	Stretch to the point of feeling tightness or slight discomfort.
Time	30 min · d^{-1} (150 min · wk^{-1}); increase to 60 min · d^{-1} or more (250–300 min · wk^{-1}).	2–4 sets of 8–12 repetitions for each of the major muscle groups	Hold static stretch for 10–30 s; 2–4 repetitions of each exercise
Type	Prolonged, rhythmic activities using large muscle groups (*e.g.*, walking, cycling, swimming)	Resistance machines and/or free weights	Static, dynamic, and/or PNF

1-RM, one repetition maximum; HRR, heart rate reserve; O_2R, oxygen uptake reserve; PNF, proprioceptive neuromuscular facilitation.

Exercise Training Considerations

- The duration of moderate-to-vigorous intensity PA should initially progress to at least 30 min · d^{-1} (78,124).

- To promote long-term weight loss maintenance, individuals should progress to at least 250 min · wk^{-1} (≥2,000 kcal · wk^{-1}) of moderate to vigorous exercise. To achieve the weekly maintenance activity goal of ≥250 min · wk^{-1}, exercise and PA should be performed on 5–7 d · wk^{-1}.
- Individuals with overweight and obesity may accumulate this amount of PA in multiple daily bouts of at least 10 min in duration or through increases in other forms of moderate intensity lifestyle PA. Accumulation of intermittent exercise may increase the volume of PA achieved by previously sedentary individuals and may enhance the likelihood of adoption and maintenance of PA (125).
- Resistance training does not result in clinically significant weight loss (35,126). The addition of resistance exercise to energy restriction does not appear to prevent the loss of fat-free mass or the observed reduction in resting EE (125).
- Resistance exercise may enhance muscular strength and physical function in individuals who are overweight or obese. Moreover, there may be additional health benefits of participating in resistance exercise such as improvements in CVD and DM risk factors and other chronic disease risk factors (125).

Special Considerations (35,127)

- Utilize goal setting to target short- and long-term weight loss. Target a minimal reduction in body weight of at least 3%–10% of initial body weight over 3–6 mo.
- Target reducing current EI to achieve weight loss. A reduction of 500–1,000 kcal · d^{-1} is adequate to elicit a weight loss of 1–2 lb · wk^{-1} (0.5–0.9 kg · wk^{-1}). This reduced EI should be combined with a reduction in dietary fat intake.
- Weight loss beyond 5%–10% may require more aggressive nutrition, exercise, and behavioral intervention (see *Chapter 12*). For those who do not respond to any degree of lifestyle intervention, medical treatments such as medications or surgery may be appropriate.
- Medically indicated very low–calorie diets with energy restrictions of up to 1,500 kcal · d^{-1} can result in greater initial weight loss amounts compared to more conservative EI reductions. These medically managed meal plans are typically only used for selected individuals and for short periods of time.
- Incorporate opportunities to enhance communication between health care professionals, registered dietitian nutritionists, and exercise professionals and individuals with overweight and obesity following the initial weight loss period.

- Target changing eating and exercise behaviors because sustained changes in both behaviors result in significant long-term weight loss and maintenance. Assist individuals with achieving evidence-based recommendations for aerobic exercise during both the weight loss and weight loss maintenance phases.

Bariatric Surgery

Surgery for weight loss may be indicated for individuals with a BMI $\geq$40 kg $\cdot$ m^{-2} or those with comorbid risk factors and BMI $\geq$35 kg $\cdot$ m^{-2}. Comprehensive treatment following surgery includes exercise, as there is evidence for enhanced weight loss (128,129); however, this has not been studied systematically. Exercise will likely facilitate the achievement and maintenance of energy balance postsurgery, and there is evidence that exercise improves insulin sensitivity and CRF following surgery (130). A multicenter National Institutes of Health–sponsored trial is underway (*i.e.*, or Longitudinal Assessment of Bariatric Surgery [LABS]) (131). When the results are published, they will provide the most comprehensive findings for exercise and bariatric surgery to date (132). Preliminary data from the LABS trial reported that the majority of those undergoing bariatric surgery increased their PA levels postsurgery, but 24%–29% were less active than prior to surgery (133).

Once individuals are cleared for exercise by their physician after surgery, a progressive exercise program for all individuals should follow the FITT principle of Ex R_x for weight loss and maintenance for overweight and obese individuals as listed previously in this section. Those with a prior history of orthopedic injuries should be assessed to reduce the risk of aggravation by weight-bearing exercise. In those for whom excessive body weight may limit the ability to engage in weight-bearing exercise or continuous exercise, intermittent exercise and non-weight-bearing alternatives should be considered. Subsequently, continuous exercise and weight-bearing exercise such as walking may be slowly introduced to make up a greater portion of the exercise program.

ONLINE RESOURCES

American College of Sports Medicine position stand on overweight and obesity: https://www.acsm.org/acsm-positions-policy/official-positions

National Heart, Lung, and Blood Institute. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report: http://www.nhlbi.nih.gov/health-pro/guidelines/archive/clinical-guidelines-obesity-adults-evidence-report

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Exercise Testing and Prescription for Populations with Other Chronic Diseases and Health Conditions

CHAPTER 10

INTRODUCTION

This chapter contains the exercise testing and exercise prescription (Ex R_x) guidelines and recommendations for individuals with chronic diseases and other health conditions not addressed in *Chapters 8* (cardiovascular and pulmonary) and *9* (metabolic). As with the other chapters, the Ex R_x guidelines and recommendations are presented using the *F*requency, *I*ntensity, *T*ime, and *T*ype (*FITT*) principle of Ex R_x based on the available professional society position papers and scientific statements or using other literature. The general principles of exercise testing are presented in *Chapter 3* and Ex R_x in *Chapter 5*. In many instances, exercise training can be performed without a prior clinical exercise test. However, if an exercise test is to be performed, this chapter presents specific recommendations for individuals with various chronic diseases and health conditions. Note that information is often lacking regarding volume and progression of exercise training for the chronic diseases and health conditions presented in this chapter. In these instances, the guidelines and recommendations provided in *Chapter 5* for apparently healthy populations should be adapted with good clinical judgment for the chronic disease(s) and health condition(s) being targeted.

ARTHRITIS

Arthritis is an umbrella term for over 100 rheumatic conditions, which together, when measured in years lived with disability (YLDs), provides the second most common cause of disability in the United States (1) and worldwide (2). And the disability burden of arthritis is rapidly escalating, with the YLD specifically attributable to osteoarthritis (OA) alone having increased globally by 75% from 1990 to 2013 (2). Among adults in the United States, approximately 23% (54.4 million) report having a doctor's diagnosis of arthritis (3), and of these 44% (23.7 million) complain of arthritis-related physical activity (PA) limitations (1).

The two most common forms of arthritis are OA and rheumatoid arthritis (RA). OA is a progressive local degenerative joint disease affecting one or more synovial joints (*i.e.*, most commonly the hands, hips, spine, and knees) and is associated with risk factors including the following: being overweight/obese, history of joint injury or surgery, genetic predisposition, aging, female sex, and certain occupations. RA is a chronic, systemic, inflammatory autoimmune disease of unknown etiology, in which the inflammatory response, locally, causes swelling (inflammation) of the joint lining (synovitis), damage to articular cartilage and supporting ligaments, and may lead to bony erosions; and, systemically, results in significant fatigue, muscle loss, fat gain, increased risk of osteoporosis, and significantly exacerbated cardiovascular disease (CVD) risk primarily due to accelerated atherosclerosis (4,5). Other common rheumatic diseases include gout, spondyloarthropathies (*e.g.*, ankylosing spondylitis [AS], psoriatic arthritis, reactive arthritis, and enteropathic arthritis), and specific connective tissue diseases (*e.g.*, systemic lupus erythematosus, systemic sclerosis [scleroderma], and dermatomyositis).

Regardless of type, arthritis is generally characterized by pain, impaired physical function, fatigue, and adverse changes in body composition (*i.e.*, muscle loss and increased adiposity), with, for example, 66% of individuals with OA being either overweight or obese at the time of disease onset (6). Due to the aging population and burgeoning obesity epidemic, the prevalence of physician-diagnosed arthritis is expected to increase to an estimated 78 million Americans (26%) by 2040 (7), with the same trend anticipated globally (2).

Pharmaceutical treatment of OA primarily involves analgesics and topical and oral nonsteroidal anti-inflammatory drugs (NSAIDs), and for RA, disease-modifying antirheumatic drugs (DMARDs), biologic therapies, and glucocorticoids. Optimal treatment of arthritis features a multidisciplinary approach, which includes drug treatment, individual education in self-management, physical therapy, occupational therapy, and exercise (*e.g.*, 8–12). When joint damage and loss of mobility are severe, and restoration of a reasonable level of function and control of pain is no longer achievable by pharmacological and conservative management (*i.e.*, "end-stage" disease), total joint replacement and other surgeries are therapeutic options.

Although pain and functional limitations can present challenges to individuals with arthritis in terms of performing PA, regular exercise is essential for managing these conditions and hence are a core recommendation of international guidelines. For instance, due to reduced PA, and in the case of inflammatory arthropathies, the disease process itself (*i.e.*, inflammation), individuals with arthritis are more likely to have muscle wasting (sarcopenia) and excess adiposity than same age and sex healthy individuals (3,13). Thus, regular exercise plays an important role in weight control and achieving a healthy body composition both through the anabolic and lipolytic effects of exercise itself and via the anti-inflammatory effects of regular PA. Regular exercise provides numerous additional benefits to individuals with arthritis, including minimizing functional decline or improving functional capacity in the deconditioned; reducing fall risk; attenuating pain and joint stiffness; reducing comorbidities such as CVD, Type 2 diabetes mellitus (T2DM), metabolic syndrome, and osteoporosis; and improving mental health and quality of life (4,11,14–20).

Exercise Testing

Most individuals with arthritis tolerate symptom-limited exercise testing consistent with recommendations for apparently healthy adults (see *Chapters 3* and *4*). The following are special considerations for individuals with arthritis:

- High intensity exercise, as during a maximal stress test, is contraindicated when there is acute inflammation (*i.e.*, hot, swollen, and painful joints; "disease flare"). If individuals are experiencing acute inflammation, exercise testing should be postponed until the flare has subsided.
- Although most individuals with arthritis tolerate treadmill walking, use of cycle leg ergometry or arm ergometry may be less painful for some, thereby providing a more accurate assessment or estimation of cardiorespiratory function and/or capacity. The mode of exercise chosen should be that which is least painful for the individual being tested.
- Allow time for individuals to warm up (at a very light or light intensity level) according to each individual's functional status prior to beginning the graded exercise test (GXT).
- Monitor pain levels during testing using a validated exercise intensity scale such as the Borg CR10 Scale (see *Figure 4.2*) (21) and a validated pain scale such as the visual numeric pain scale (*Figure 10.1*) (22).
- Muscle strength and endurance can be measured using standard protocols (see *Chapter 3*). However, the tester should be aware that pain and swelling may impair maximum voluntary muscle contraction via neural inhibition of muscle fiber recruitment in affected joints.

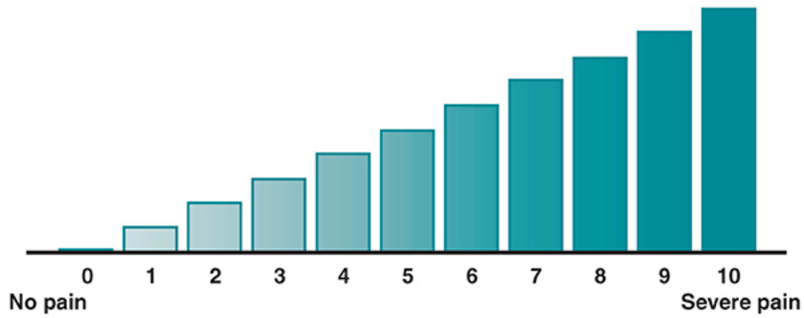

Figure 10.1 Visual numeric pain scale. Reprinted with permission from (22).

Exercise Prescription

A major barrier to individuals with arthritis starting an exercise program is the belief that exercise, particularly weight-bearing exercise, will exacerbate joint damage and symptoms such as pain and fatigue. This fear is prevalent not only among individuals with arthritis but also among some physicians and allied health professionals (23). Thus, individuals with arthritis need to be reassured that exercise is not only safe but also widely and consistently reported to reduce pain, fatigue, inflammation, and disease activity (11,14–20,24–27). Those with arthritis, particularly those with pain and those who are deconditioned, should gradually progress to exercise intensities and volumes that provide clinically significant health benefits. In general, recommendations for Ex R_x are consistent with those for apparently healthy adults (see *Chapter 5*) with observance of FITT recommendations and additional consideration of an individual's disease activity, pain, joint integrity, functional limitations, and personal exercise/PA preferences. Although these recommendations will likely be appropriate for most individuals with arthritis for both aerobic and resistance training, an individual's personal exercise mode and intensity preference needs to be considered to optimize adoption and adherence to exercise.

FITT	FITT RECOMMENDATIONS FOR INDIVIDUALS WITH ARTHRITIS (11,14,23,27–32)		
	Aerobic	**Resistance**	**Flexibility**
Frequency	3–5 d · wk^{-1}	2–3 d · wk^{-1}	Daily
Intensity	Moderate (40%–59% $\dot{V}O_2R$ or HRR) to vigorous (≥60% $\dot{V}O_2R$ or HRR)	60%–80% 1-RM. Initial intensity should be lower (*i.e.*, 50%–60% 1-RM) for those unaccustomed to resistance training.	Move through ROM feeling tightness/stretch without pain. Progress ROM of each exercise only when there is little or no joint pain.
Time	Accumulate 150 min · wk^{-1} of moderate intensity, or 75 min · wk^{-1} of vigorous intensity, or an equivalent combination of the two, in bouts of ≥10 min.	Use healthy adult values and adjust accordingly (*i.e.*, 8–12 repetitions for 1–3 sets); include all major muscle groups.	Up to 10 repetitions for dynamic movements; hold static stretched for 10–30 s and repeat two to four times.
Type	Activities with low joint stress, such as walking, cycling, swimming, or aquatic exercise	Machine, free weights, resistance bands, tubing. Body weight exercises are also appropriate for most individuals with arthritis.	A combination of active, static, and proprioceptive neuromuscular facilitation stretching (see *Box 5.5*) of all major joints with a focus on affected joints and muscles crossing these joints.

1-RM, one repetition maximum; HRR, heart rate reserve; ROM, range of motion; $\dot{V}O_2R$, oxygen uptake reserve.

Exercise Training Considerations

- The goal of aerobic exercise training is to improve cardiorespiratory fitness (CRF) without exacerbating joint pain or damage. There is no clear evidence that supports avoiding or discouraging high-impact activities, such as running, stair climbing, and those with stop and go actions, in individuals with arthritis unless they present with obvious biomechanical or joint stability issues. However, because individuals with arthritis often have lower levels of CRF, muscle strength, and neuromuscular protective reflexes, they should approach high-impact exercise cautiously in order to minimize the risk of incurring injury or aggravating joint symptoms.
- Long, continuous bouts of aerobic exercise may initially be difficult for those who are very deconditioned and restricted by pain and joint mobility, so breaking up sedentary behavior by encouraging movement throughout the day is beneficial and should be encouraged. It is appropriate to start with short bouts of as little as 5 min, or what can be initially tolerated.
- In addition to improving muscular strength and endurance, research evidence indicates that resistance training improves physical function, and is likely to reduce chronic pain through local (*i.e.*, enhanced dynamic stability, attenuated joint forces) and systemic changes (*i.e.*, decreased inflammation, elevated endogenous opioids) (33,34).
- Flexibility training is important to enhance range of motion (ROM) and to counteract the negative effects of arthritis on joint mobility. Additionally, active ROM can shorten episodes of “morning stiffness” in individuals with RA.
- Balance training is important for individuals with lower limb involvement as pain and impaired coordination, protective reflexes, and proprioception put them at greater risk of falling. Both static (*e.g.*, standing in tandem foot position or on one leg) and dynamic (*e.g.*, walking, changing directions, stepping over obstacles) balance activities are recommended.

- Adequate warm-up and cool-down periods (5–10 min) are critical for minimizing pain. Warm-up and cool-down activities should involve controlled movement of joints through their full ROM along with light intensity aerobic exercise.
- Individuals with significant pain and functional limitation may need interim goals that are shorter than the recommended FITT and should be encouraged to undertake and maintain any amount of PA that is safely tolerated. In the absence of specific recommendations for people with arthritis, the general population recommendation of increasing duration aerobic exercise by 5–10 min every 1–2 wk over the first 4–6 wk of an exercise training program can be applied.
- Regular progression of resistance training exercises is critical for achieving gains in muscular strength and endurance, and function. Following the American College of Sports Medicine (ACSM) guidelines (35) for progression of resistance training in healthy adults is a good starting point while recognizing individuals with arthritis may need to increase loads at slower rates and in smaller increments to minimize localized joint reaction and discomfort.

Special Considerations (23,25)

- Avoid strenuous exercise during acute flare-ups. However, it is appropriate to gently move joints through their full ROM and break up sedentary behavior with light activity during these episodes.
- Inform individuals with arthritis that a small amount of discomfort in the muscles or joints during or immediately after exercise is common following performance of unfamiliar exercise and hence does not necessarily mean joints are being further damaged. Higher pain ratings 48–72 h after exercise may be due to delayed onset muscle soreness (DOMS), especially in those who are new to exercise; individuals should be informed that this is a normal response to unaccustomed exercise, which will progressively diminish as their training progresses and they adapt to the demands of exercise.
- If specific exercises exacerbate joint pain, alternative exercises that work the same muscle groups and energy systems should be considered.
- Encourage individuals with arthritis to exercise during the time of day when pain is typically least severe and/or in conjunction with peak activity of pain medications.
- Appropriate shoes that provide good shock absorption and stability are particularly important for individuals with arthritis. Shoe specialists can provide recommendations appropriate for an individual's biomechanics.
- Incorporate functional exercises such as the sit-to-stand, step-ups, stair climbing, and carrying to improve neuromuscular control, balance, and enhance the ability to perform activities of daily living (ADL).
- For pool-based exercise, a water temperature of 83° to 88° F (28° to 31° C) aids in relaxing and increasing the compliance of muscles and reducing pain.

ONLINE RESOURCES

American College of Rheumatology: http://www.rheumatology.org; https://www.rheumatology.org/I-Am-A/Patient-Caregiver/Diseases-Conditions/Living-Well-with-Rheumatic-Disease/Exercise-and-Arthritis

Arthritis Foundation: http://www.arthritis.org. Individuals can click on "Your Local Area" to locate appropriate walking, group exercise, and aquatic classes in their community.

Exercise is Medicine's Rx for Health Series: https://www.exerciseismedicine.org/support_page.php/rx-for-health-series/

CANCER

Cancer is the second leading cause of mortality in both men and women in the United States. Each year, more than 320,000 U.S. men and 286,000 U.S. women die of cancer (36). Cancer is increasingly being recognized as not one, but many diseases, defined not only by different anatomic locations but also by cell of origin, etiologic factors, and susceptibly to treatment. Thus, cancer treatment has become increasingly individualized.

Evidence has emerged demonstrating the role of PA in both cancer prevention and control. Higher volumes of PA are associated with lower risk of developing 13 types of cancer (*e.g.*, primary cancer prevention [37]) and a reduction of cancer-related mortality in individuals with several common cancers (*e.g.*, secondary cancer prevention [38]). Exercise, a subset of PA, has also been shown to help mitigate the side effects of cancer therapy and improve functional measures in individuals with cancer (10,39). The benefits of PA for primary cancer prevention are briefly outlined in *Chapter 1*. This section describes the benefits of PA and exercise for individuals with a history of cancer, known as cancer survivors (40), and offers considerations for exercise testing and prescription in this population.

Overview of Importance of Physical Activity in Cancer Survivors

Cancer-Related Mortality

Observational studies suggest that participation in regular and sufficient amounts of PA after diagnosis of early-stage, potentially curable, cancer is associated with a lower risk of cancer-specific mortality in breast, prostate, and colon cancers (38). Emerging evidence also suggests that sedentary behavior and screen-based activities are independent risk factors for cancer-specific mortality (41). Currently, there are no definitive data from randomized controlled trials (RCTs) evaluating the effects of PA interventions with cancer recurrence or mortality as a primary endpoint. However, several ongoing multicenter randomized trials will determine if PA reduces the risk of cancer recurrence and prolongs survival in cancer survivors (42–44).

Physiological and Quality of Life Outcomes

Cancer survivors derive a variety of physiological and quality of life benefits from exercise. Meta-analyses and systematic reviews of exercise intervention trials in individuals with cancer during and after treatment demonstrate that aerobic exercise during and after cancer treatment increases cardiovascular fitness (45), and resistance exercise during and after cancer treatment increases upper and lower extremity muscular strength, and increases lean body mass (46), with data suggesting that supervised exercise improves these outcomes more than unsupervised exercise (47). Additionally, more limited evidence suggests that combined resistance and higher impact (*e.g.*, jumping, hopping, skipping) activities may have a subtle osteogenic effect on bone mineral density (BMD) of the lumbar spine (48).

Many studies have also evaluated the effect of exercise on quality of life and related outcomes in cancer survivors. Meta-analyses have demonstrated that exercise interventions reduce fatigue and depression during and after cancer treatment and also improve quality of life and reduce sleep disturbance after cancer treatment (49,50). Again, studies suggest that both supervised and unsupervised interventions can be effective; however, supervised tend to yield greater improvements (51,52) and also show that higher levels of baseline fatigue and other symptoms predict larger benefits from exercise interventions (47,51).

Physical Activity Patterns in Cancer Survivors

Exercise volume often decreases during cancer treatment and may not return to prediagnosis volume after completing treatment (53–55). In a nationally representative sample of cancer survivors, only 8% engaged in 150 $\text{min} \cdot \text{wk}^{-1}$ of moderate-to-vigorous intensity exercise (56). A similar study demonstrated that breast cancer survivors engaged in a daily average of 1 min of moderate-to-vigorous intensity exercise, spending most of their day in sedentary (66%) or light intensity activities (33%) (57). Consequently, there are significant opportunities to utilize exercise as a therapeutic modality to improve numerous outcomes in cancer survivors (58). Also, more than 60% of cancer survivors are ≥65 yr (59) and will often have other preexisting health conditions, such as CVD, T2DM, arthritis, and obesity (60). The combined result of cancer-related side effects, aging, and other health conditions often manifest as impaired cardiovascular fitness, functional limitations, and reduced quality of life in cancer survivors (61–64). Therefore, promoting exercise without creating unnecessary barriers to participation is of critical importance in cancer survivors (65,66). Exercise is safe for almost everyone, including most cancer survivors, and the health benefits of exercise outweigh the risks for most people (67).

Preparticipation Evaluation

Preexercise Assessments

Given the known benefits of exercise in cancer survivors and the current low adherence to exercise guidelines, it is important to not create barriers to exercise. Given the low absolute risk of serious adverse events that occur with exercise, most screening methods in asymptomatic individuals will produce high false positive rates (68). However, cancer survivors often experience a variety of acute, chronic, and late side effects from cancer and its treatments that may influence the approach to exercise testing and prescription (69). A preexercise assessment based on self-reported instruments such as the Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) (*e.g.*, *Chapter 2*; *Figure 2.4*) can identify cancer survivors with overt cardiopulmonary symptoms (*e.g.*, chest discomfort at rest) who may benefit from a medical evaluation or exercise testing prior to engaging in moderate-to-vigorous intensity exercise. Health/fitness professionals can administer a brief cancer history and symptom inventory to inform the design of the Ex R_x (*Box 10.1*) along with knowing the recommended preexercise assessments specific to individuals with cancer (*Figure 10.2*).

Box 10.1 Sample Cancer History Questions

- What kind of cancer?
- Whether the individual is currently receiving cancer treatment (and if so, what agents)?
- Whether the cancer was removed or is still present?
- If the individual has any symptoms or side effects attributed to cancer treatment? Including:
  - Neuropathy
  - Lymphedema
  - Ostomy
  - Bone metastases
  - Any other symptom the individual believes may influence their ability to exercise

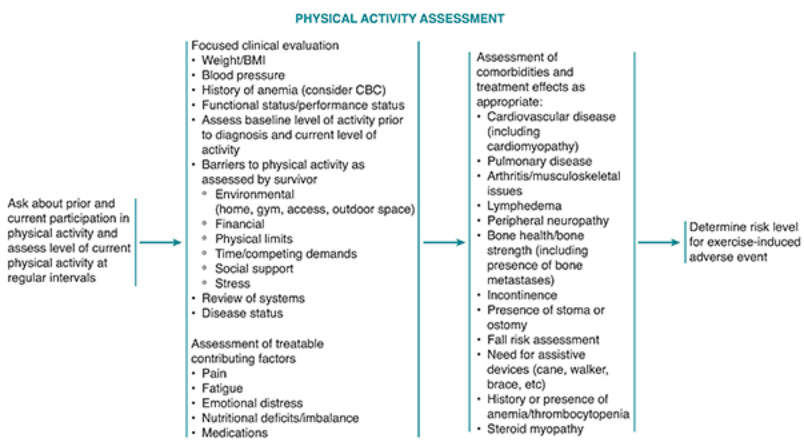

Figure 10.2 Recommendations for assessments prior to exercise among participants with a history of cancer. Reproduced with permission from (70).

Medical Assessment and Exercise Testing

The ACSM preparticipation screening algorithm can be used to determine whether exercise testing is needed for cancer survivors prior to participation in moderate-to-vigorous intensity exercise. As described earlier, exercise testing is not required for preparticipation assessment for most cancer survivors (66), and the 2019 American College of Sports Medicine Roundtable on Exercise Guidelines for Cancer Survivors concluded that exercise testing is not required before walking, resistance, or flexibility activities (71). Specific cancer survivor populations for whom medical evaluation and/or exercise testing should be considered include those with metastatic disease, those with persistent and significant cancer treatment-related side effects, or those with significant comorbidities (72). Given the lack of precision regarding the definition of “significant” side effects and comorbidities, collaboration between health fitness professionals and the oncology team and/or primary care provider is strongly encouraged. In addition, a preexercise medical assessment is suggested (*Table 10.1*).

TABLE 10.1 • Preexercise Medical Assessments for Individuals with Cancer						
Cancer Site	**Breast**	**Prostate**	**Colon**	**Adult Hematologic (No HSCT)**	**Adult HSCT**	**Gynecologic**
General medical assessments recommended prior to exercise	Recommend evaluation for peripheral neuropathies and musculoskeletal morbidities secondary to treatment regardless of time since treatment. If there has been hormonal therapy, recommend evaluation of fracture risk. Individuals with known metastatic disease to the bone will require evaluation to discern what is safe prior to starting exercise. Individuals with known cardiac conditions (secondary to cancer or not) require medical assessment of the safety of exercise prior to starting. There is always a risk that metastasis to the bone or cardiac toxicity secondary to cancer treatments will be undetected. This risk will vary widely across the population of survivors. Fitness professionals may want to consult with the patient's medical team to discern this likelihood. However, requiring medical assessment for metastatic disease and cardiotoxicity for all survivors prior to exercise is not recommended, as this would create an unnecessary barrier to obtaining the well-established health benefits of exercise for the majority of survivors, for whom metastasis and cardiotoxicity are unlikely to occur.					
Cancer site specific medical assessments recommended prior to starting an exercise program	Recommend evaluation for arm/shoulder morbidity prior to upper body exercise.	Evaluation of muscle strength & wasting.	Patient should be evaluated as having established consistent and proactive infection prevention behaviors for an existing ostomy prior to engaging in exercise training more vigorous than a walking program.	None	None	Patients with morbid obesity may require additional medical assessment for the safety of activity beyond cancer-specific risk. Recommend evaluation for lower extremity lymphedema prior to vigorous aerobic exercise or resistance training.

HSCT, hematopoietic stem cell transplantation.
Reprinted with permission from (73).

There is no evidence that the level of medical supervision required for symptom-limited or maximal exercise testing needs to be different for cancer survivors than for other populations. Exercise testing techniques and contraindications for the general population are appropriate for cancer survivors, with the following cancer-specific considerations:

- *Arm morbidity and lymphedema:* Cancer survivors with arm or shoulder morbidity that makes it unsafe or not possible for resistance exercise testing should be referred to physical therapy for rehabilitation (74). Resistance exercise with one repetition maximum testing is safe among breast cancer survivors with and at-risk for upper extremity lymphedema (75).
- *Bone metastases:* Cancer survivors with bone metastases are at an increased risk of skeletal fracture, spinal compression, and exacerbation of bone pain. Selected modalities for exercise testing should avoid direct musculoskeletal loading to metastatic lesions or loading of muscles that are proximal to metastatic lesions (76,77).
- *Neuropathy:* Cancer survivors with peripheral neuropathy may have instability, balance difficulty, and altered gait biomechanics that increase the risk of falls (78). Assessment of stability, balance, and gait biomechanics may be useful to refine selection of exercise testing modality (*e.g.*, stationary cycle vs. treadmill).
- *Ostomy:* During resistance exercise testing, survivors should be reminded to avoid inducing excessive intra-abdominal pressure (*e.g.*, Valsalva maneuver). There is no empirical evidence to support this recommendation, and it is based on expert opinion (73).

Exercise Prescription

General Recommendations

The *2018 Physical Activity Guidelines for Americans* forms the basis from which adaptations are made for cancer survivors (67). Important recommendations from these guidelines that are applicable to cancer survivors include avoiding inactivity, accumulating at least 150–300 $min \cdot wk^{-1}$ of moderate intensity, or 75–150 $min \cdot wk^{-1}$ of vigorous intensity aerobic exercise when possible, engaging in resistance exercise on 2 or more days each week, and integrating balance and flexibility exercises on days that aerobic and resistance exercises are performed. Multiple organizations including ACSM (73), American Cancer Society (76), and the National Comprehensive Cancer Network (72) have endorsed similar guidelines for Ex R_x in cancer survivors. As part of the general recommendations for exercise testing and prescription, the fitness professionals should understand the relevant contraindications (*Table 10.2*).

TABLE 10.2 • Contraindications for Starting Exercise, Stopping Exercise, and Injury Risk for Cancer Survivors

	Breast	Prostate	Colon	Adult Hematologic (No HSCT)	Adult HSCT	Gynecologic
General contraindications for starting an exercise program common across all cancer sites	Allow adequate time to heal after surgery. The number of weeks required for surgical recovery may be as high as 8. Do not exercise individuals who are experiencing fever, extreme fatigue, significant anemia, or ataxia. Follow *ACSM Guidelines* for exercise prescription with regard to cardiovascular and pulmonary contraindications for starting an exercise program. However, the potential for an adverse cardiopulmonary event might be higher among cancer survivors than age matched comparisons given the toxicity of radiotherapy and chemotherapy and long term/late effects of cancer surgery.					
Cancer specific contraindications for starting an exercise program	Women with acute arm or shoulder problems secondary to breast cancer treatment should seek medical care to resolve those issues prior to exercise training with the upper body.	None	Physician permission recommended for patients with an ostomy prior to participation in contact sports (risk of blow), weight training (risk of hernia).	None	None	Women with swelling or inflammation in the abdomen, groin, or lower extremity should seek medical care to resolve these issues prior to exercise training with the lower body.
Cancer specific reasons for stopping an exercise program. (Note: General *ACSM Guidelines* for stopping exercise remain in place for this population.)	Changes in arm/shoulder symptoms or swelling should result in reductions or avoidance of upper body exercise until after appropriate medical evaluation and treatment resolves the issue.	None	Hernia, ostomy related systemic infection.	None	None	Changes in swelling or inflammation of the abdomen, groin, or lower extremities should result in reductions or avoidance of lower body exercise until after appropriate medical evaluation and treatment resolves the issue.
General injury risk issues in common across cancer sites	Patients with bone metastases may need to alter their exercise program with regard to intensity, duration, and mode given increased risk for skeletal fractures. Infection risk is higher for patients that are currently undergoing chemotherapy or radiation treatment or have compromised immune function after treatment. Care should be taken to reduce infection risk in fitness centers frequented by cancer survivors. Patients currently in treatment and immediately following treatment may vary from exercise session to exercise session with regard to exercise tolerance, depending on their treatment schedule. Individuals with known metastatic disease to the bone will require modifications and increased supervision to avoid fractures. Individuals with cardiac conditions (secondary to cancer or not) will require modifications and may require increased supervision for safety.					
Cancer specific risk of injury, emergency procedures	The arms/shoulders should be exercised, but proactive injury prevention approaches are encouraged, given the high incidence of arm/shoulder morbidity in breast cancer survivors. Women with lymphedema should wear a well-fitting compression garment during exercise. Be aware of risk for fracture among those treated with hormonal therapy, a diagnosis of osteoporosis, or bony metastases.	Be aware of risk for fracture among patients treated with ADT, a diagnosis of osteoporosis or bony metastases	Advisable to avoid excessive intra-abdominal pressures for patients with an ostomy.	Multiple myeloma patients should be treated as if they are osteoporotic.	None	The lower body should be exercised, but proactive injury prevention approaches are encouraged, given the potential for lower extremity swelling or inflammation in this population. Women with lymphedema should wear a well-fitting compression garment during exercise. Be aware of risk for fractures among those treated with hormonal therapies, with diagnosed osteoporosis, or with bony metastases.

ACSM, American College of Sports Medicine; ADT, androgen deprivation therapy; HSCT, hematopoietic stem cell transplantation.
Information from (71).

FITT Principle

Exercise training is safe during and after cancer treatment, and cancer survivors should avoid physical inactivity and engage in exercise on a regular basis. Overall recommendations for cancer survivors are consistent with the guidelines presented in *Chapter 5* and elsewhere (35,79–82).

FITT — **FITT RECOMMENDATIONS FOR CANCER SURVIVORS**

	Aerobic	Resistance	Flexibility
Frequency	3–5 d · wk^{-1}	2–3 d · wk^{-1} with a minimum of 48 h between sessions	2–3 d · wk^{-1} up to daily
Intensity	40%–<60% $\dot{V}O_2R$ or HRR. Survivors may find RPE useful to gauge exercise intensity.	60%–80% 1-RM or allow for 6–15 repetitions. Increase weight as tolerated and when repetitions >15. RPE is correlated with % 1-RM in cancer survivors (83).	Stretch within limits of pain to the point of tightness or slight discomfort.
Time	≥30 min · d^{-1}. No lower limit on bout length. During treatment, exercise length may need to be modified due to chemotherapy or radiation-related toxicities.	≥1 set, ≥8 repetitions per set; ≥60 s rest between sets	Hold each stretch for 10–30 s.
Type	Walking, cycling, swimming. Swimming should not be prescribed for survivors with central lines, those with ostomies, those in an immunocompromised state or who are currently receiving radiation therapy.	8–10 exercises of major muscle groups; machines or free weights	Static stretches (passive and/or active), for all major muscle tendon groups. Tai chi and yoga may be preferred.

1-RM, one repetition maximum; HRR, heart rate reserve; RPE, rating of perceived exertion; $\dot{V}O_2R$, oxygen uptake reserve.

Health fitness professionals may wish to implement these recommendations sequentially, first prescribing a small volume of activity, then incrementally increasing the frequency, intensity, and time of exercise, as tolerated (72). In addition to the ACSM guidelines, the U.S. Department of Health and Human Services publishes exercise guideline alterations needed for cancer survivors (*Table 10.3*). Ex R_x for the general population are appropriate for cancer survivors, with the following cancer-specific considerations:

- *Arm morbidity and upper extremity lymphedema:* Survivors with established upper extremity lymphedema should wear a compression garment during resistance exercise (76), progress weight slowly, and should consider working with a certified health fitness professional. There is no upper limit on the amount that breast cancer survivors with or at risk for lymphedema can lift (74,75). The safety of exercise for lower extremity lymphedema remains unknown (84).

- *Bone metastases:* Selected modalities for exercise should avoid direct musculoskeletal loading to metastatic lesions or loading of muscles that are proximal to metastatic lesions (76,77). Bone pain should be monitored during and after exercise (76,77). If bone pain worsens, exercise should be ceased; if pain does not improve with cessation of exercise, referral to medical provider is encouraged.
- *Neuropathy:* Systematic assessment of falls may be informative in older cancer survivors (85) or those with a history of falls and/or significant neuropathy of the lower extremities (78,86). Weight-bearing activities should be carefully selected to reduce risk of falls. Neuropathy symptoms should be monitored during and after exercise. If neuropathy worsens, exercise should be ceased or alternative exercises considered; if neuropathy symptoms do not improve with cessation of exercise, referral to medical provider is encouraged.
- *Ostomy:* Cancer survivors with an ostomy should adhere to infection risk reduction practices. Resistance exercise should start with low resistance and progress slowly. Avoid contact sports and exercises that cause excessive intra-abdominal pressure (*e.g.*, Valsalva maneuver). There is no empirical evidence to support this recommendation, and it is based on expert opinion (73).

Among all cancer survivors, the presence of ataxia, severe fatigue, significant anemia, profound weakness, or any other worsening or changing physical condition that may make it unsafe to exercise should be referred to medical providers for care (72). To date, there are no established recommendations regarding the supervision of exercise across the continuum of survivorship or in various exercise settings. Health fitness professionals should use prudent judgment in deciding the level of exercise supervision as needed on an individual basis.

TABLE 10.3 • Review of U.S. DHHS Physical Activity Guidelines (PAGs) for Americans and Alterations Needed for Cancer Survivors

	Breast	Prostate	Colon	Adult Hematologic (No HSCT)	Adult HSCT	Gynecologic
General Statement	Avoid inactivity, return to normal daily activities as quickly as possible after surgery. Continue normal daily activities and exercise as much as possible during and after non-surgical treatments. Individuals with known metastatic bone disease will require modifications to avoid fractures. Individuals with cardiac conditions (secondary to cancer or not) may require modifications and may require greater supervision for safety.					
Aerobic exercise training (volume, intensity, progression)	Recommendations are the same as age appropriate guidelines from the PAGs for Americans.				Ok to exercise every day, lighter intensity and lower progression of intensity recommended.	Recommendations are the same as age appropriate guidelines from the PAGs for Americans. Women with morbid obesity may require additional supervision and altered programming.
Cancer site specific comments on aerobic exercise training prescriptions	Be aware of fracture risk.	Be aware of increased potential for fracture.	Physician permission recommended for patients with an ostomy prior to participation in contact sports (risk of blow).	None	Care should be taken to avoiding overtraining given immune effects of vigorous exercise.	If peripheral neuropathy is present, a stationary bike might be preferable over weight bearing exercise.
Resistance training (volume, intensity, progression)	Altered recommendations. See below.	Recommendations same as age appropriate PAGs.	Altered recommendations. See below.	Recommendations same as age appropriate PAGs.		Altered recommendations. See below.
Cancer site specific comments on resistance training prescription	Start with a supervised program of at least 16 sessions and very low resistance, progress resistance at small increments. No upper limit on the amount of weight to which survivors can progress. Watch for arm/shoulder symptoms, including lymphedema, and reduce resistance or stop specific exercises according to symptom response. If a break is taken,	Add pelvic floor exercises for those who undergo radical prostatectomy. Be aware of risk for fracture.	Recommendations same as age-appropriate PAGs. For patients with a stoma, start with low resistance and progress resistance slowly to avoid herniation at the stoma.	None	Resistance training might be more important than aerobic exercise in BMT patients. See text for further discussion on this point.	There is no data on the safety of resistance training in women with lower limb lymphedema secondary to gynecologic cancer. This condition is very complex to manage. It may not be possible to extrapolate from the findings on upper limb lymphedema. Proceed with caution if the patient has had lymph node removal and/or radiation to lymph nodes in the groin.

	lower the level of resistance by 2 wk worth for every wk of no exercise (*e.g.*, a 2 wk exercise vacation = lower to the resistance used 4 wk ago). Be aware of risk for fracture in this population.					
Flexibility training (volume, intensity, progression)	Recommendations are the same as age appropriate PAGs for Americans.		Recommendations same as age appropriate PAGs, with care to avoid excessive intraabdominal pressure for patients with ostomies.	Recommendations are the same as age appropriate PAGs for Americans.		
Exercises with special considerations (*e.g.*, yoga, organized sports, and Pilates)	Yoga appears safe as long as arm and shoulder morbidities are taken into consideration. Dragon boat racing not empirically tested, but the volume of participants provides face validity of safety for this activity. No evidence on organized sport or Pilates.	Research gap.	If an ostomy is present, modifications will be needed for swimming or contact sports. Research gap.	Research gap.	Research gap.	Research gap.

BMT, bone marrow transplantation; HSCT, hematopoietic stem cell transplantation; U.S. DHHS, U.S. Department of Health and Human Services.
Information from (71).

Summary

- All cancer survivors should be encouraged to avoid inactivity and be as physically active as possible.
- Exercise is generally safe for cancer survivors during and after cancer treatment.
- General Ex R_x for most[*] cancer survivors:
  - At least 150 min · wk^{-1} of moderate intensity or 75 min · wk^{-1} of vigorous intensity or an equivalent combination of moderate and vigorous intensity aerobic activity. Preferably, aerobic activity should be spread throughout the week.
  - Resistance training activities of moderate-to-vigorous intensity and that involve all major muscle groups on 2 or more days a week, as these activities provide additional health benefits.
  - Stretch major muscle groups and engage in balance and neuromuscular activities on as many days as tolerable.
- Exercise may be tailored to minimize risk of adverse events and maximize likelihood of desired health outcome. Tailoring should incorporate an individual’s abilities, preferences, preexisting health conditions, and treatment-related side effects.
- Symptom response may be used to guide to the Ex R_x. Starting at light intensity and progressing slowly may reduce the risk of symptom exacerbation. The mnemonic, *start low and progress slow*, may be useful for

survivors.

- For individuals undergoing active cancer treatment and those living with metastatic cancer, health fitness professional collaboration with oncology providers may be able to offer information that is useful to tailor the Ex R_x.

*Cancer survivors for whom the Ex R_X may be individualized include those with metastatic disease, persistent and significant cancer treatment-related side effects, or significant comorbidities (72).

ONLINE RESOURCES

American Cancer Society: http://www.cancer.org

American College of Sports Medicine/American Cancer Society Certified Cancer Exercise Trainer: https://www.acsm.org/get-stay-certified/get-certified/specialization/cet

Livestrong at the YMCA: https://www.livestrong.org/what-we-do/program/livestrong-at-the-ymca

FIBROMYALGIA

Fibromyalgia is a syndrome characterized by chronic widespread pain as the pivotal symptom. Additional common, but not universal, symptoms include fatigue (90% of individuals), sleep disturbances and mood disorders such as anxiety and depression (75% of individuals), and cognitive dysfunction (87–89) (see *Box 10.2* for a listing of signs and symptoms). Individuals with fibromyalgia often experience concomitant and comorbid conditions (92) that cause pain, including musculoskeletal conditions, cardiovascular or endocrinology disorders, interstitial cystitis bladder syndrome, chronic pelvic pain, temporomandibular joint disorder, psychiatric disorders, irritable bowel syndrome, migraine, and dysmenorrhea (90,93,94). Fibromyalgia symptoms fluctuate and their intensity changes from day to day and even within the same day (95–97). Symptoms and concomitant conditions affect individuals' quality of life, highlighting the need for practitioners to understand the complexity and heterogeneity of fibromyalgia and the necessity of the personalized management approach (98,99).

Box 10.2 Signs and Symptoms of Fibromyalgia[a]

Widespread pain
Fatigue
Nonrestorative sleep
Anxiety
Depression
Cognitive dysfunction
Morning stiffness
Hyperalgesia (increased pain in response to normally painful stimuli) and/or allodynia (pain in response to normally nonpainful stimuli)
Sensory and environmental sensitivity (cold, lights, noise, odor)
Paresthesia (sensations of burning, prickling, tingling, or itching of skin with no apparent physical cause)
Weakness
Feelings of swelling in hands or feet
Headache
Restless legs

[a]Symptoms may worsen with emotional stress, poor sleep, injury or surgery, high humidity, physical inactivity, or excessive physical activity. From (87,88,90,91).

To date, there is no definitive etiology, nor is a clinical or laboratory test available to confirm a diagnosis of fibromyalgia. Evidence suggests that fibromyalgia is in part a central nervous system (CNS)-driven pain amplification syndrome. It is not an autoimmune, inflammatory, joint, or muscle disorder (100). Individuals display an augmented sensory processing and inability to modulate pain effectively. Hyperalgesia (increased pain in response to normally painful stimuli) and/or allodynia (pain in response to normally nonpainful stimuli) (90,91,101) are common symptoms. Genetic factors seem to have a role; relatives of individuals with fibromyalgia are eight times more likely to have the condition (102,103).

The American College of Rheumatology (ACR) published the first diagnostic criteria (104) requiring the presence of widespread pain lasting longer than 3 mo and 11 of 18 active tender points. After ongoing concerns with the 1990 criteria, the ACR published a symptom-based alternative method of diagnosis (105,106). The ACR 2010 (used as a clinician-administered or a survey questionnaire) includes the widespread pain index (WPI) (19 areas representing anterior and posterior axis and limbs) and a symptom severity (SS) scale. The SS contains items related to symptoms such as fatigue, sleep disturbances, cognition, and somatic complaints. Individuals meet the ACR 2010 diagnostic criteria as follows: (a) score 7 of 19 WPI pain sites and score of 5 out of 12 on the SS scale (or between WPI 3–6/19 and SS 9/12), (b) presence of generalized pain (defined as pain in at least 4 of 5 regions), (c) presence of symptoms at a similar level for at least 3 mo, and (d) the absence of another disorder that could explain the pain (88).

Fibromyalgia is most common in women over 50 yr of age and of low socioeconomic and educational status (107). Although common in middle-aged women, fibromyalgia can also affect children, men, and older adults. Using the ACR 1990 diagnostic criteria (104), the worldwide mean prevalence is 2.7%, including 4.1% females and 1.4% males; a more recent review (108) reported an overall prevalence of 0.2%–4.7%. Very few prevalence studies have used the ACR 2010 diagnostic criteria. It seems the diagnosis sensitivity and specificity improves when using both criteria simultaneously (109).

There has been tremendous growth in research about fibromyalgia management in adults over the past two decades. Evidence-based guidelines created from this body of research emphasize shared decision making and active individual participation for both nonpharmacological strategies and pharmacological management strategies (110–115). These guidelines recognize the beneficial effect of exercise training on fibromyalgia symptoms (110–116) and advocate incorporation of exercise as a major component of the syndrome management.

Fibromyalgia has a profound impact on people's lives; the severity and unpredictability of the symptoms makes daily tasks (*i.e.*, work, social, or exercise) difficult (117). People with fibromyalgia are often less tolerant of PA, which may lead to sedentary behavior (118,119), and have less perceived functional ability and impaired physical performance (120,121). In addition, research points to sedentary behavior being independently and positively correlated with levels of pain, fatigue, and impact of fibromyalgia in women (122). These factors increase the risk of additional morbidity (123,124) and potential loss of autonomy (125). People with fibromyalgia may become fearful (and avoidant) of exercise, anticipating postexercise pain or increase of fatigue (126). This avoidance has negative consequences both physically (*i.e.*, loss of strength, endurance, mobility, and other components of health) and psychologically (*i.e.*, loss of self-esteem, isolation, depression) (125,127).

Although pain and fatigue can present challenges to engaging in and maintaining regular exercise for individuals with fibromyalgia, there is evidence that regular exercise improves some symptoms of fibromyalgia and maintains or improves physical fitness (128–143). It is important to recognize, however, that these findings are based on studies that have focused primarily on middle-aged women from high-income countries.

Exercise Testing

Studies investigating the effects of exercise training for adults with fibromyalgia have used a variety of tests to assess components of physical fitness. However, identification of exercise tests that are best suited to and specific precautions for individuals with fibromyalgia have received less attention. Understanding current fibromyalgia symptoms in conjunction with exercise history will help practitioners to select tests and equipment that are best suited to the individual.

Because adults with fibromyalgia appear to tolerate moderate intensity aerobic exercise better than vigorous intensity exercise, we suggest the use of submaximal aerobic tests. A systematic review (144) sought to identify cardiorespiratory tests (including field tests) that are valid and reliable to use with individuals with fibromyalgia. The following submaximal tests can be used to assess aerobic response and change over time: Åstrand, modified Åstrand, and lean body mass-based Åstrand test; submaximal bicycle ergometer test following protocols other than the Åstrand test; 5-min, 6-min, and 10-min walk tests; shuttle walk test (144). In contrast, researchers have advised against use of the aerobic 2-km walk test, mainly due to the inability to control effort during the walk (144,145).

There are many protocols in use for strength and flexibility testing for people with fibromyalgia, and none are preferred to another. Similar to tests outlined for the general population (see *Chapter 3*), practitioners may utilize assessments of strength and flexibility in adults with fibromyalgia. Lastly, all tests should be as specific as possible to the planned exercise.

The senior fitness test battery is a set of field tests that evaluates cardiorespiratory endurance, muscular strength, speed/agility, and flexibility. This battery was originally developed for community-residing older adults

(146) and subsequent research established criterion-referenced fitness standards for older adults that predict the level of capacity needed for maintaining physical independence into later life (146). With the addition of handgrip strength, this battery has been used to develop physical fitness reference standards for individuals with fibromyalgia (147–149).

In summary, people with fibromyalgia can safely participate in exercise testing, but practitioners should be aware of each individual's symptoms and how the individual feels at all times (*i.e.*, before, during, and after the test period).

Before Testing

- Prior to testing, the practitioner should ensure that assessment includes medical history, fibromyalgia symptoms, current lifestyle, level of PA and sedentary behavior (122), exercise history, and attitudes.
- The assessment should include information on times of day at which symptoms (including morning stiffness, pain, fatigue) are usually less intrusive, and schedule all tests and training sessions at such times.
- Understanding current fibromyalgia symptoms in conjunction with exercise history will help the practitioner to select tests and equipment that are best suited to the individual. For example, if the individual has painful gluteal tender points, consider a walking test instead of a cycle ergometer test. In contrast, if the individual has leg pain before testing, consider a weight-supported test using a leg or recumbent cycle ergometer. This understanding will help the practitioner to be mindful of symptom-limited tests.
- People with fibromyalgia may have symptoms that make exercise testing difficult to complete. Commonly used, the disease-specific Fibromyalgia Impact Questionnaire (FIQ) (150) or FIQ-Revised (151) may aid assessing physical function, overall impact of disease, and symptoms of fibromyalgia.
- Individuals with fibromyalgia, and clinicians, may clarify potential and ongoing symptom impact on exercise/PA (and the reverse) using a daily record of symptoms, symptom fluctuation during the day, exercise, and PA.
- Determine the level of understanding if the individual presents with cognitive dysfunction (89); ensure that verbal and written instructions for testing and training are suited to the individual to ensure individual safety.
- Educate the individual about the difference between postexercise soreness and fatigue and the normal fluctuations in pain, fatigue, and other symptoms that occur with fibromyalgia.
- Practitioners should establish how best to verbally encourage individuals to perform well during an exercise test while being consistent across individuals and testing sessions.

During Testing

- Ensure that individuals get enough rest between tests. It may be preferable to conduct tests for cardiorespiratory endurance, strength, and flexibility on separate days. If completing tests on 1 d, consider the order of testing to allow for adequate rest and recovery of different physiologic systems and/or muscle groups.
- Individual's limits of painful movements should guide positioning on the exercise testing equipment and of the testing itself. Modify exercise test equipment accordingly.
- Monitor how the individual is feeling during the test. The Borg CR-10 scale (see *Figure 4.2*) and visual analogue scales for pain and fatigue can help monitoring rate of perceived exertion (RPE) and how the individual is feeling. Ensure that the individual knows that the test can stop at any time.

Exercise Prescription

Evidence-based guidelines recognize exercise as an important component in fibromyalgia symptom management (110,112,113,115,116). Exercise training may improve health-related quality of life and physical function; lead to decreases in pain, stiffness, anxiety, fatigue, and depression; and maintain or improve physical fitness (128–138,140–142). These effects are reported for land- and aquatic-based exercise training and for training using one type (aerobic or resistance) or a combination (aerobic, resistance, and flexibility) of exercise training types (139,143).

Flexibility exercise as a stand-alone form of training does not appear to improve symptoms of fibromyalgia (152); however, when added to programs of aerobic or resistance training, a flexibility component is expected to contribute to overall individual physical functioning. Meditative exercise programs such as tai chi and yoga may improve some fibromyalgia symptoms, independent of aerobic training (139,143).

The FITT principles of Ex R_x are based on the current fibromyalgia and exercise training research literature.

FITT	EVIDENCE-BASED FITT RECOMMENDATIONS FOR INDIVIDUALS WITH FIBROMYALGIA (128–133,135,138,142,152,153)		
	Aerobic	**Resistance**	**Flexibility**
Frequency	Begin with 1–2 d · wk^{-1} and gradually progress to 2–3 d · wk^{-1}.	2–3 d · wk^{-1} with a minimum of 48 h between sessions	2–3 d · wk^{-1}
Intensity	Begin with light (30%–39% $\dot{V}O_2R$ or HRR). Gradually progress to moderate intensity (40%–59% $\dot{V}O_2R$ or HRR).	40%–80% 1-RM. Gradually increase to 60%–80% concentric 1-RM for strength. For muscle endurance, use ≤50% 1-RM.	Stretch within limits of pain to the point of tightness or slight discomfort.
Time	Begin with 10 min · d^{-1} and progress to a total of 30–60 min · d^{-1} as soon as tolerated.	Strength: Gradually progress, as tolerated, from 4–5 to 8–12 repetitions, increasing from 1 to 2–4 sets per muscle group with at least 2–3 min between sets; endurance: 15–20 repetitions, increasing from 1 to 2 sets with a shorter rest interval	Hold each stretch for 10–30 s.
Type	Low-impact (*e.g.*, aquatic exercise, walking, dance and other aerobic movement to music, swimming, cycling)	Body weight, elastic bands, dumbbells, cuff/ankle weights, weight machines. For resistance in water, use devices to manipulate turbulence (velocity, surface area). For resistance in water, use devices to manipulate turbulence (velocity, surface area).	Static stretches (passive and/or active), for all major muscle tendon groups. Dynamic stretches may also be used.

1-RM, one repetition maximum; HRR, heart rate reserve; $\dot{V}O_2R$, oxygen uptake reserve.

The information in the FITT table summarize current fibromyalgia and exercise training research literature used in the RCTs that have been included in the cited systematic reviews; these studies have reported few adverse events. The dose-response curves for intensity and frequency of each type of exercise versus fibromyalgia symptoms and whether the dose-response curves differ among subgroups of individuals with fibromyalgia is unclear in the current body of evidence.

Exercise Training Considerations

- It is crucial to recognize that individuals with fibromyalgia are part of a heterogeneous group. Ex R_x must be individualized, based on the individual's baseline and ongoing physical function, severity and fluctuation of pain, fatigue and other fibromyalgia symptoms, and tolerance to exercise and exercise-induced pain (154).
- Evidence-based guidelines advocate shared decision making (114) and active participation (112) of individuals in fibromyalgia symptom management. Work collaboratively to develop individualized prescriptions for exercise and PA that best fit the individual's symptoms, potential symptom flares, and exercise preferences, and promote regular long-term adherence to exercise that maximizes function and well-being.
- Although positive changes are noted with a frequency of 1–2 d · wk^{-1}, symptom reduction is greater when the frequency is increased to 3 d · wk^{-1} (129).

- Aerobic exercise training can begin at very light intensities (<30% of oxygen uptake reserve [$\dot{V}O_2R$] or heart rate reserve [HRR]) but should be progressed to light ($\dot{V}O_2R$ or HRR 30%–39%) and then moderate intensities ($\dot{V}O_2R$ or HRR 40%–59%) as tolerated. As recommended in *Chapter 5* of this book, when initiating an exercise program for deconditioned individuals, the principle of "start low and go slow," increasing exercise time/duration per session before intensity may help avoid adverse effects. Light-to-moderate intensities are more widely tolerated, but studies have shown that some individuals can tolerate progression to vigorous intensities ($\dot{V}O_2R$ or HRR 60%–89%) (128–133,135,142,152,153).
- Practitioners can make use of the RPE to prescribe exercise intensity for both aerobic and muscular strength and endurance training. RPE may be particularly useful during flares of pain and/or fatigue.
- Teach individuals with fibromyalgia to adjust exercise intensity according to their symptoms (self-regulation). For example, advise individuals to "Go harder when you can; back off if you need to because of symptom flares."
- Teach individuals breathing control to avoid the Valsalva maneuver.
- Individuals with fibromyalgia may be physically inactive because of their symptoms. Initially, prescribe exercise at a physical exertion level that the individual will be able to do without undue pain or exacerbation of symptoms; progress slowly to allow for physiologic adaptation without an increase in symptoms. Monitor fatigue and pain (150,151) intermittently to assess ongoing overall impact of disease and symptoms of fibromyalgia with exercise.
- Tailor the rate of progression of the FITT principle of Ex R_x to the individual's fibromyalgia symptoms and functioning.
- Individualize recovery times to minimize worsening or exacerbation of fibromyalgia symptoms.
- Aquatic (131) and land-mixed exercise (128) that include two or all three types of training (aerobic, resistance, flexibility) in each session or within each week of training, as well as training using a single type of exercise, are equally beneficial in fibromyalgia symptom management (154). For promotion of long-term physical function and health, mixed exercise programs are recommended (155).
- Identify times of day for exercise that symptoms are the least intrusive. For example, those who experience morning stiffness should avoid early morning exercise.
- Work with the individual to identify strategies to maintain inclusion of some PA during flares of symptoms such as pain and fatigue. Use functional activities (*e.g.*, walking, stair climbing, rising from a chair, dancing) to facilitate maintenance of light-to-moderate intensity PA during symptom flares. It may be better to decrease intensity or duration prior to reducing frequency to maintain a pattern of regular PA (156).
- Include stretching exercises, breathing exercises, and relaxation techniques at the end of exercise sessions.
- Teach and demonstrate the correct mechanics for performing each exercise to reduce the potential for injury and pain.

Special Considerations

- Ensure that the individual has information about the potential benefits of exercise for symptoms of fibromyalgia and for physical fitness (113,128–143) and health (155).
- Because of the difficulties individuals with fibromyalgia have with exercise, provide information about improvements in health that can be derived by decreasing time spent in sedentary behavior through even modest increases in regular PA (155). Encourage individuals to avoid prolonged sitting and inactivity as much as their symptoms allow. Strategize with the individual to identify other ways to translate this idea into daily life.
- Assist individuals with fibromyalgia to set realistic short- and long-term goals. Improvements in symptoms with exercise training are modest and may take more than 7 wk after initiating an exercise program to be clinically relevant (129).

- Individuals may experience an increase in symptoms during the first days or weeks until exercise adaptation occurs.
- For aquatic testing and exercise, use pools with water temperatures of 91° to 97° F (33° to 36° C) to improve comfort and maximize performance (131).
- Motivational interviewing may have a positive short-term effect on pain and self-report PA in individuals with fibromyalgia (157). To minimize barriers to adherence, focus on the individual's exercise experiences and preferences in applying the principle of specificity when choosing exercise tests and prescribing exercise.
- Individuals may require additional support and encouragement to maintain an exercise program. Encourage supervised or group exercise early in a training program to provide a social support system for reducing physical and emotional stress and promote adherence (158–160). Discuss ways to foster exercise independence in an effort to increase long-term adherence.

ONLINE SOURCES

Canadian Guidelines for the Diagnosis and Management of Fibromyalgia Syndrome: http://fmguidelines.ca/
EULAR (European League Against Rheumatism): https://www.eular.org/recommendations_management.cfm
IASP (International Association for the Study of Pain): http://www.iasp-pain.org/
National Fibromyalgia & Chronic Pain Association (NfmCPA): https://www.fmcpaware.org/
National Fibromyalgia Association (NFA): http://www.fmaware.org/new-home-page/
OMERACT (Outcome Measures in Rheumatology): https://omeract.org/

HUMAN IMMUNODEFICIENCY VIRUS

Over the last two decades, rates of new human immunodeficiency virus (HIV) infection have been highest among minority and lower socioeconomic classes. Because of the relatively high incidence rate among these populations, people living with HIV (PLWH) are generally beginning therapy with a higher body mass index (BMI) and reduced muscle strength and mass. They are also more likely to have social and environmental conditions that predispose them to high visceral fat and obesity (161,162). It is not yet clear how advancing age will interact with HIV status, sociodemographic characteristics, and chronic disease risk. However, in older men, evidence suggests that low CRF is associated with the presence of additional comorbidities, such as hypertension, but not CD4 cell count or HIV viral load (163).

Broad use of antiretroviral therapy (ART) to reduce the viral load of HIV has significantly increased life expectancy following diagnosis of HIV infection (164,165). Recent investigations indicate that the life expectancy of PLWH is similar to that of the non-HIV infected population (166). ART also dramatically reduces the prevalence of the wasting syndrome and immunosuppression. However, certain ART drugs are associated with metabolic and anthropomorphic health conditions including sarcopenia, dyslipidemia, abnormal distribution of body fat (*i.e.*, abdominal obesity and subcutaneous fat loss), and insulin resistance (167,168). Protease inhibitors, another common treatment option, are associated with insulin resistance and an increased risk of diabetes. Additionally, HIV infection is associated with cardiac dysfunction and a higher risk of CVD (169,170). Before effective ART, treatment options included anabolic steroids, growth hormone, and growth factors for acquired immunodeficiency syndrome (AIDS) muscle wasting (171). PA and dietary counseling should be evaluated as viable treatment options in conjunction with ART for PLWH.

Numerous studies have indicated that aerobic and resistance exercises provide important health benefits for PLWH (172–176). Exercise training enhances functional aerobic capacity, cardiorespiratory and muscular endurance, and general well-being. PA can also reduce body fat and the risk for diabetes and other metabolic conditions. There have been fewer studies of PLWH examining the effects of resistance training alone on muscle and bone quality. However, a meta-analytical report suggests a consistency among studies indicating that progressive resistance exercise increases muscular strength, but overall, the evidence does not support an increase in muscle mass (177). In addition, reviews of the effect of exercise on bone density indicate that, despite the high prevalence of osteoporosis and osteopenia in PLWH, progressive resistance exercise is effective in increasing BMD (178). As is the case in other healthy and clinical populations, numerous exercise studies have reported enhanced mood and psychological status in PLWH (174). It is important to note that there is no evidence to suggest that regular participation in moderate intensity exercise will suppress immune function in either asymptomatic or symptomatic individuals, and therefore, exercise should not be voided out of fear of exacerbating the condition (173,179).

Exercise Testing

Not all PLWH require a preparticipation exercise test. However, if an exercise test is to be performed, the increased prevalence of cardiovascular pathophysiology, metabolic disorders, T2DM, hyperlipidemia, and the complex medication routines of PLWH require specialized consultation before exercise testing. This consultation should be completed by an infectious disease expert, or at minimum, a health care professional with extensive knowledge of HIV-related pharmacological regimens and symptoms. Besides the usual considerations prior to exercise testing, the following list of issues should be considered:

- Exercise testing should be postponed in individuals with acute infections.
- Variability of exercise test results will be higher for individuals with HIV than in a healthy population. It is common for this population to have a significantly lower peak oxygen consumption ($\dot{V}O_{2peak}$) when compared to age-matched healthy individuals (180,181).

When conducting cardiopulmonary exercise tests outside of the clinical setting, attention to compliance with established precautions should be employed for individuals being tested as well as those performing the test (182,183). Although HIV is not transmitted through saliva, possible oral or pulmonary infections and possible presence of blood within the mouth or gums necessitate following recommended guidelines for thorough sterilization of reusable equipment and supplies when disposables are not available. Consider the use of disposable mouth pieces and proper sterilization of all nondisposable equipment after each test, and yearly flu vaccinations and tuberculosis testing for all research staff and personnel, as required in the clinical setting. A level beyond standard precautions, transmission-based precautions should be used for individuals with known or suspected infection with other significant pathogens transmitted through air, fluids, or contaminated surfaces (*e.g.*, hepatitis B or tuberculosis).

- The increased prevalence of cardiovascular impairments, and particularly cardiac arrhythmias, requires monitoring of blood pressure (BP) and an electrocardiogram (ECG).
- Because of the higher prevalence of peripheral neuropathies, testing mode should be altered, if necessary, to accommodate any functional limitations, including limited ROM.
- Typical limitations to stress testing by stage of disease include the following:
  - Asymptomatic: normal exercise test with reduced exercise capacity
  - Symptomatic: reduced exercise time, $\dot{V}O_{2peak}$, and ventilatory threshold (VT)
  - AIDS will dramatically reduce exercise time and $\dot{V}O_{2peak}$. Reduced exercise time will likely preclude reaching VT, and achieving >85% of age-predicted HR_{max} will potentially produce abnormal nervous and endocrine systems responses.

Exercise Prescription

The chronic disease and health conditions associated with HIV infection suggest health benefits would be gained by regular participation in a program of combined aerobic and resistance exercise. Indeed, numerous clinical studies have shown participation in habitual PA results in physical and mental health benefits (172–176,179,184).

The varied clinical presentation of individuals with HIV, however, requires a flexible approach, and notably, no clinical study of the effects of PA on symptomatology of HIV infection has shown an immunosuppressive effect. Furthermore, data indicate PLWH adapt readily to exercise training, with some studies showing more robust responses than would be expected in a healthy population (172–176,179,184) and tolerance of vigorous intensity aerobic exercise despite comorbidities (185). There is little data available to specifically guide exercise training in the HIV population (186). Therefore, the general FITT principle of Ex R_x is consistent with that for apparently healthy adults (see *Chapter 5*) or older adults (see *Chapter 6*), but the management of CVD risk should be emphasized. Exercise professionals should be mindful of the potentially rapid change in health status of this population, particularly the high incidence of acute infections, and should adjust the Ex R_x accordingly.

FITT **FITT RECOMMENDATIONS FOR INDIVIDUALS WITH HUMAN IMMUNODEFICIENCY VIRUS**

	Aerobic	Resistance	Flexibility
Frequency	3–5 d · wk^{-1}	2–3 d · wk^{-1}	≥2–3 d · wk^{-1}
Intensity	Begin at light intensity (30%–39% $\dot{V}O_2R$ or HRR). Gradually progress to moderate intensity (40%–59% $\dot{V}O_2R$ or HRR).	Begin at light intensity with goal of gradual progression to 60% 1-RM.	Stretch to the point of tightness or slight discomfort.
Time	Begin with 10 min and progress to 30–60 min · d^{-1}.	1–2 sets, with gradual progression to 3 sets of 8–10 repetitions	Hold static stretch for 10–30 s; 2–4 repetitions of each exercise
Type	Modality will vary with the health status and interests of the individual. Presence of osteopenia will require weight-bearing physical activities.	Machine weights are safe and effective without supervision; free weights can be used for experienced lifters and/or under supervision.	Static, dynamic, and/or PNF stretching

1-RM, one repetition maximum; HRR, heart rate reserve; PNF, proprioceptive neuromuscular facilitation; $\dot{V}O_2R$, oxygen uptake reserve.

Exercise Training Considerations

- Contact and high-risk (*e.g.*, mixed martial arts, boxing, skateboarding, rock climbing) sports are not recommended because of risk of bleeding.
- Because of virus and drug side effects, progression will likely occur at a slower rate than in healthy populations. However, the long-term goals for asymptomatic PLWH should be to achieve the ACSM recommendations for aerobic and resistance exercise for healthy adults, with appropriate modifications for symptomatic individuals. The Ex R_x should be adjusted accordingly based on the individual’s age and current health status.

Special Considerations

- There are no established guidelines regarding contraindications for exercise for individuals with PLWH.
- Supervised exercise, whether in the community or at home, is recommended for symptomatic PLWH or those with diagnosed comorbidities.

- In addition to supervised exercise sessions, PLWH require a higher level of health monitoring. This is especially important for those engaging in strenuous activity and/or interval training (*i.e.*, vigorous intensity aerobic exercise and/or resistance training).
- PLWH should report to their health care provider any increase in general feelings of fatigue or perceived effort during activity, lower gastrointestinal distress, or shortness of breath.
- Minor increases in feelings of fatigue should not preclude participation, but dizziness, swollen joints, or vomiting should be evaluated prior to continuing.
- The increased risk of peripheral neuropathy among PLWH may require adjustment of exercise type, intensity, and ROM.
- Regular monitoring of the health/fitness benefits related to PA and CVD risk factors is critical for clinical management and continued exercise participation.

ONLINE RESOURCES

Centers for Disease Control and Prevention: http://www.cdc.gov/hiv/

KIDNEY DISEASE

Most recent estimates indicate that more than 30 million adults in the United States (*i.e.*, ~14.8% of the adult population) have chronic kidney disease (CKD) (187), and the incidence is expected to increase due to the increasing prevalence of diabetes mellitus and obesity. Hypertension, diabetes mellitus, and CVD are very common in the CKD population, with the prevalence of these comorbidities rising incrementally with the severity of CKD (188). CKD is diagnosed in individuals who have either kidney damage or have poor kidney function. Kidney damage is evidenced by moderately increased urine levels of albumin, whereas poor kidney function is noted with a ≥3-mo estimated glomerular filtration rate (eGFR) of <60 mL · min^{-1} · 1.73 m^{-2} (189). CKD is categorized into five distinct stages, based on the eGFR and the amount of albumin present in the urine. The level of kidney function and evidence of damage are used to identify the risk of disease progression and the likelihood of poor outcomes (*Table 10.4*) (189). Stage 1 CKD indicates normal or high eGFR, but this is associated with some evidence of kidney disease or damage. Stage 5 individuals have an eGFR <15 mL · min^{-1} · 1.73 m^{-2} and are approaching the need for renal replacement therapy such as hemodialysis (in-center or at home), peritoneal dialysis, kidney transplantation, or conservative management (*i.e.*, no dialysis or transplant). The latter option is often chosen by frail, elderly individuals. The symptoms and complications of late-stage CKD dictate the timing and initiation of renal replacement therapy.

TABLE 10.4 • Glomerular Filtration Rate (GFR) Categories in Chronic Kidney Disease		
GFR Category	**GFR (mL · min^{-1} · 1.73 m^{-2})**	**Terms**
G1	**≥90**	Normal or high
G2	60–89	Mildly decreased[a]
G3a	45–59	Mildly to moderately decreased
G3b	30–44	Moderately to severely decreased
G4	15–29	Severely decreased
G5	<15	Kidney failure

NOTE: In the absence of kidney damage, neither GFR category G1 nor G2 fulfill the criteria for chronic kidney disease.
[a]Relative to young adult level.
Reprinted from (189).

Exercise Testing

Those who have not participated in regular exercise training in the previous 3 mo should be referred for medical clearance prior to beginning exercise (see *Chapter 2*). Because CVD is the major cause of death in individuals with CKD, when symptoms are present, or CVD is diagnosed, exercise testing may be indicated as part of the medical clearance process prior to beginning an exercise program of moderate-to-vigorous intensity (190). In some cases, exercise testing may also be included in the workup for possible kidney transplantation or in those with CKD presenting with chest pain (191). However, some suggest that exercise testing for individuals with end-stage renal disease (ESRD) (*i.e.*, stage 5 CKD), as well as those who are frail, is not warranted because their performance may be affected by muscle fatigue, and such testing may act as an unnecessary barrier to their participation in an exercise training program (192,193). If performed, exercise testing of individuals with CKD should use standard test termination criteria and test termination methods (see *Chapter 4*).

Most research on individuals with CKD has been done on individuals classified with stage 5 CKD. These individuals have low functional capacities, or approximately 50%–80% of healthy age- and sex-matched controls, with $\dot{V}O_{2peak}$ ranges between 15 and 25 mL · kg^{-1} · min^{-1} (194). $\dot{V}O_{2peak}$ values can increase with training by approximately 17%–23%, but in general will never reach the values achieved by age- and sex-matched controls (194). This reduced functional capacity is thought to be related to several factors including a sedentary lifestyle, cardiac dysfunction, anemia, and musculoskeletal dysfunction. In those referred for exercise testing, the following considerations should be noted:

- Medical clearance should be obtained.

- Individuals with CKD are likely to be on multiple medications, many of which could impact exercise test capacity or results (see *Appendix A*).
- When performing an exercise test on individuals with stage 1–4 CKD, standard exercise testing procedures should be followed (see *Chapters 3* and *4*). However, in individuals receiving maintenance hemodialysis, testing should be scheduled for nondialysis days, and BP should be monitored in the arm that does not contain the arteriovenous fistula or graft (193).
- For comfort purposes, individuals receiving continuous ambulatory peritoneal dialysis should be tested with little dialysate fluid in their abdomen (193).
- Standard exercise testing procedures are used with individuals who are transplant recipients.
- Both treadmill and cycle leg ergometry protocols can be used to test individuals with kidney diseases. Because of the low functional capacity in this population, more conservative treadmill protocols such as the modified Balke or Naughton are appropriate (195) (see *Chapter 4*). If cycle leg ergometry is used, initial warm-up work rates should be 20–25 W with the work rate increased by 10–30-W increments every 1–3 min (196,197).
- In individuals receiving maintenance hemodialysis, the peak heart rate (HR_{peak}) is often attenuated and may not surpass 75% of age-predicted maximum (198); therefore, RPE should always be monitored (see *Chapter 4*).
- As a result of the very low functional capacity, traditional exercise tests may not always yield the most valuable information for Ex R_x and the assessment of exercise training adaptations (199). Consequently, a variety of physical performance tests that have been used in other populations (*e.g.*, older adults) can be used (see *Chapter 6*). The short physical performance battery (SPPB) has been identified as a useful functional test in low-functioning individuals with CKD (200,201). Tests can be chosen to assess CRF, muscular strength, balance, and flexibility (199,202).
- Isotonic strength testing should be done using a 3-RM or higher load (*e.g.*, 10–12-RM) as 1-RM testing is generally thought to be contraindicated in individuals with late stage CKD because of the fear of spontaneous avulsion fractures (193,203–205). There are equations to predict the 1-RM from a multiple-RM test (206,207), which can be used to develop the resistance training Ex R_x. Some researchers have used 1-RM testing in predialysis individuals with CKD with no adverse responses reported (208,209).
- Muscular strength and endurance can be safely assessed using isokinetic dynamometers employing angular velocities ranging from 60 to 180 degrees $\cdot$ s^{-1} (195,210,211).
- Muscle power should be assessed using a computerized dynamometer because power appears to be more related to functional ability than either muscular strength or endurance (199). To assess power, individuals should be asked to perform a repetition at a specific percentage of their estimated maximum as quickly as possible (212).

Exercise Prescription

Exercise training in those with CKD leads to BP reductions and improvements in aerobic capacity, heart rate (HR) variability, muscular function, and quality of life (213). The ideal FITT principle of Ex R_x for individuals with CKD has not been fully developed, but based on the available research, programs for these individuals should consist of a combination of aerobic and resistance training (190,211). The Kidney Diseases: Improving Global Outcomes (KDIGO) clinical practice guidelines recommend that those with CKD aim for PA of an aerobic nature 5 d $\cdot$ wk^{-1} for at least 30 min but do not provide more specific guidance regarding the Ex R_x (189). The National Kidney Foundation encourages individuals with CKD to be active and provides some general recommendations that are similar to those for healthy adults (214). Because the ideal FITT has not been developed for individuals with CKD, it is prudent to modify the recommendations for the general population, initially using light-to-moderate intensities and gradually progressing over time based on individual tolerance. Medically cleared recipients of kidney transplants can initiate exercise training soon after the transplant operation (202,215).

FITT	FITT RECOMMENDATIONS FOR INDIVIDUALS WITH KIDNEY DISEASE (194)		
	Aerobic	**Resistance**	**Flexibility**
Frequency	3–5 d · wk^{-1}	2–3 d · wk^{-1}	2–3 d · wk^{-1}
Intensity	Moderate intensity (40%–59% $\dot{V}O_2R$, RPE 12–13 on a scale of 6–20)	65%–75 % 1-RM. Performance of 1-RM is not recommended unless medically cleared for such effort; instead, estimate 1-RM from a ≥3-RM test.	Static: stretch to the point of tightness or slight discomfort; PNF: 20%–75% of maximum voluntary contraction
Time	20–60 min of continuous activity; however, if this cannot be tolerated, use 3–5 min bouts of intermittent exercise aiming to accumulate 20–60 min · d^{-1}.	A minimum of 1 set of 10–15 repetitions, with a goal in most individuals to achieve multiple sets. Choose 8–10 different exercises targeting the major muscle groups.	60 s per joint for static (10–30 s hold per stretch); 3–6 s contraction followed by 10–30 s assisted stretch for PNF
Type	Prolonged, rhythmic activities using large muscle groups (*e.g.*, walking, cycling, swimming)	Machines, free weights, or bands	Static or PNF

1-RM, one repetition maximum; 3-RM, three repetition maximum; PNF, proprioceptive neuromuscular facilitation; RPE, rating of perceived exertion; $\dot{V}O_2R$, oxygen uptake reserve.

Exercise Training Considerations

- Some individuals with CKD are unable to do continuous exercise and therefore should perform intermittent exercise with intervals as short as 3 min interspersed with 3 min of rest (*i.e.*, 1:1 work-to-rest ratio). As the individual adapts to training, the duration of the work interval can be gradually increased, whereas the rest interval can be decreased. Initially, a total exercise time of 15 min can be used, and this can be increased within tolerance to achieve up to 20–60 min of continuous activity.
- The clinical status of the individual is important to consider, and progression may need to be slowed if the individual has a medical setback.
- Individuals with CKD, including individuals with ESRD, should be gradually progressed to a greater exercise volume over time. Depending on the clinical status and functional capacity of the individual, the initial intensity selected for training should be light (*i.e.*, 30%–39% of $\dot{V}O_2R$) and for as little as 10–15 min of continuous activity, or whatever amount the individual can tolerate. The duration of PA should be increased by 3–5-min increments weekly until the individual can complete 30 min of continuous activity before increasing the intensity.
- Because individuals with CKD tend to be sedentary, in addition to stressing the need to increase their levels of PA to comply with current recommendations, they should also be encouraged to decrease the amount of time spent daily engaged in sedentary behavior (216).

Special Considerations

- Hemodialysis

- Immediately postdialysis, most individuals do not feel energetic enough to engage in PA, and therefore, the general recommendation is to wait 2 h postdialysis. However, for those who feel capable, PA can be initiated as early as the last hour of dialysis treatment. It is recommended that they have a snack at least 1 h prior to being active, and or during the PA. These recommendations should be individualized, as those individuals who can tolerate being physically active during or immediately postdialysis without any adverse responses should be encouraged to do so.
- During any aerobic exercise, it may be beneficial to use RPE to guide exercise intensity because HR can be unreliable. Aim to achieve an RPE in the light (9–11) to moderate (12–13) intensity range. However, there is preliminary evidence that higher intensity exercise may be equally or more effective, and just as well tolerated, in well-screened individuals with CKD (217,218).
- Individuals may exercise the arm with permanent arteriovenous access but should always avoid placing weight or pressure on the access device (204).
- Measure BP in the arm that does not contain the fistula.
- If exercise is performed during dialysis, it should typically be done during the first half of the treatment to avoid hypotensive episodes, although some individuals may use late dialysis exercise to counteract a hypotensive response. Exercise modes typically used during dialysis are pedaling and stepping devices, which can be used while seated in a dialysis chair. During dialysis, individuals should not exercise the arm with permanent arteriovenous access.
- These individuals need to be counseled to break up their sitting time throughout the day when off dialysis.

- Home hemodialysis
  - These individuals should be encouraged to participate in moderate intensity PA programs 3–5 $d \cdot wk^{-1}$, as is true for the general population. They should also be encouraged to reduce sedentary time.
- Peritoneal dialysis
  - Individuals on continuous ambulatory peritoneal dialysis may attempt exercising with fluid in their abdomen; however, if this produces discomfort, then they should be encouraged to drain the fluid before exercising (204).
- Recipients of kidney transplants
  - During periods of rejection, the intensity of exercise should be reduced, but exercise can still be continued (202).

ONLINE RESOURCES

Kidney Disease: Improving Global Outcomes: http://kdigo.org/home/
National Institute of Diabetes and Digestive and Kidney Diseases: http://www2.niddk.nih.gov/
National Kidney Foundation: http://www.kidney.org/
United States Renal Data System: http://www.usrds.org/atlas.htm

MULTIPLE SCLEROSIS

Multiple sclerosis (MS) is a chronic, inflammatory, autoimmune disease of the CNS that currently affects an estimated 2–3 million individuals worldwide (219). Causal factors for MS include environmental factors (*e.g.*, vitamin D deficiency and cigarette smoking), genetic factors, and exposure to infectious agents (219). The underlying pathogenesis of MS is complex and believed to be controlled by a cascade of inflammatory responses affecting the CNS, involving cells from both the adaptive and innate immune systems (*e.g.*, B cells and T cells) (219). The resulting effects of these immune responses include axonal or neuronal loss (neurodegeneration) and damage to the myelin sheath (demyelination). This leads to the observed clinical symptoms of MS (*e.g.*, optic neuritis, ataxia, and bladder dysfunction), which vary depending on the location of the inflammatory demyelinating lesions within the CNS and the extent of the inflammation (219). Transient episodes of neurological deficits, known as relapses, characterize early MS. Diagnosis of MS is made using a combination of clinical, imaging, and laboratory findings. Most people who develop MS will experience a single episode, known as a clinically isolated syndrome, which resolves over time. A second relapse indicates onset of MS.

The onset of MS usually occurs between the ages of 20 and 50 yr and affects women at a rate two to three times more than men (220). The disease course of MS is highly variable from individual to individual and within a given individual over time (*Table 10.5*). People with MS are described as having relapsing remitting MS if they experience at least two relapses (219). This is the most common type of MS. Of these, 15%–30% develop progressive disability with or without relapses (*i.e.*, secondary progressive MS) (219). Approximately 15% of people with MS experience progressive disability from the onset of MS, which is described as primary progressive MS (219). In 2013, it was recommended that MS be further subcategorized as active or nonactive, where active MS is defined as “the occurrence of clinical relapse or the presence of new T2 or gadolinium-enhancing lesions over a specified period of time, preferably at least one year” (221). *Table 10.6* is a summary of the expanded disability status scale (EDSS; range 0–10), which is commonly used to indicate the level of disability related to the progression of MS (222).

TABLE 10.5 • Disease Courses of Multiple Sclerosis

Type	Characteristic
Relapsing-remitting	Periodic exacerbations followed by full or partial recovery of deficits
Primary progressive	Continuous disease progression from onset with little or no plateaus or improvements
Secondary progressive	Slow and steady disease progression that transitioned from the relapsing-remitting type
Progressive-relapsing	Progression from onset with distinct relapses superimposed on the steady progression with or without full recovery

TABLE 10.6 • Summary of Kurtzke Expanded Disability Status Scale

Rating	Disability
0–2.5	None to minimal disability
3–5.5	Moderate disability but still ambulatory without assistive device
6–7	Severe disability but still ambulatory with assistive device
7.5–9	Essentially wheelchair-bound or bedbound
10	Death attributable to multiple sclerosis

Symptoms of MS include spasticity; fatigue; pain; mobility impairment; ataxia and tremor; bladder, bowel, and sexual dysfunction; emotional lability; cognitive impairment; and visual disturbances (219) (*Box 10.3*). These symptoms may limit ability to complete ADL and impact quality of life. Fatigue is one of the most common symptoms of MS (224), as well as mobility impairment, which may lead people with MS to avoid participation in PA. Fatigue can be both primary (*i.e.*, directly related to disease pathology) and secondary to reduced physical fitness. People with MS also experience heat sensitivity and impaired temperature regulation, which can result in worsening symptoms including fatigue and physical and cognitive function during PA (225). Avoidance of PA because of fatigue and impaired thermoregulation may lead to reduced aerobic capacity (226), which is known to decrease with increasing levels of disability (227). This can result in a negative cycle of deconditioning, reduced participation in PA (228), and worsening symptoms including fatigue and mobility impairment.

Box 10.3 Common Signs and Symptoms of Multiple Sclerosis

Symptoms

Muscle weakness
Symptomatic fatigue
Numbness
Visual disturbances
Walking, balance, and coordination problems
Bowel dysfunction
Cognitive dysfunction
Dizziness and vertigo
Depression
Emotional changes

Bladder dysfunction	Sexual dysfunction Pain
Signs	
Optic neuritis	Paresthesia
Nystagmus	Spasticity

Reprinted from (223).

Decreased muscle performance is also commonly observed in MS. Upper and lower limb isometric muscle strength, lower limb muscle power, and lower limb rate of force development is reduced in people with MS compared to those without MS (229). Decreased muscle flexibility may also be apparent in people with MS, particularly among those with spasticity. Reduced muscle strength may be due to reduced muscle mass among people with MS found in some studies (230–232), although this is not consistent across all studies (233–235). Reduced maximal voluntary contraction, in the presence of no changes in cross-sectional area, suggests that impaired central activation in MS contributes to decreased muscle performance (234). Physical inactivity may also contribute to reductions in muscle size and muscle strength and therefore feed into a negative cycle of deconditioning and physical inactivity.

Participation in habitual PA is associated with improvements in cardiovascular risk factors (*i.e.*, waist circumference, cholesterol levels, glucose levels) (236), longevity (237), and improvements in health-related quality of life (238). Furthermore, reduced participation in PA may be associated with worsening of MS symptoms (239). There is evidence that exercise interventions, including aerobic exercise training, resistance training, and a combination of aerobic and resistance training improve health-related quality of life (240), walking speed and walking endurance (241), balance (242), depressive symptoms (243), muscle strength (244), and CRF (226,245) in people with mild-to-moderate disability. Interventions that incorporate gait, balance, and functional training demonstrate the greatest improvement in balance, but these improvements may not carry over to reduced falls (242). There is low-quality evidence (according to the Grading of Recommendations, Assessment, Development and Evaluation or GRADE approach) that PA programs (including physiotherapy and structured exercise programs) improve spasticity in people with MS (246). Among people specifically with progressive MS and moderate disability, there is weak evidence that aerobic exercise training improves CRF, mobility, and cognitive function and that resistance training improves muscle strength (247).

As it is one of the most common and debilitating symptoms of MS, managing fatigue is often an important objective for people with MS. There is moderate quality evidence that exercise interventions can improve fatigue among people with MS compared to no exercise (248). Specifically, there is moderate quality evidence that aerobic exercise and mixed training, respectively, have a positive effect on fatigue in comparison to no exercise (248). However, studies are limited to people with minimal-to-moderate disability (248–250), and there is large variability between studies in terms of type of exercise intervention used and type of comparison (248,250). Studies also assess fatigue using different outcome measures, such as the Fatigue Severity Scale and the Modified Fatigue Impact Scale, which may not measure the same construct, and therefore, results may not be comparable (248). Furthermore, fatigue is not typically the primary outcome of interest in studies of exercise interventions, and therefore, the majority of studies to date did not select individuals based on their level of fatigue or calculate the sample size required to detect a difference in fatigue.

As indicated previously, the majority of research regarding exercise for MS includes individuals with minimal-to-moderate disability. Although exercise has benefits for this group, similar exercise training approaches may not be accessible or feasible for people with severe disability. A review of exercise for individuals with an EDSS score of ≥6.0 concluded that there was unclear evidence regarding the benefits of conventional aerobic exercise programs but that conventional progressive resistance training may improve muscular fitness, balance, fatigue, and quality of life (251). Although benefits of aerobic exercise were not clear, included studies reported that it was safe and feasible for people with severe disability (251). For those who are unable to perform conventional exercise, adapted exercise training may be particularly useful. Bodyweight support treadmill training and recumbent stepping are two such adapted exercises, which may improve disability, strength, fatigue, and quality of life for these individuals (251).

Exercise Testing

Exercise testing is useful in determining the fitness level, physiological response, and the effectiveness of exercise training in individuals with MS. Prior to exercise testing, medical clearance should be sought (see *Chapter 2*, and it is recommended to review an individual's medical history, list of medications, and functional capacity. An expert group recommended the following core set of outcome measures for use within exercise studies in MS (252): quality of life assessed using the Multiple Sclerosis Impact Scale (MSIS-29) or MSQoL54, fatigue assessed using the Modified Fatigue Impact Scale or Fatigue Severity Scale, exercise tolerance assessed using the 6-min walk test, muscle function assessed using the Timed Up and Go, body composition assessed using waist-to-hip ratio or BMI. Additionally, a clinical practice guideline relating to outcome measures for adults with neurologic conditions recommended the use of the Berg Balance Scale to assess static and dynamic sitting and standing balance, the Functional Gait Assessment to assess walking balance, the 10-m walk test to assess walking speed, and the five times sit-to-stand to assess transfer ability (253).

Exercise Testing Considerations

- Avoid testing during an acute exacerbation of MS symptoms.
- Closely monitor for any signs of fatigue, overheating, or general worsening of symptoms as exercise intensity increases.
- Perform exercise testing earlier in the day because fatigue generally worsens throughout the day in individuals with MS.
- Conduct exercise testing in a climate-controlled room (72° to 74° F [22.2° to 24.4° C], low humidity) and use electric fans or cold neck packs as appropriate.
- Furthermore, assess for impaired sensation prior to applying a heat pack.
- Use RPE in addition to HR to evaluate exercise intensity. Individuals with MS may experience cardiovascular dysfunction as a result of autonomic dysfunction (254). HR responses may be blunted during exercise, and therefore, HR may not be a valid indicator of exercise intensity (255).
- In most individuals with MS, a cycle ergometer is the recommended method of testing aerobic fitness because this modality requires less balance and coordination compared with walking on a treadmill (256). Individuals with balance and coordination problems may require the use of an upright or recumbent cycle leg ergometer with foot straps.
- In select individuals, a recumbent stepping ergometer or dual action stationary cycle that allows for the use of upper and lower extremities may be advantageous because it distributes work to all extremities, thus minimizing the potential influence of local muscle fatigue or weakness in one limb on maximal exercise testing.
- Individuals who are nonambulatory with sufficient upper body function can be assessed using an arm ergometer.
- Assessment of $\dot{V}O_{2peak}$ is a valid measure of CRF in individuals with mild disability (EDSS score ≤4.0). However, $\dot{V}O_{2peak}$ in individuals with moderate disability (EDSS score >4.0) may be symptom limited and therefore indicate their functional ability rather than CRF (257).
- Depending on the disability and physical fitness level of the individual, the use of a continuous or discontinuous protocol of 3–5 min stages increasing work rate for each stage from 12 to 25 W for leg ergometry and 8 to 12 W for arm ergometry is recommended.
- In general, muscle strength and endurance can be determined using standard protocols in individuals with MS. Each large muscle group and all limbs should be tested because weakness may present itself in a particular muscle group or limb due to the heterogeneity of lesion location and impact in MS. Isokinetic dynamometry can

be used to reliably evaluate muscle performance (229). In a clinical or community setting, an 8–10-RM or functional testing (*e.g.*, 30-s sit-to-stand test) can be used to measure muscular strength and endurance.

Exercise Prescription

Individuals with MS who are not able to meet guidelines for PA of 150 min of moderate intensity per week should engage in regular PA according to their abilities with support from health care providers. For individuals with minimal disability (EDSS 0–2.5), the FITT principle of Ex R_x is generally consistent with those outlined in *Chapter 5* for healthy adults. As MS symptoms and level of disability increase, the following modifications outlined may be required.

FITT **FITT RECOMMENDATIONS FOR INDIVIDUALS WITH MULTIPLE SCLEROSIS**

	Aerobic	Resistance	Flexibility
Frequency	2–5 d · wk^{-1}	2 d · wk^{-1}	5–7 d · wk^{-1}, one to two times · d^{-1}
Intensity	40%–70% $\dot{V}O_2R$ or HRR; RPE 12–15	60%–80% 1-RM	Stretch to the point of feeling tightness or mild discomfort.
Time	Increase time initially to a minimum of 10 min before increasing intensity. Progress to 30–60 min as tolerated.	Begin with 1 and gradually work up to 2 sets of 10–15 repetitions.	Hold 30–60 s, 2–4 repetitions.
Type	Prolonged, rhythmic activities using large muscle groups (*e.g.*, walking, cycling, swimming)	Multijoint and single-joint exercises using machines, free weights, resistance bands, or body weight	Static stretching

1-RM, one repetition maximum; HRR, heart rate reserve; RPE, rating of perceived exertion; $\dot{V}O_2R$, oxygen uptake reserve.
Based on data from (258).

Exercise Training Considerations

- With individuals who have significant paresis, consider assessing RPE of the extremities separately using the 0–10 OMNI scale (*Figure 10.3*) (259) to evaluate effects of local muscle fatigue on exercise tolerance.
- During an acute exacerbation of MS symptoms, decrease the FITT of the Ex R_x to the level of tolerance. If the exacerbation is severe, focus on maintaining functional mobility and/or focus on aerobic exercise and flexibility. Recognize that in times of severe relapse, any exercise may be too difficult to perform.
- When strengthening weaker muscle groups or working with easily fatigued individuals, increase rest time (*e.g.*, 2–5 min) between sets and exercises as needed to allow for full muscle recovery. Focus on large muscle groups and minimize total number of exercises performed.
- To eliminate balance concerns during flexibility exercises, slow and gentle passive ROM exercise should be performed while seated or lying down.
- Muscles and joints with significant tightness or contracture may require longer duration (several minutes to several hours) and lower load positional stretching to achieve increases in joint ROM. Very low intensity, low-speed, or no-load cycling may be beneficial in those with frequent spasticity.

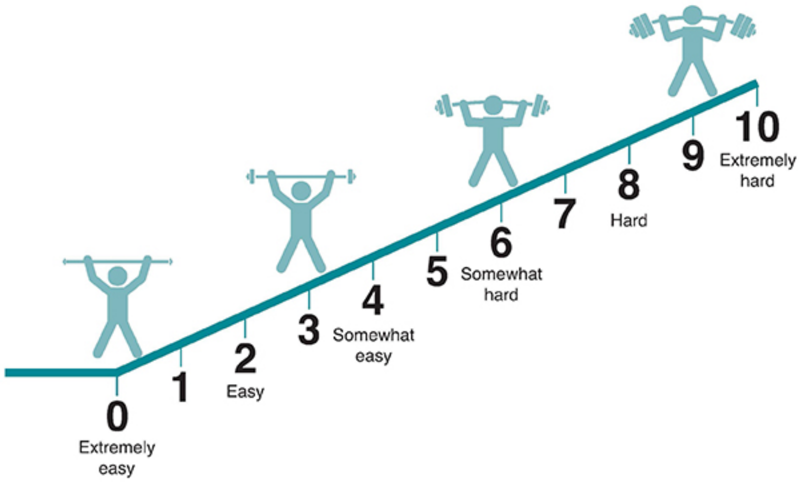

FIGURE 10.3 OMNI Resistance Exercise Scale of perceived exertion. Used with permission from (258).

Special Considerations

- Commonly used disease-modifying medications such as interferon β-1a and glatiramer acetate have common side effects including altered mood, flu-like symptoms, liver failure, and localized irritation at the injection site. Take medication side effects into consideration with exercise testing and scheduling.
- The individual should be helped to understand the difference between more general centrally mediated MS fatigue and temporary peripheral exercise-related fatigue.
- Some individuals may restrict their daily fluid intake because of bladder control problems. They should be counseled to increase fluid intake with increased PA levels to prevent dehydration and hyperthermia, secondary to impaired thermoregulation.
- Many individuals with MS have some level of cognitive deficit that may affect their understanding of testing and training instructions. They may also have short-term memory loss that requires written instructions and frequent verbal cueing and reinforcement.
- Watch for transient worsening of sensory and motor symptoms, most commonly, visual impairment, associated with exercise and elevation of body temperature. Symptoms can be minimized by using cooling strategies and adjusting exercise time and intensity.

ONLINE RESOURCES

National Institute of Neurological Disorders and Stroke: https://www.ninds.nih.gov/Disorders/All-Disorders/Multiple-Sclerosis-Information-Page
National Multiple Sclerosis Society: http://www.nationalmssociety.org
Physical Activity Guidelines for Americans: https://health.gov/sites/default/files/2019-09/16_F-10_Individuals_with_Chronic_Conditions.pdf

OSTEOPOROSIS

Osteoporosis is a skeletal disease that is characterized by low BMD and changes in the microarchitecture of bone that increase susceptibility to fracture. The official position of the International Society of Clinical Densitometry defines osteoporosis in postmenopausal women and in men ≥50 yr as a BMD T-score of the lumbar spine, total hip, or femoral neck of ≤−2.5 (260). The National Bone Health Alliance (NBHA) Working Group proposes additional diagnostic criteria for osteoporosis to include those with diagnosed osteopenia who have sustained a low-trauma vertebral, proximal humerus, pelvis, or distal forearm fracture, or who have an elevated fracture risk per the Fracture Risk Algorithm (FRAX) (261). Based on the criteria from NBHA, and using data from the National Health and Nutrition Examination Survey, Wright et al. (262) found that for individuals in the United States older than 50 yr, 30% of women and 16% of men have osteoporosis.

The burden of osteoporosis on society and the individual is significant. More than 54 million individuals in the United States have osteoporosis or low bone density (263). The International Osteoporosis Foundation estimates that the direct costs of treating osteoporotic fractures is $48 billion U.S. dollars for people in the United States, Europe, and Canada (264). As a result of the aging population and the continued decrease in PA, both the cost and incidence of osteoporosis are expected to rise by as much as 25% within the next few years (263,264). Although osteoporosis more than doubles the risk of any fracture, 50% of women who have a fracture have osteopenia (low bone mass) rather than osteoporosis (265).

Recent evidence indicates that exercise can delay the onset of osteoporosis and reduce fracture risk (265–267). The benefits of exercise on bone health occur in both children and adults and are due primarily to increases in bone density, volume, and strength, and to a parallel increase in muscle strength (265,268). Exercise also improves balance in both young and older populations, which can reduce falls and subsequent osteoporotic fracture risk (269,270). Thus, exercise can generally be regarded as the primary nonpharmacological treatment for prevention of osteoporosis. Nevertheless, many investigators have concluded that large RCTs are still needed in both women and men to determine optimal Ex R_x for preventing both osteoporosis and fracture (265,267,271). Recent evidence does indicate a minimum frequency of two exercise sessions per week is likely necessary for increasing BMD in osteopenic women (272).

Exercise Testing

In general, when an exercise test is clinically indicated for those with osteoporosis, normal testing procedures should be followed (see *Chapter 3*). However, when exercise tests are performed in individuals with osteoporosis, the following issues should be considered:

- Use of cycle leg ergometry as an alternative to treadmill exercise testing to assess cardiorespiratory function may be indicated in individuals with severe vertebral osteoporosis for whom walking is painful or risky.
- Multiple vertebral compression fractures leading to a loss of height and spinal deformation can compromise ventilatory capacity and result in a forward shift in the center of gravity. The latter may affect balance during treadmill walking.
- Maximal muscle strength testing may be contraindicated in individuals with severe osteoporosis, although there are no established guidelines for contraindications for maximal muscle strength testing.
- Balance testing or fall risk assessment should be considered in individuals with osteoporosis or low bone density. Available assessments include the Performance-Oriented Mobility Assessment and the Modified Falls Efficacy Scale (273).

Exercise Prescription

Currently, little evidence exists regarding the optimal exercise regime for individuals with or at risk for osteoporosis. In general, aerobic exercise is primarily for overall health benefits, but weight-bearing aerobic exercise along with some form of higher impact, higher velocity, higher intensity resistance training is considered the best choice (79,265,274). Supervised training appears to be superior to unsupervised training with regard to most outcomes (bone mass, balance, fall prevention), although there is limited evidence on unsupervised training (275).

FITT	FITT RECOMMENDATIONS FOR INDIVIDUALS WITH OSTEOPOROSIS (79,265,274)		
	Aerobic	**Resistance**	**Flexibility**
Frequency	4–5 d · wk^{-1}	Start with 1–2 nonconsecutive d · wk^{-1}; may progress to 2–3 d · wk^{-1}	5–7 d · wk^{-1}
Intensity	Moderate intensity (40%–59% $\dot{V}O_2R$ or HRR). Use of the CR-10 scale with ratings of 3–4 might be a more appropriate method of establishing intensity.	Adjust resistance so that last 2 repetitions are challenging to perform. High intensity and high velocity training can be beneficial in those who can tolerate it.	Stretch to the point of tightness or slight discomfort.
Time	Begin with 20 min; gradually progress to a minimum of 30 min (with a maximum of 45–60 min).	Begin with 1 set of 8–12 repetitions; increase to 2 sets after ~2 wk; no more than 8–10 exercises per session	Hold static stretch for 10–30 s; 2–4 repetitions of each exercise
Type	Walking, cycling, or other individually appropriate aerobic activity (weight bearing preferred). Impact loading exercises such as jumping or bench stepping can be used in those with low or moderate risk for fracture.	Standard equipment can be used with adequate instruction and safety considerations. Compound movement exercises are best	Static stretching of all major joints

HRR, heart rate reserve; $\dot{V}O_2R$, oxygen uptake reserve.

Special Considerations

- Aerobic activity primarily benefits individuals with osteoporosis or osteopenia through improved cardiovascular and metabolic health. Depending upon the type of aerobic activity, impact (ground reaction forces) and speed associated with weight-bearing aerobic exercise may also contribute to bone loading.
- It is difficult to quantify exercise intensity in terms of bone loading forces. However, the magnitude of bone loading force generally increases in parallel with exercise intensity quantified by conventional methods (*e.g.*, %HRR for aerobic training or %1-RM for resistance training), and bone strengthening only occurs in the involved area. Weight-bearing aerobic and high-velocity resistance training modes are recommended. Proper form and alignment are more important than intensity, especially for those with a history of fractures (265,274).
- There are currently no established guidelines regarding contraindications to exercise for individuals with osteoporosis. The general recommendation is to prescribe moderate intensity weight-bearing exercise that does not cause or exacerbate pain. Exercises that involve explosive movements or high-impact loading should be avoided, especially in those at high risk for fracture (265). Specific exercises or portions of group-led routines (*e.g.*, yoga, Pilates) that require excessive twisting, bending, or compression of the spine should also be carefully assessed and avoided, particularly in those with very low spinal BMD values (79,265).
- Falls in those with osteoporosis increase the likelihood of a bone fracture. For older women and men at increased risk for falls, the Ex R_x should also include activities that improve balance (see *Chapters 5* and *6*, the relevant ACSM position stand [79], and Beck et al. [265]). Primary considerations should be exercises that

strengthen the quadriceps, hamstrings, and gluteal and trunk muscles because these are the primary balance muscles (269). Tasks done with the eyes closed should also be considered for individuals with low- or moderate- (but not high) risk for fracture (265).

- In light of the rapid and profound effects of immobilization and bed rest on bone loss, and poor prognosis for recovery of BMD after remobilization, even the frailest elderly should remain as physically active as health permits because this will best preserve musculoskeletal integrity. Even short bouts of standing or walking are desirable during prolonged illnesses.
- The recommendations in this section are generalized for exercise in individuals with, or at risk for, osteoporosis. Modifications based on clinical judgment may be necessary for some individuals (265,274). Goals and preferences of the individual should also be considered to help with compliance (265).

ONLINE RESOURCES

International Society of Clinical Densitometry: http://www.iscd.org/official-positions/
National Institutes of Health Osteoporosis and Related Bone Diseases:
http://www.niams.nih.gov/Health_Info/Bone/default.asp
National Osteoporosis Foundation: http://www.nof.org

SPINAL CORD INJURY

Spinal cord injury (SCI) results in a loss of somatic, sensory, and autonomic functions below the lesion level. Lesions in the cervical region typically result in tetraplegia (also known as quadriplegia, resulting in the partial or total loss of function below the cervical level of lesion), whereas lesions in the thoracic, lumbar, and sacral regions lead to paraplegia (which does not influence arm function). SCI level and neurological completeness are currently determined by the International Standards for Neurological Classification of SCI (ISNCSCI) or the American Spinal Cord Injury Impairment Scale (AIS) Classification. This classification primarily considers motor and sensory impairment at or below the level of injury. SCI may lead to either motor-complete (AIS A and B) or motor-incomplete (AIS C and D) paralysis. An individual with a loss of sacral sparing (*i.e.*, loss of sensory and motor response at S4–S5) is considered AIS A (*i.e.*, complete loss in both motor and sensory function). Individuals with sensory function below the neurological lesion level, but no motor function, are classified as AIS B. Motor-incomplete injuries are distinguished by functional ability below the level of injury (AIS C; more than half the key muscle groups having a muscle testing grade <3: AIS D; at least half the key muscle groups having a muscle testing grade ≥3).

Incomplete injuries are the most frequent neurological classification (45.8% and 20.9% for incomplete tetraplegia and paraplegia, respectively) in which some somatosensory functions below the lesion are still maintained (276). Approximately, 19.7% of individuals have a motor-complete paraplegia, with the remaining 13.2% being classified as motor-complete tetraplegia. The most common causes of SCI can be attributed to motor-vehicle accidents or falls, with males accounting for ~81% of new SCI cases (276). SCI of traumatic origin often occurs at an early age (18–40 yr old). Individuals with SCI have a high risk for the development of secondary conditions (*e.g.*, shoulder pain, urinary tract infections, skin pressure ulcers, osteopenia, chronic pain, problematic spasticity, joint contractures, depression, anxiety, fatigue, obesity, dyslipidemia, T2DM, and CVD).

The SCI level and neurological completeness directly impact physical function, along with metabolic and autonomic cardiorespiratory responses to exercise. For example, individuals with SCI at or above T6 exhibit a loss of autonomic supraspinal control of visceral organs (including the heart and blood vessels), which blunts maximal HR, impairs blood redistribution and BP regulation during exercise (277). Such alterations result in reduced venous return to the heart, which limits stroke volume and thus cardiac output, often leading to premature fatigue. It is therefore crucial to consider the SCI lesion level when performing exercise testing and prescribing exercise for those with complete SCI. The following points describe specific motor and autonomic considerations dependent on the level of SCI lesion:

- L2–S2: lack voluntary and autonomic control of the bladder, bowel, and sexual function; however, the upper extremities and trunk usually have normal function
- T6–L2: have respiratory and motor control that depends on the functional capacity of the abdominal muscles (*i.e.*, minimal at T6 to maximal at L2)
- T1–T6: can experience impaired thermoregulation, orthostatic and postexercise hypotension (with debilitating symptoms, *i.e.*, light-headedness, dizziness, fatigue), and autonomic dysreflexia (AD). AD is an unregulated, spinally mediated reflex response called the *mass reflex* that can be a life-threatening medical emergency with sudden hypertension, bradycardia, pounding headache, piloerection, flushing, goose bumps, shivering, sweating above the level of injury, nasal congestion, and blotching of the skin. When there is no supraspinal sympathetic input to the heart (T1–T5), resting HR may be bradycardic due to cardiac vagal dominance, and HR_{peak} is limited to ~115–130 beats · min^{-1}. Breathing capacity is further diminished by intercostal muscle paralysis; however, arm function is normal.
- C5–C8 are tetraplegic. Those with C8 lesions have voluntary control of the scapula, shoulder, elbow, and wrist but decreased hand function, whereas those with C5 lesions rely on the biceps brachii and shoulder muscles for self-care and mobility.
- Above C4 requires ventilator support for breathing. These individuals are commonly recommended to receive an implanted phrenic nerve stimulator for direct activation of the diaphragm muscle in order to function as a diaphragmatic pacing technique. AD, orthostatic and postexercise hypotension, along with thermoregulatory issues, can also occur in individuals with C4–C8 injuries.

Exercise Testing

It should be noted that exercise-testing options following SCI have advanced to include functional electrical stimulation (FES) of paralytic muscles, locomotor modalities (*i.e.*, body weight supported treadmill training [BWSTT], robotic exoskeletons), and other hybrid forms including brain-computer interface (BCI), neuromodulation (*i.e.*, epidural or transcutaneous spinal cord stimulation), and virtual reality strategies, which can be used in conjunction with traditional locomotor modalities. This is in addition to commonly available forms of exercise that primarily focus on the voluntary activation of spared muscle above the level of injury (*i.e.*, arm-crank ergometer [ACE], circuit resistance training, and wheelchair propulsion).

When exercise testing individuals with SCI, consider the following issues:

- Level of functional independence should be assessed including ROM, strength, using manual muscle testing for both lower and upper extremities, sitting and standing balance, independence in transfer, wheelchair mobility, and upper and lower extremity motor involvement. This assessment will facilitate the choice of exercise testing equipment, protocols, and adaptations.
- Consider the purpose of the exercise test, the level and completeness of SCI, and the physical fitness level of the individual to optimize equipment and protocol selection.
- Choose an exercise mode that allows the individual to engage the largest possible muscle mass. If substantial trunk and lower limb function is intact, consider combined voluntary arm and leg cycle ergometry (hybrid exercise) or recumbent stepping. If injuries are motor-complete, voluntary arm-crank ergometry is the easiest to perform and is norm-referenced for the assessment of CRF (278). Other norm-referenced data exist for wheelchair exercise (279,280).
- The paradigms of FES necessary to evoke muscle activation may vary from a single-trained muscle, using neuromuscular electrical stimulation (NMES), or multiple muscle activation using functional electrical stimulation lower extremity cycling (FES-LEC; *i.e.*, up to six muscle groups). With either paradigm, it is

recommended that adequate recovery is provided between sessions (at least 48 h) to avoid exercise-induced muscle damage that typically occurs following activation of paralyzed skeletal muscles (281).

- Individuals with SCI at or above the T6 level are likely to experience AD (sudden increase in systolic BP [SBP] 20–40 mm Hg above baseline) during FES-LEC and sometimes NMES. Individuals prone to AD should have access to a fast-acting antihypertensive agent (*i.e.*, nifedipine, captopril, or nitroglycerin), which can be administered should SBP remain above 150 mm Hg. It is important for exercise practitioners to periodically monitor BP throughout each exercise session (ideally every 3–5 min) and modulate the stimulation parameters to reduce the charge density developed under the electrodes during FES-LEC. When exercising, individuals should always be in a seated position (to ensure an orthostatic hypotension response protecting the cerebrovasculature) and exercise may be paused or terminated based on the individual's BP responses.
- If available, a stationary wheelchair roller system or motor-driven treadmill should be used with the individual's wheelchair adjusted as necessary. Motor-driven treadmill protocols allow for realistic simulation of external conditions such as slope and speed alterations (282).
- Incremental exercise tests for the assessment of CRF in the laboratory should begin at 0 W with incremental increases of 5–10 W per stage for individuals with tetraplegia. Depending on function and fitness, individuals with paraplegia can use increments of 10–25 W per stage.
- For sport-specific CRF assessments in the field, an incremental test adapted from the Léger and Boucher shuttle test around a predetermined rectangular court is recommended. However, floor surface characteristics and wheelchair–user interface should be standardized (282,283).
- After maximal-effort exercise in individuals with tetraplegia, it may be necessary to treat postexercise hypotension and exhaustion with rest, recumbency, leg elevation, and fluid ingestion. Individuals should consider wearing elastic leg stockings and/or an abdominal binder to prevent venous blood pooling during exercise. Maximal exercise testing, particularly in individuals with high-level SCI, should be accompanied with concurrent ECG monitoring for cardiac arrhythmias. There are no special considerations for the assessment of muscular strength regarding the exercise-testing mode beyond those for the general population with the exception of the lesion level, which will determine residual motor function and thus the need for stabilization, hand-wraps (*i.e.*, Active Hands), and accessibility of testing equipment.
- Individuals with SCI requiring a wheelchair for mobility may develop joint contractures because of muscle spasticity, strength imbalance, flexed joint position in the wheelchair (*i.e.*, hip flexion, hip adduction, and knee flexion), excessive wheelchair pushing, and manual transfers (*i.e.*, anterior chest and shoulder). Therefore, intensive sport-specific training must be complemented with an upper extremity stretching of prime movers and strengthening antagonists program to promote muscular balance around the joints.
- During locomotor exercise (*i.e.*, BWSTT, robotic exoskeleton), individuals can experience orthostatic hypotension (a drop in SBP or diastolic BP [DBP] of 20 or 10 mm Hg, respectively) and associated debilitating symptoms when transitioning to standing. This is particularly common in individuals with injuries at or above T6. BP should be routinely monitored and individuals returned to the seated or supine position if symptoms persist.

Exercise Prescription

The goals of exercise training include the prevention of deconditioning; improved health (*i.e.*, weight management, glucose homeostasis, lower cardiovascular risk); improved muscular strength, muscular endurance, and flexibility for functional independence (wheelchair mobility, transfers, ADL); prevention of falls and sports injuries; and improved performance (safety and success in adaptive sports and recreational activities). Currently, there are no published consensus recommendations for developing an Ex R_x in the SCI population, and further research is warranted (284,285). Thus, the specific FITT principle of Ex R_x recommendations provided in the box is based on several systematic reviews and consensus documents as listed in the Ex R_x box.

FITT FITT RECOMMENDATIONS FOR INDIVIDUALS WITH SPINAL CORD INJURY (286–289)

	Aerobic	Resistance	Flexibility
Frequency	Minimum of 2 d · wk^{-1}; progress to 3 d · wk^{-1}. Athletes can increase to 3–5 d · wk^{-1}.	Minimum of 2 d · wk^{-1}	Daily, especially in presence of joint contracture, spasticity, or frequent wheelchair propulsion and manual transfers
Intensity	Beginners: moderate intensity (40%–59% HRR) progressing to vigorous intensity (75%–90% HRR)	Initially, use 50% of 1-RM progressing to 80% 1-RM for all large muscle groups for each exercise.	Do not allow stretching discomfort >2 on the 0–10 pain scale.
Time	Initially, bouts of 5–10 min alternating with 5-min active recovery periods. Gradually increase to at least 20–40 min per session[a] or 30–44 min per session,[b] depending on health variable of interest. Aim to decrease or eliminate rest periods altogether with progression.	Initially, 1–2 sets of 8 repetitions each exercise per session. Gradually progress to 3 sets of 10 repetitions.	Stretch each muscle group repeatedly for 3–4 min · d^{-1}, preferably after warm-up or following training/competition.
Type	Engage the largest possible muscle mass: voluntary arm + leg ergometry or combined FES-LCE and voluntary arm ergometry or rowing, recumbent stepping, arm ergometry, wheelchair ergometry/rollers, or wheeling.	Accessible resistance exercise machines are convenient and safe. If not available, use dumbbells, cuff weights, or elastic bands/tubing. Surface neuromuscular electrical stimulation–resistance training can also be performed for paralytic muscles.	Active stretching is preferred, but if this is not possible, low intensity passive stretching may be used by the individual or assistant. A standing frame can also be utilized.[c]

[a]Minimal guideline recommendation if aerobic exercise is combined with resistance training to improve cardiorespiratory fitness, power output, and muscle strength.

[b]Minimal guideline recommendation if solely aerobic exercise is performed (without resistance training) to improve muscle strength, body composition, and cardiometabolic disease risk.

[c]Those with spinal cord injury (SCI) and limited or no recent standing history may be at an increased risk for fracture due to osteoporosis. Full weight-bearing activities should be limited to those individuals with uncomplicated history of standing or for whom prior medical clearance for full weight bearing has been obtained. Preferably, individuals should have a dual energy x-ray absorptiometry scan to assess bone mineral density (BMD), with T-score less than −2.5 SD for total body or BMD less than 0.6 g · cm^{-2} for distal femur or proximal tibia, considered high-risk for standing.

1-RM, one repetition maximum; FES-LCE; functional electrical stimulation-leg cycle ergometry; HRR, heart rate reserve.

The recent systematic review, which informed the aforementioned FITT recommendations for individuals with SCI, mentioned that high-quality RCT evidence to inform population-specific exercise guidelines are still lacking (286). The low prevalence and considerable heterogeneity of the SCI population negatively impacts the quality and quantity of the existing exercise training literature. Other authors have advocated for volumes of moderate-to-vigorous intensity exercise more akin to able-bodied guidelines, such as those proposed by ACSM (*i.e.*, >150 min ·

wk^{-1}) (290). Whereas such recommendations may be purely aspirational for profoundly inactive individuals, or those with significant motor impairments, it has been suggested that stratifying individuals into "*beginning*," "*intermediate*," and "*advanced*" will assist with the application of able-bodied guidelines into clinical practice for individuals with SCI. The aforementioned FITT recommendations are consistent with the recent International Spinal Cord Society (ISCoS) exercise guidelines (287) (*i.e.*, 20–30 min of moderate-to-vigorous intensity two to three times per week). It is important to note that this volume of exercise is approximately a third of that advised by World Health Organization (WHO) and ACSM to improve CRF and cardiometabolic disease risk factors.

The aforementioned FITT recommendations are primarily for forms of exercise that focus on the voluntary activation of spared muscle above the level of injury. The guidelines for FES exercise are currently not well established (291). However, preliminary evidence supports that two to three times per week may be a reasonable frequency to evoke skeletal muscle hypertrophy, improve cardiometabolic health, and attenuate bone loss.

It is encouraged that applications of FES start as soon as few weeks postinjury to attenuate injury induced loss in both muscle and bone tissues (292). Muscle is a highly plastic tissue and individuals with SCI are likely to experience substantial disuse muscle atrophy, accompanied with the infiltration of intramuscular fat, just a few weeks postinjury (293). Supporting evidence in individuals with acute SCI indicated that FES two to three times weeks (for 30–60 min per session) ranging from 8 wk up to 6 mo is likely to attenuate muscle atrophy (291).

For bone health with FES, studies have been inconclusive. At least 6 mo of FES training are necessary to induce changes in trabecular bone as well as decreasing biomarkers of bone resorption (294). Loads of between 1 and 1.5 times body weight, applied via electrical stimulation of the soleus muscle for 3 yr, can result in higher distal tibia trabecular BMD compared to the untrained contralateral limb (295). Therefore, it may be that more intensive, long-term training regimes are necessary to improve bone health with FES in individuals with SCI.

Other forms of exercise that involve locomotor training to improve cardiorespiratory fitness have been recommended (*i.e.*, BWSTT and exoskeletal-assisted walking). For BWSTT, the general consensus has been to conduct exercise training three to five times per week for 60 min, starting with 50% body weight support or enough support that individuals would not buckle at the knees. RCTs have been unable to establish the superiority of BWSTT compared to over ground ambulation, especially in individuals with acute incomplete SCI (296). It appears that the dosing and intensity of training is highly proportional to the extent of recovery in individuals with incomplete SCI. Based on the available evidence, to optimize spontaneous neurological recovery, training should be scheduled for five times per week during the first 12–18 mo postinjury and then gradually limited to three times per week.

The consensus regarding exoskeletal-assisted walking is also still not well established. Currently, the available evidence supports that two to three times per week for 30–60 min may be sufficient to improve quality of life and promote CRF in individuals with chronic SCI. However, a major caveat is that the speed of walking is restricted by the individual's ability to achieve postural control and balance. Walking below $0.5\ m \cdot s^{-1}$ does not provide a perceived exertion greater than 12–13, which may not elicit an exercise intensity above that recommended by the ACSM guidelines to improve cardiorespiratory fitness. Therefore, similar to BWSTT, it is possible that health improvements achieved with exoskeletal-assisted walking is dependent on the level and severity of SCI. It should also be considered that these approaches are resource heavy, that is, they rely on trained staff and expensive equipment that might not be available to all individuals with SCI or exercise practitioners.

Evidence for exercise and various health outcomes specific to individuals with SCI is weak for individuals with acute (<1 yr) SCI, motor-incomplete injuries (AIS C–D), and older adults (those aged >65 yr are neglected in the wider exercise and SCI literature). The strength of existing evidence is also higher for young and middle-aged adults (286,287). The evidence is currently insufficient to comment on inverse dose-response associations for exercise and health-related variables. If changes in individuals' exercise behaviors are accurately tracked and recorded (using validated methods) (297), future research may permit a deeper understanding of the optimal dose of exercise, specifically in this population. Importantly, few adverse events have been documented with exercise in this population, besides the occasional musculoskeletal complaints, and the risk seems to be comparable to those observed in the general population (287).

Exercise Training Considerations

- Include resistance exercises for all innervated muscle groups, typically involving the upper body but not ignoring paretic arm, trunk, or leg muscles. Paralyzed muscle groups can now be exercised using surface NMES-resistance training (298). A recent video publication has provided the opportunity for clinicians and researchers to learn step-by-step procedures on how to simply activate paralyzed muscles, using both surface NMES-resistance training and FES-LEC in individuals with SCI (299). Based on this established protocol, electrically evoked resistance training is offered in the forms of 4×10 repetitions per leg (40 repetitions). While seated in a wheelchair, individuals with SCI start moving their legs against gravity without ankle weights for 1–2 wk. This is followed by gradually loading the legs, using ankle weights with 2-lb incremental progression on a weekly basis. Failure to achieve 40 repetitions precludes the progression of adding more weight.
- Despite this strategy being safe to apply in individuals with SCI, certain precautions need to be considered, including conducting regional bone scans for hip and knee joints using dual energy x-ray absorptiometry. A T-score of less than 3.5% SD of the femoral necks or BMD of less than $0.6 \text{ g} \cdot \text{cm}^{-2}$ may require medical clearance to ensure safe participation in a protocol aiming to electrically evoked resistance training of the paralyzed muscles.
- Resist overemphasis of "pushing" motions such as bench/chest press or rickshaw dips that develop the anterior shoulder/pectoral muscles, scapular protractors, and internal rotators (prime movers for functional skills such as wheelchair propulsion and transfers).
- Balance the "pushing" exercises with "pulling" exercises such as rowing and lat pull-downs that develop the scapular retractors and depressors, posterior deltoids, external rotator cuff muscles, and latissimus dorsi.
- If strength is the goal and arm overuse syndromes do not develop, increase resistance to 5- to 10-RM. As exercise tolerance increases and if arm overuse syndromes do not develop, increase volume to 3–4 sets per session.
- Advanced exercises for athletes may include ballistic medicine ball exercises, battle rope training, and sport-specific skills requiring power and speed.
- Therapeutic exercises may be indicated for joints with muscle imbalance and spasticity. The primary goal is the prevention/correction of joint contractures and loss of ROM.
- All muscles should be stretched slowly, especially spastic muscles, to minimize elicitation of stretch reflexes (spasticity), which can aggravate muscle imbalance and contracture. Emphasize prime mover muscles of the chest, anterior shoulders, and shoulder internal rotators. Adjacent joints must be stabilized to stretch the intended muscles/tendons.
- Stretch spastic muscles that may cause joint contractures (*e.g.*, elbow flexors, hip/knee flexors, hip adductors, and ankle plantar flexors). Passive/active standing can also stretch hip and plantar flexors.
- Progression (increased ROM) should be slow and based on pain tolerance, especially in advanced age, arthritis, permanent joint contracture, periodic immobilization (bed rest, hospitalizations), heterotopic ossification (HO), and chronic overuse syndromes and pain.

Special Considerations

Autonomic

- Individuals with complete SCI at or above T6, particularly those with complete tetraplegia, may exhibit lower exercise performance due to motor and cardiovascular dysfunction. These individuals may reach their HR_{peak}, maximal cardiac output (Q), and oxygen consumption ($\dot{V}O_2$) at lower exercise levels than those with paraplegia with lesion levels below T5–T6.
- Individuals with higher SCI levels may benefit from the use of lower body positive pressure by applying compressive antithromboembolic stockings, an elastic abdominal binder, electrical stimulation to leg muscles,

and/or exercise in recumbent posture. Beneficial hemodynamic effects may include maintenance of BP, lower HR, and higher stroke volume during arm work to compensate for blood pooling below the lesion.

- During exercise, the occurrence of AD results in an increased release of catecholamines that increases HR, $\dot{V}O_2$, BP, and exercise capacity (300). BP may be elevated to excessively high levels (*i.e.*, SBP 250–300 mm Hg and/or DBP 200–220 mm Hg). In these situations, immediate emergency responses to decrease BP are needed (*i.e.*, stopping exercise; sitting upright; and identifying and removing the irritating stimulus such as an obstructed catheter/urinary collection device, tight clothing, or braces). Emergency medical attention should be sought immediately if the symptoms persist.
- The practice of self-inducing AD is termed *boosting* and has been used to induce a competitive advantage in athletes with SCI (301). However, the International Paralympic Committee (IPC) prevents athletes from competing with AD due to the potential catastrophic health consequences including cerebral hemorrhage, seizure, myocardial infarction, or even death (302). The IPC recommends measuring resting BP before competition to detect boosting. If SBP is found to be above 160 mm Hg, then it is reexamined 10 min later. If SBP remains elevated above 160 mm Hg, then the athlete is withdrawn from competition. Pharmaceutical intervention is advocated when SBP remains above 150 mm Hg. Changes in SBP >20 mm Hg also are considered indicative of AD. This is relevant when you consider that low resting BP (*i.e.*, 90/60 mm Hg) is common in individuals with higher lesion levels, with an increase to or above 160 mm Hg (Δ ≥70 mm Hg) considered quite dangerous. The practice of self-inducing AD should be widely discouraged by practitioners.
- Individuals should empty their bowels and bladder or urinary bag before exercising. The most common causes of AD are a full bladder or bowel distension.
- Individuals with SCI tend to endure higher core temperatures during endurance exercise than their able-bodied counterparts. Despite this enhanced thermoregulatory drive, they generally have lower sweat rates. The following factors reduce heat tolerance and should be avoided: lack of acclimatization, dehydration, glycogen depletion, sleep loss, alcohol, and infectious disease. During training and competition, the use of light clothing, ice vests, protective sunscreen cream, and mist spray are recommended (303).

Musculoskeletal

- Novice, unfit but healthy individuals with SCI will probably experience muscular fatigue before achieving substantial central cardiovascular stimulus. Individuals with tetraplegia who have a very small active musculature will also experience muscular fatigue before exhausting central cardiorespiratory capacity.
- Muscular strength training sessions from a seated position in the wheelchair should be complemented with nonwheelchair exercise bouts to involve all trunk-stabilizing muscles. However, transfers (*e.g.*, from wheelchair to the exercise apparatus) should be limited because they increase the glenohumeral contact forces and the risk of repetitive strain injuries such as shoulder impingement syndrome and rotator cuff strain/tear, especially in individuals with tetraplegia (304). Special attention should be given to shoulder muscle imbalance and the prevention of repetitive strain injuries. The prime movers of wheelchair propulsion should be lengthened (*i.e.*, muscles of the anterior shoulder and chest), and antagonists should be strengthened (*i.e.*, muscles of the posterior shoulder, scapula, and upper back) (305).
- *Tenodesis* (*i.e.*, active wrist extensor-driven finger flexion) allows functional grasp in individuals with tetraplegia who do not have use of the hand muscles. To retain the tenodesis effect, these individuals should never stretch the finger flexor muscles (*i.e.*, maximal and simultaneous extension of wrist and fingers).
- HO is considered as an ectopic bone growth that commonly occurs around the hip joints in individuals with SCI. HO may cause nerve pain, ischemic pressure, and limitations in the ROM. Radiological examination is recommended, especially for individuals likely to be involved in FES-LEC or exoskeleton training to prevent additional growth. This condition should be considered as a relative and not absolute contraindication for exercise. Medical clearance should be sought based on the individual’s condition.

Skin

- Skin pressure injuries should be avoided at all costs, and potential risk areas should be checked on a regular basis. It is commonly recommended that individuals with sacral or pelvic pressure injuries greater than grade II only exercise following medical clearance. This protects the skin against shear stress and allows essential healing time. Pressure mapping testing is now available, which can provide an indication of problem areas for individuals when seated that are likely to progress into future pressure injuries.

Exercise Options

- In individuals with spastic paralysis above T12 who have substantial sensory loss and respond to stimulation with sustainable static or dynamic contractions, hybrid exercise may provide higher intensity cardiovascular exercise than voluntary arm exercise alone. Hybrid exercise activates a larger muscle mass and elicits higher peak and submaximal training values of $\dot{V}O_2$, stroke volume, and Q than either arm ergometry or functional electrical stimulation-leg cycle ergometry (FES-LCE) alone, especially for individuals with tetraplegia (306,307). However, there is evidence that there may not be additional benefit of hybrid cycling versus hand cycling in this population (308).
- Prescribing exercise intensity based on HR data can be difficult for individuals with autonomic cardiovascular dysregulation (>T6). It has been suggested that ratings of perceived exertion or a talk test are viable alternatives to prescribe exercise at a given intensity in this population (309,310,311).
- High-intensity interval training (HIIT) may be a viable alternative exercise strategy to promote vigorous intensity exercise in individuals with SCI (312). Whereas the optimal protocol for upper body exercise specifically for this population remains to be elucidated, this approach offers a relatively simple, readily available, and time-efficient exercise solution. By nature, HIIT also facilitates rest periods that may reduce peripheral fatigue, and recent evidence suggests this form of exercise is more enjoyable than traditional moderate intensity exercise for individuals with SCI (313).

ONLINE RESOURCES

American Spinal Injury Association Learning Center: https://asia-spinalinjury.org/learning/
National Center on Health, Physical Activity and Disability:
http://www.nchpad.org/Articles/9/Exercise~and~Fitness
Peter Harrison Centre for Disability Sport: http://www.lboro.ac.uk/research/phc/educational-toolkit/
SCI Action Canada: https://sciactioncanada.ok.ubc.ca/
Spinal Cord Injury Rehabilitation Evidence: https://scireproject.com/evidence/rehabilitation-evidence/

MULTIPLE CHRONIC DISEASES AND HEALTH CONDITIONS

The Centers for Disease Control and Prevention estimates that half of the U.S. adult population (117 million) has at least one of the top 10 chronic disease conditions and that one in four has more than one of these conditions (314). For those over 65 yr, 80% have at least one and 77% have at least two chronic conditions (315).

This makes it increasingly likely exercise professionals will be designing Ex R_x for individuals with multiple chronic diseases and health conditions. *Chapters 8*, *9*, and this chapter present Ex R_x guidelines for many individual chronic diseases and conditions. This section considers guidelines for individuals with more than one chronic disease or condition. In general, recommendations should follow the disease or condition with the most conservative guidelines. Exercise is generally safe for the majority of individuals with multiple diseases and chronic conditions who are medically stable and wish to participate in a light-to-moderate intensity exercise program (see *Chapters 1* and *2*). However, exercise professionals are encouraged to consult with medical providers when there are questions about an individual's known disease and/or health conditions that may limit their participation in an exercise program.

Exercise Testing

Follow the preparticipation screening process in *Chapter 2* to determine if medical clearance is warranted for any single individual. An exercise test is often not warranted to begin a regular exercise program. However, if such a test is recommended by a health care provider or requested by the individual to establish a baseline fitness level, refer to the information for the disease or condition that dictates the most conservative approach.

Exercise Prescription

In general, the FITT principle of Ex R_x for individuals with multiple diseases and/or health conditions will follow the recommendations for healthy adults (see *Chapter 5*) except when a disease or condition dictates a more conservative approach. Review the Ex R_x recommendations for each disease and condition to make this determination. The primary challenge is determining the specifics of the Ex R_x that should be recommended for the individual who presents with multiple chronic diseases, because there is some variability in the exercise dose that most favorably impacts a particular disease, health condition, or CVD risk factor (*e.g.*, BP requires lower doses of exercise to improve than does high-density lipoprotein [HDL], abdominal adiposity, or bone density).

Special Considerations

- In those with multiple chronic diseases or conditions, it is important to make sure all are stable prior to initiating an exercise training program.
- In some instances, exercise training adaptations may allow exercise intensity increases to elicit symptoms of a disease. For instance, in the individual with intermittent claudication, regular walking may allow an increase in exercise intensity that may subsequently uncover angina or dyspnea symptoms that were not present at lower intensity levels.
- A large body of scientific evidence supports the role of PA in delaying premature mortality and reducing the risks of many chronic diseases and health conditions. There is also clear evidence for a dose-response relationship between PA and health. Thus, any amount of PA should be encouraged, even if the level is very low due to a chronic disease or condition.
- Begin with an Ex R_x for the single disease and health condition that confers the greatest risk and/or is the most limiting regarding ADL, quality of life, and/or starting or maintaining an exercise program. Also consider individual preference and goals.
- Alternatively, begin with the most conservative Ex R_x for the multiple diseases, health conditions, and/or CVD risk factors with which the individual presents.
- Know the magnitude and time course of response of the various health outcome(s) that can be expected as a result of the Ex R_x that is prescribed in order to progress the individual safely and appropriately.
- Frequently monitor signs and symptoms to ensure safety and proper adaptation and progression.

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CHAPTER 11

Brain Health and Brain-Related Disorders

INTRODUCTION

Brain health can be broadly defined as the optimal or maximal functioning of behavioral and biological measures of the brain and the subjective experiences arising from brain function (*e.g.*, mood). The *2018 Physical Activity Guidelines Scientific Report* (1) concluded that there is unequivocal evidence that exercise influences brain health and that individuals with conditions that affect brain health (*e.g.*, major depression) could greatly benefit from engaging in exercise.

This chapter contains the exercise testing and exercise prescription (Ex R_x) guidelines and recommendations for individuals with health conditions related to the brain. As with the other chapters, the Ex R_x guidelines and recommendations are presented using the Frequency, Intensity, Time, and Type (FITT) principle of Ex R_x based on the available evidence from professional society position papers and scientific literature. For some brain health conditions, there is insufficient information regarding appropriate volume and progression of exercise training. In these instances, guidelines and recommendations provided in other chapters of the *ACSM Guidelines* should be adapted with good clinical judgment for the condition being targeted. In many instances, exercise training can be performed without a prior clinical exercise test. However, if an exercise test is to be performed, this chapter presents specific recommendations for individuals with various brain health conditions.

One area of brain health that is of high public interest is concussion. However, at the time this 11th edition of the *ACSM Guidelines* was published, there was limited evidence on the role of exercise or physical activity in the mitigation of, or recovery from, concussion. Future editions of the *ACSM Guidelines* and other ACSM publications will contain concussion information as it relates to exercise and physical activity, as the supporting evidence emerges.

ATTENTION-DEFICIT/HYPERACTIVITY DISORDER

Attention-deficit/hyperactivity disorder (ADHD) is a common neurodevelopmental disorder characterized by inattention, hyperactivity-impulsivity, or both (2). The prevalence of ADHD worldwide is approximately 5% in children-adolescents and an average around 2.5%–3.4% for adults (3). However, estimates in children-adolescents vary across sex, being markedly more prevalent in boys than in girls with a ratio of 2–3:1 (4,5). Existing data support that ADHD prevalence has not increased over the last three decades (4). Despite the popular belief that ADHD is mainly a pediatric disorder, meta-analyses of follow-up studies have shown that around 65% of ADHD children will continue having ADHD when adults (6). Problems related to ADHD include psychiatric comorbidities (*e.g.*, major depression, anxiety, bipolar disorder), health problems (*e.g.*, obesity, hypertension), psychological dysfunction, academic and occupational failure, social disability, and risky behaviors (*e.g.*, lying, stealing, and substance abuse) (2).

ADHD is a complex disorder, and its etiology is not yet completely understood. Although there is evidence that environmental factors play an important role, ADHD has a strong genetic component, with heritability estimates averaging approximately 75% (6–8). Both pharmacological and nonpharmacological treatments are used to treat ADHD. Although nonstimulants (*e.g.*, selective noradrenaline reuptake inhibitor atomoxetine and long-acting formulations of two α2-adrenergic agonist drugs clonidine and guanfacine) are sometimes used based on contraindications or personal preferences, stimulants (such as amphetamine or methylphenidate) are mostly used to treat ADHD in individuals of all ages (2). Additionally, nonpharmacological treatments, such as dietary, neurocognitive, and behavioral therapies, are also used as an alternative or complement to pharmacological treatments.

According to the 2018 Physical Activity Guidelines Advisory Committee, regular physical activity (PA) improves multiple dimensions of cognition, including two which are of utmost importance for individuals with ADHD: attention and inhibition (1). Inattentiveness is one of the core symptoms of ADHD, and the most updated evidence from the Physical Activity Guidelines Advisory Committee report strongly supports the use of PA to improve attention (9). Impulsivity is another core symptom of ADHD. Existing evidence supports a link between engagement in PA and improvements in cognitive inhibition (10,11). Cognitive inhibition is a major component of executive function dealing with the ability of people to inhibit responses in order to better respond to a specific stimulus. In this context, exercise has been shown to improve inhibition in the general population (12) and children suffering from ADHD (10). Other cognitive functions, such as a better ability to plan and organize daily life activities, considered to be part of executive function, are also positively related to exercise in the general population and can provide additional benefits to those with ADHD (1,13,14). Moreover, sleep duration and quality are often impaired in those with ADHD (15; see reference [13] for a review). The Physical Activity Guidelines Advisory Committee report supports that physically active people have a better sleep quality in terms of the time in bed to sleep onset, number and duration of times that a person wakes up at night after having fallen asleep, and sleep efficiency, among others (1). This would, therefore, be another mechanism by which exercise can improve ADHD symptomatology.

Major comorbidities in ADHD include obesity (see *Chapter 9*), hypertension (see *Chapter 9*), and depression/anxiety (as discussed in this chapter) (2,3,16,17), and exercise can play a key role in mitigating each of these conditions (1).

Exercise Testing

Given the higher prevalence of ADHD in childhood/adolescence than in adulthood, the considerations about exercise testing for individuals with ADHD will be mainly those referred to children and adolescents. In most of cases, individuals with ADHD can start a moderate intensity exercise program without previous medical screening, considering exercise testing for clinical purposes is not necessary unless there is any other health concern (18–20). However, exercise testing both in pediatric and adult populations is always informative as a health indicator and for monitoring improvements in fitness as a consequence of exercise (21). When doing so, the recommendations for exercise testing in the general population (see *Chapters 3* and *4*) will apply to ADHD (22). In children and adolescents, the most updated and evidence-based fitness test battery is the European Union-funded ALPHA battery (23–26), also supported by the Institute of Medicine in the United States (27,28). The tests selected for being the most valid, reliable, and related to future health are (a) the 20-m shuttle run test to assess cardiorespiratory fitness (CRF); (b) the handgrip strength and (c) standing broad jump to assess musculoskeletal fitness; and (d) body mass index (BMI), (e) skinfold thickness, and (5) waist circumference to assess body composition (26). International reference values for correct sex- and age-specific interpretation of fitness assessment are available elsewhere (29–32). Most of these tests are also included in the FITNESSGRAM battery. If ADHD is presented with comorbidities, exercise professionals should review relevant exercise testing options as listed elsewhere in the *ACSM Guidelines*.

Exercise Prescription

Because ADHD is most commonly diagnosed early in life, the Ex R_x principles for healthy children and adolescents apply in ADHD (see *Chapter 6*). Given that ADHD continues into adulthood for nearly two-thirds of children, adult Ex R_x principles also apply (see *Chapter 5*).

Exercise Considerations

- Attention should be paid to potentially coexisting comorbidities, such as overweight/obesity, hypertension, and depression/anxiety.
- Emerging evidence suggests that low physical fitness is common in ADHD (18–20,33). Care should be taken to start slow and to set realistic goals for fitness in this population.
- Developmental coordination disorder is frequently present in ADHD individuals (34–36). Therefore, complex exercises that require specific motor skills with high neuromuscular control (such as dancing) can be incorporated but should be done in a more progressive way (37,38).
- To increase exercise adherence in those with ADHD, it is important to choose fun and stimulating activities that provide motivation and positive feedback and, whenever possible, to train in small groups. These can all contribute to enhancing social skills and improving compliance.

- High intensity interval training (HIIT) may be a good choice for those with ADHD once a moderate fitness level is achieved. The shorter duration and higher intensity tend to require greater levels of concentration and focus, which may be beneficial (39).

Special Considerations

- For most individuals with ADHD, PA, and/or exercise will be complementary to their pharmacological treatment. It has been demonstrated that exercise can enhance the effects of stimulants (*i.e.*, methylphenidate) on clinical symptoms, cognitive function, and brain activity of individuals with ADHD (40–43). Therefore, those with ADHD are advised to discuss with their doctors information about medication doses and how they may interact with an exercise program. Adjustments in dosage may be necessary.
- The use of behavior change techniques (see *Chapter 12*) to target and create short- and long-term behavior goals might also be appropriate in this population (44,45).
- Features to be considered when prescribing exercise for individuals with ADHD:
  - Exercise sessions that are structured, previously planned, and part of a routine, done with a sports specialist or in a group setting
  - Program variety, including functional movement patterns
  - A defined, specific, measurable goal for the day and for short term

Future Directions

Overall, there is a need for more rigorous and well-designed randomized controlled trials testing the effects of exercise for ADHD children, adolescent, and adults. To date, most of studies on exercise and ADHD are conducted in children and most exercise interventions in ADHD focused exclusively on aerobic exercise. Given the multiple benefits of resistance training for health in the general population, future studies should include strength training among individuals with ADHD to explore its effects on overall health and on the specific ADHD symptomatology. Additionally, future studies should investigate how exercise interacts with ADHD medication (*e.g.*, whether incorporating PA into the daily life of a medicated person with ADHD could contribute to reducing the drug dose).

ONLINE RESOURCES

ADHD Europe: https://www.adhdeurope.eu/

ADHD in Adults: http://www.adhdinadults.com

American Academy of Pediatrics ADHD Toolkit: https://www.aap.org/en-us/pubserv/adhd2/Pages/kit/data/introframe.html

American Professional Society for ADHD and Related Disorders: http://www.apsard.org

Australian NHMRC: http://www.nhmrc.gov.au/guidelines-publications/mh26

Children and Adults with ADHD: http://www.chadd.org

European Network on Adult ADHD: http://www.eunetworkadultadhd.com/

International Collaboration on ADHD and Substance Abuse: http://www.adhdandsubstanceabuse.org

Mayo Clinic Diseases and Conditions. Attention-deficit/hyperactivity disorder: https://www.mayoclinic.org/diseases-conditions/adult-adhd/symptoms-causes/syc-20350878

National Institute of Mental Health: https://www.nimh.nih.gov/health/topics/attention-deficit-hyperactivity-disorder-adhd/index.shtml

The Canadian ADHD Resource Alliance: http://www.caddra.ca

UK Adult ADHD Network: http://www.ukaan.org

World Federation of ADHD: http://www.adhd-federation.org

ALZHEIMER’S DISEASE

Alzheimer’s disease is the most common cause of dementia, comprising 60%–80% of all dementia cases (46). Alzheimer’s disease is characterized by early and progressive declines in learning and memory, as well as other cognitive processes (*e.g.*, executive functions), followed by more severe declines in cognition, mood, and motor abilities as the disease progresses

(47). Alzheimer's disease is also characterized by increased depressive symptoms, behavioral problems such as wandering or agitation, and significant sleep disturbances, all of which may mediate or exacerbate memory impairments (48). Over time, the impairments become severe enough to interfere with the ability to complete instrumental activities of daily living (ADL). Although Alzheimer's disease is most common in individuals over the age of 65 yr, its early-onset form commonly affects those younger than 65 yr. Additionally, the neurodegenerative and neuropathological processes associated with the disease begin one to two decades before the onset of any cognitive symptoms, making a search for prevention and early treatment of the disease a major priority for public health (49,50).

Alzheimer's disease is currently the sixth leading cause of death in the United States, with nearly 46 million suffering from Alzheimer's disease or a related dementia. Given the projected increase in the number of adults over the age of 65 yr, the *World Alzheimer's Report* and the Alzheimer's Association both indicate that without the discovery of effective prevention and treatment measures, the number of cases may double by 2050 (46). Age is the greatest risk factor for Alzheimer's disease, with 81% of cases being 75 yr or older. The prevalence rate exponentially increases with age such that about 3% of individuals 65–74 yr old have the disease, whereas 32% of individuals over the age of 85 yr have Alzheimer's disease (51). An individual diagnosed with Alzheimer's disease survives for 7–12 yr on average (52,53). Unfortunately, at present, Alzheimer's disease is incurable.

Alzheimer's disease is primarily characterized by two hallmark pathological features: amyloid-β plaques and neurofibrillary tangles. In the preclinical phase of Alzheimer's disease, plaques and tangles accumulate in the brain up to two decades before the development of cognitive symptoms (49,54). In fact, 20%–40% of individuals over the age of 65 yr without evidence of memory loss or cognitive decline have detectable pathological features of the disease, and the presence of this pathology is thought to lead to other downstream neuropathological processes such as atrophy of the hippocampus and other brain regions (55). Subsequent to the preclinical stage is a second stage characterized by both presence of Alzheimer's disease pathology and neurodegeneration (*e.g.*, hippocampal atrophy) along with signs of mild cognitive impairment (MCI). The final stage (dementia due to Alzheimer's disease) is characterized by more significant objectively measured cognitive impairments as well as an inability to independently perform many instrumental ADL and subjective reports of cognitive or memory problems.

There have been numerous studies examining the potential for pharmaceutical and nonpharmaceutical treatments to prevent, delay, or reverse the course of Alzheimer's disease. These treatments include pharmaceuticals that target the cholinergic system or enzymatic pathways in the amyloid or tau cascade, nonpharmaceuticals that target oxidative stress, and behavioral interventions such as exercise. Unfortunately, the majority of these treatments have met with limited clinical success. Because of this, it is suggested that the greatest chance of success for altering the trajectory of the disease course is by targeting the earliest possible stages, when amyloid-β first begins to show increased accumulation.

Observational studies often consider leisure activities, PA, and exercise behaviors together when assessing longitudinal risk for dementia or cognitive impairment. In contrast, structured exercise programs are often used in randomized clinical trials that assess whether exercise could be used as an effective treatment for symptoms of the disease. A significant body of research demonstrates that greater amounts of PA are associated with a reduced risk of experiencing cognitive decline in late adulthood (56) as well as a reduced risk of developing Alzheimer's disease (57,58). There is also preliminary evidence that exercise may improve physical and cognitive function in individuals with Alzheimer's disease (59), but these findings are far from conclusive (see references [60] and [61]) and more research is necessary to determine the magnitude and consistency of such an effect. There are also data suggesting that higher CRF is related to less brain atrophy in early Alzheimer's disease (62) and that increasing fitness levels through exercise interventions may slow memory loss and brain atrophy (63). In cognitively healthy adults, there is limited evidence that exercise might be capable of positively altering the size and function of brain areas that are affected in the disease course (62), which improve as a function of exercise-induced changes in cellular and molecular pathways that could mitigate the effect of neuropathology or reduce the accumulation of amyloid-β plaques. Based on these data, the 2018 Physical Activity Guidelines Advisory Committee reported that there is strong evidence that greater amounts of PA reduce the risk for dementia (64). Although there is much to learn about the potential for PA and exercise to influence cognitive and brain health in Alzheimer's disease, there is emerging evidence of increased functional ability in early stages of Alzheimer's disease (63) and strong and unequivocal evidence that exercise reduces risk of falls and injuries as well as improves physiological pathways associated with conditions that often co-occur with Alzheimer's disease (*e.g.*, Type 2 diabetes mellitus).

Exercise Testing

Recommendations for exercise testing are dependent on the stage and severity of the disease, such that individuals that are in the preclinical and early stages are much more likely to understand and tolerate exercise testing procedures more so than individuals later in the disease course (65,66). Thus, clinical judgment is always needed to determine a person's safety for conducting a test, and it is recommended that all exercise testing be conducted in consultation with a physician and/or neuropsychologist who understands the individual's level of impairment. Because dementia often co-occurs with cardiovascular and cardiometabolic conditions, exercise testing should also take into consideration the presence of these conditions. High intensity exercise testing, as during a maximal stress test, is safe unless there are balance, muscle, or coronary contraindications, as outlined in *Chapter 4*. Cycle ergometry may be a more effective and less painful procedure for some individuals with comorbid conditions that increase pain during exercise testing (*e.g.*, significant arthritis).

For all procedures, it is recommended to allow individuals to warm up at a light intensity level according to the individual's level of impairment and functional status, and to provide a sufficient period for cool-down while closely monitoring vital signs. Individuals with more severe cognitive impairments may have difficulty remembering the goals of the test or remembering what they are there to do. These memory impairments may fluctuate from one moment to the next, making exercise testing contraindicated in conditions of severe memory loss. Standard measures of exertion such as the Borg scale (see *Figure 4.2*) may also be invalid in cases of severe Alzheimer's disease but, in preclinical and early stages, could be considered a valid assessment tool. Strength testing is also possible in this population, especially in cases of preclinical, MCI, or early dementia stages. In cases of more severe memory impairments, strength testing becomes more hazardous and should always be conducted in consultation with the physician and/or neuropsychologist who understands the severity of the impairment.

Exercise Prescription

Depending on the severity of the cognitive impairment, health professionals and caregivers are sometimes hesitant to start an exercise program with the fear that cognitive losses might result in a greater likelihood of distraction, forgetting what one is doing, or overestimation of one's current abilities to perform exercise. Despite these fears, individuals with Alzheimer's disease are safe to exercise as long as the Ex R_x is progressed and monitored in a similar fashion to that of cognitively normal older adults (see *Chapter 5*). There is evidence that cognitively impaired individuals, including those with Alzheimer's disease, might also benefit from lower intensity activities, thereby allowing them to engage in a variety of exercises with a range of intensities (56). Individuals with Alzheimer's disease may also benefit from targeting multiple exercise modes, aerobic, strength, coordination, flexibility, and balance training (67), as the usual health benefits associated with these are all applicable in the individual with Alzheimer's disease. Individuals with Alzheimer's disease should avoid inactivity and sedentariness. As is the case with exercise testing, all Ex R_x should be done in consultation with the physician and/or neuropsychologist who understands the severity of the impairment as well as other comorbid conditions that could affect exercise safety or prescription (see *Chapters 8*–*10*). All exercise, including aerobic and resistance training (68), for individuals with Alzheimer's disease should be conducted based on a relative intensity of the person's symptoms and physical status, and progress at a rate that would optimize adoption and adherence. Finally, anyone with Alzheimer's disease should engage in levels of PA as their abilities allow.

FITT	FITT RECOMMENDATIONS FOR INDIVIDUALS WITH ALZHEIMER'S DISEASE		
	Aerobic	**Resistance**	**Flexibility**
Frequency	3 d · wk^{-1}	2–3 d · wk^{-1}	≥2–3 d · wk^{-1} with daily being most effective
Intensity	Dependent on disease severity, start with light intensity and progress to moderate intensity based on the performance of the individual (40%–59% $\dot{V}O_2R$ or HRR; RPE of 12–13 on a scale of 6–20)	40%–50% of one repetition maximum (1-RM) for individuals beginning to improve strength; 60%–70% 1-RM for more advanced exercisers. Always consider the severity of the cognitive impairments as well as the presence of any co-occurring conditions that could modify these levels.	Full extension, flexion, rotation, or stretch to the point of slight discomfort
Time	Depending on disease severity, it may be necessary to start with bouts <10 min and progress at	≥1 set of 8–12 repetitions; 10–15 repetitions in adults with Alzheimer's	Hold static stretch for 10–30 s; 2–4 repetitions

	a rate comfortable with the individual. Exercise could be performed up to 30–60 min of continuous or accumulated exercise.	disease starting an exercise program	of each exercise
Type	Prolonged, rhythmic activities using large muscle groups (*e.g.*, walking, cycling, swimming, dancing)	For safety, avoid free weights; focus on weight machines and other resistance devices (*e.g.*, bands, body weight).	Slow static stretches for all major muscle groups

HRR, heart rate reserve; RPE, rating of perceived exertion.

Exercise Considerations

- There is growing evidence that individuals with Alzheimer's disease can realize benefits of exercise through improved aspects of physiological and brain health; whether an individual can perform exercise activities on their own depends on the severity of the disease.
- Long, continuous bouts of exercise are more likely to be helpful and safe in preclinical and early stages of the disease and less likely to be feasible during later stages of the disease.
- Metabolic, cardiovascular, joint, and muscle atrophy comorbidities may restrict the frequency and duration of exercise. Therefore, it may be appropriate to start an exercise regimen with short bouts of 10 min or less.
- Targeting multiple modes of activity might be the most effective for enhancing balance, flexibility, strength, and endurance.

- Adequate warm-up and cool-down periods with monitoring of vital signs are critical for minimizing safety concerns.

Special Considerations

- In the earliest stages of Alzheimer's disease, including MCI, individuals are still capable of performing exercise independently and in the community.
- Ex R_x should always be performed with the consultation of the individual's physician and/or neuropsychologist.
- There may be benefits of training and exercising with the caregiver to help provide support, motivation, and monitoring of safety.
- Inform individuals, as well as caregivers, that a small amount of musculoskeletal pain during or immediately following an exercise bout is a normal consequence of starting an exercise regimen.
- Exercising in the morning hours might be easiest and most beneficial, as morning is often when an individual is demonstrating the lowest severity of symptoms.
- Exercise in nursing homes, memory clinics, or senior care facilities, is encouraged as long as there are properly trained staff to monitor individual progress and safety.

Future Directions

Future research should be conducted to examine parameters and modes of activity that are optimal for both preventing and treating the symptoms of Alzheimer's disease. In addition, we have a poor understanding of whether exercise could reduce the incidence of the disease or the optimal window in the disease course to begin an exercise regimen. Future research should examine whether exercise is more effective at treating symptoms in preclinical stages before cognitive decline is evident or whether it is equally effective at later stages of the disease course.

ONLINE RESOURCES

Alzheimer's Association: https://www.alz.org
Mayo Clinic: https://www.mayoclinic.org/diseases-conditions/alzheimers-disease/symptoms-causes/syc-20350447
National Institute of Aging: https://www.nia.nih.gov/health/alzheimers
World Alzheimer's Report: https://www.alz.co.uk/research/world-report

ANXIETY AND DEPRESSION

Anxiety and depression are disorders that interfere with social, occupational, or other important aspects of daily functioning. Diagnostic criteria have been outlined in the *Diagnostic and Statistical Manual of Mental Disorders* (69). Anxiety and depression share a negative affective tone. The prevailing subjective experiences that might indicate anxiety or depression involve the anticipation of threat or experience of sadness, respectively, on more days than not for an extended period of time; however, individual presentations can vary widely.

Anxiety and depression are also often comorbid, meaning that individuals with one disorder frequently experience symptoms of the other (sometimes enough to qualify for a dual diagnosis). A critical risk with depression is suicidality (*i.e.*, suicidal ideation, plans, or attempts). Exercise professionals should not attempt to diagnose anxiety or depressive disorders but should instead refer individuals of concern to licensed mental health professionals for assessment, diagnosis, and treatment planning.

The World Health Organization (70) estimates that over 300 million people suffer from depression and over 250 million suffer from anxiety disorders worldwide, with prevalence for both increasing over the past decade. Lifetime prevalence is such that over 33% of the U.S. adult population will experience an anxiety disorder and 21% will experience a mood disorder (13% for recurrent major depressive disorder) (71). Every year, over 21% of American adults experience an anxiety disorder and nearly 10% experience a mood disorder (over 7% experiencing recurrent major depressive episodes) (71). Unfortunately, 45%–80% of people with anxiety or depressive disorders do not receive treatment and, of those who do, many do not respond to first-line treatments (72–74).

Mental disorders are among the costliest health conditions in the United States. More money is spent in treating and managing mental health annually ($201 billion · yr^{-1}) than on cancer, heart conditions, diabetes, pulmonary conditions, kidney disease, or hypertension (75). Although scaling up treatments to treat anxiety and depressive disorders would be costly, the long-term economic benefits from increasing healthy life years and improving productivity are estimated to be 3.3–5.7 times greater (76).

Exercise Testing

For those with anxiety and depression, submaximal exercise tests are highly recommended because these individuals often have poor physical health and fitness levels, low physical self-worth, and limited aerobic training experience, energy, and motivation for maximal physical effort (77,78). Pretest anxiety can also influence testing results due to fears of physiological reactions, which mimic physical symptoms of anxiety and depression (*e.g.*, shortness of breath, chest pain) (79). Frequently used submaximal tests include the 6-min walk test (6-MWT) (80) and the Franz ergocycle test (78).

- All individuals with anxiety and/or depression should be screened for medication use prior to exercise testing for potential contraindications. In particular, benzodiazepines may cause drowsiness and poor coordination as well as reduce the plasma catecholamine response to exercise (81).
- Individuals with anxiety disorders have had mildly impaired blood pressure (BP) responses to cardiovascular exercise and should be screened prior to exercise testing (79,82). In particular, individuals with generalized anxiety disorder have demonstrated elevated worry and poor

vagal tone via heart rate (HR) variability, both of which could negatively impact their exercise testing (83).

- Women with anxiety disorders and without coronary artery disease history have an increased ischemia risk during exercise testing (84).

Exercise Prescription

Anxiety

Exercise is effective for reducing anxious symptoms, and this applies to people with and without anxiety disorders, and those with and without other medical diagnoses (77,85–89). The number of high-quality randomized controlled trials is limited, and many trials with clinically anxious participants have combined exercise with other treatments. Nevertheless, although limited, it is possible to make preliminary recommendations on how to prescribe exercise based on the available evidence.

In individuals with clinical anxiety disorders, exercise is effective for reducing symptoms both in combination with other treatments and in comparison to nonactive control groups (87,89). Symptom severity does not alter these effects (89). For individuals with other medical problems, multimodal treatments do not appear to be more effective than exercise by itself (86).

In general, meeting the 2018 Physical Activity Guidelines for Americans recommendations is appropriate for reducing anxiety (1). These guidelines recommend that adults accumulate at least 150 min $\cdot$ wk^{-1} of moderate intensity PA (*e.g.*, walking) or 75 min $\cdot$ wk^{-1} of vigorous intensity PA (*e.g.*, running, fast cycling, or the equivalent combination thereof). They also recommend that adults engage in muscle-strengthening exercise (*e.g.*, push-ups, yoga, weight training) for all major muscle groups at least two times per week. Beyond those general guidelines, systematic reviews of exercise effects on anxiety symptoms provide specific guidance to inform Ex R_x.

- *Frequency*. In the general population, the effects of exercise appear to be greatest when sessions occur three to four times per week (90). In individuals with anxiety disorders, weekly exercise frequency was not associated with anxiety reduction, nor was an optimal frequency identified (89). In individuals with primary diagnoses of other medical conditions (*e.g.*, cardiovascular disease, fibromyalgia, multiple sclerosis, cancer), effects were greatest for programs held three or five times per week (86).
- *Intensity*. In the general population, moderate and vigorous intensity PA (*i.e.*, exercise) reduce anxiety (90). Comparative effectiveness trials in individuals with anxiety disorders are limited, but based on the available trials, moderate-to-vigorous intensity physical activity (MVPA) may be effective for reducing anxiety symptoms (87). In individuals with primary diagnoses of other medical conditions, light, moderate, and vigorous intensity exercise were all associated with reduced anxiety (86). There is some evidence that higher intensity aerobic exercise programs (*e.g.*, treadmill running at 60%–90% maximum heart rate [HR_{max}] or 60% $\dot{V}O_{2max}$ or greater) had greater effects for decreasing anxiety than lower intensity ones (*e.g.*, walking below 60% HR_{max} or $\dot{V}O_{2max}$) (91).
- *Time*. In the general population, exercise has acute effects that reduce state anxiety following exercise sessions (1), and there does not appear to be a minimum bout length for these effects. Anxiety reductions are evident following bouts lasting 1–30 min and may increase for bouts lasting 61–90 min (90). Effects are evident in programs lasting from 4 to 15+ wk; however, effects may taper over time. In individuals with anxiety disorders, longer exercise programs are associated with greater reductions in anxiety symptoms but little is known about bout duration requirements (87,89). In individuals with other medical conditions, program length and session duration both appear to influence the size of treatment responses. The largest responses have been found from sessions lasting 30+ min and programs lasting 3–12 wk (86).

- *Type*. Both aerobic and resistance exercise training appear to be effective for reducing symptoms of anxiety in healthy and clinical populations (87,90). Resistance training may reduce anxiety more in healthy populations than in populations with physical or mental illness (85). It is not clear whether combining different types of activity leads to greater reductions in anxiety.

Depression

Exercise is effective for both reducing depressive symptoms in people with and without clinical depression and for reducing the odds of a clinical diagnosis in those who started with a clinical diagnosis of depression. The effects of aerobic exercise are more profound among individuals who are clinically depressed (92,93). In individuals with depression, aerobic exercise has proven to be as effective as psychotherapy or pharmacotherapy for reducing depressive symptoms (92,93). Exercise is also more effective for reducing depression than bright light therapy and other controls (92).

- *Frequency*. The cumulative frequency of exercise matters more for individuals with depressive disorders than those without (93). Programs with 12 or fewer days of exercise have inconsistent effects; however, programs lasting 13 or more days consistently reduce depressive symptoms in individual samples.
- *Intensity*. There is not enough evidence to indicate that one particular intensity is more effective than another for reducing depressive symptoms. PA at any intensity level appears to be effective for reducing depressive symptoms (92,93). Even though more evidence has been collected on moderate-to-vigorous than light PA, it appears that exercise at all intensities is beneficial for reducing depressive symptoms.
- *Time*. Exercise has acute or immediate effects on core affective states that can be useful for temporarily alleviating depressive symptoms after exercise (94,95). Bouts as brief as 20 min appear to be sufficient to reducing depressive symptoms in individuals without depressive disorders (93). For individuals with depressive disorders, 45 min is the recommended bout length (77,93).
- *Type*. The effects of aerobic exercise on depressive symptoms have been characterized better than the effects of flexibility exercises (92). In general, both aerobic and resistance training reduce depressive symptoms (92,93,96,97). Mixed programs including both aerobic and resistance training components appear to be more effective than programs with only

one form of training; however, this conclusion is based on limited evidence (93). For individuals with depressive disorders, both aerobic and resistance exercises reduce depressive symptoms (92). Exercise produces similar effects on depressive mood to stretching, meditation, and relaxation (92).

Exercise Considerations

- Exercise can induce physiological changes similar to a panic attack (*e.g.*, increased HR, shortness of breath); therefore, individuals with known panic disorders should be advised to expect these symptoms as a normal result of exercise.
- Some exercise appears to be better than none for reducing anxiety and depression, although meeting recommended levels of PA has had the best results.
- For depressed individuals, it is important to find PAs that will be maintained, and they should include a mix of aerobic and resistance training activities.

Special Considerations

- Suicidality involves ideation, plans, or actions intended to end one's life. Suicidality is a risk with depressive disorders, and the consequences can be severe. Exercise professionals should refer individuals they suspect of depressive disorders to licensed mental health professionals for assessment, diagnosis, and comprehensive treatment planning.
- For individuals with depressive disorders, reduced sensitivity to rewards can create additional challenges for adhering to a PA program.
- Individuals can benefit from supplementing exercise with support for self-regulation (*e.g.*, digital tools, training on evidence-based strategies) to manage these chronic disease states.

Future Directions

Dose-response relations between exercise and mental health outcomes need to be characterized in greater detail using comparative effectiveness research designs. These studies can indicate the optimal prescription in terms of frequency, intensity, timing, and type of activity. Limited information exists on the effects of varying exercise intensities for individuals with depression and anxiety. Additional research is needed for the effects of resistance training as well as combined or mixed aerobic, resistance training, and flexibility exercises for anxiety and depression. Anxiety and depression are often comorbid, and the effects of exercise on comorbid anxiety and depression are not well understood.

ONLINE RESOURCES

Anxiety

- Anxiety: https://www.nimh.nih.gov/health/topics/anxiety-disorders/index.shtml
- Anxiety disorders: https://www.psychiatry.org/patients-families/anxiety-disorders/what-are-anxiety-disorders
- Generalized anxiety disorder: https://www.nimh.nih.gov/health/publications/generalized-anxiety-disorder-gad/index.shtml
- Panic disorder: https://www.nimh.nih.gov/health/publications/panic-disorder-when-fear-overwhelms/index.shtml
- Social anxiety disorder: https://www.nimh.nih.gov/health/publications/social-anxiety-disorder-more-than-just-shyness/index.shtml

Depression

- Depression: https://www.nimh.nih.gov/health/topics/depression/index.shtml
- Overview and diagnostic criteria: https://www.psychiatry.org/patients-families/depression/what-is-depression
- Depression in teens: https://www.nimh.nih.gov/health/publications/teen-depression/index.shtml
- Depression in college students: https://infocenter.nimh.nih.gov/pubstatic/NIH%2012-4266/NIH%2012-4266.pdf
- Depression in older adults: https://www.nimh.nih.gov/health/publications/older-adults-and-depression/index.shtml
- Postpartum depression: https://www.nimh.nih.gov/health/publications/postpartum-depression-

facts/index.shtml

AUTISM SPECTRUM DISORDER

Autism spectrum disorder (*ASD*) is a complex neurological and developmental disorder with estimated prevalence rates of 1 case per 59 children in the United States. Diagnosis is based on observation of atypical behaviors, signifying persistent deficits in social communication and social interaction, and restricted, repetitive patterns of behavior, interests, or activities (69). Moreover, comorbidities are also prevalent, including medical conditions (*e.g.*, higher rates of seizures, gastrointestinal disorders, metabolic conditions, psychiatric illness, ADHD) (98,99), and motor coordination deficits (100,101). In all, ASD is a heterogeneous condition with multiple developmental trajectories. Although the etiology is not completely understood, genetic and environmental factors are known to be at play. The genetic contribution to ASD is supported by family and twin studies that report heritability estimates from 50% to 95% (102). The study of nongenetic contributory factors has identified advanced parental age and preterm birth as risk factors, and factors including air pollution and short interpregnancy interval may be potential risk factors (102).

Treatment options to address the symptoms of ASD — the core characteristics of the disorder and associated comorbidities — include medical and behavioral approaches. Behavioral interventions, usually implemented early in life, are considered the current gold standard treatment for ASD's behavioral symptoms (103). Treatments target symptoms of ASD and can include applied behavioral therapy, speech therapy, occupational therapy, and physical therapy. An array of other therapies exists that incorporate evidence-based practices to help improve symptoms of ASD; these evidence-based practices are classified by the National Professional Development Center on Autism Spectrum Disorder (104). Pharmacological treatment options, although commonly used, frequently are lacking evidence supporting their benefit (105). Risperidone and aripiprazole, common treatments for challenging and repetitive behaviors among children with ASD, have the clearest evidence and remain as the only two pharmaceutical interventions for the treatment of symptoms associated with ASD that are approved by the U.S. Food and Drug Administration (FDA) (105). Significant adverse effects of medical treatments for individuals with ASD are often reported, including weight gain, fatigue, sedation, and somnolence — effects often associated with a discontinuation of treatment.

Exercise is included as one of the 27 evidence-based practices identified for individuals with ASD, cited as improving physical fitness, increasing desired behavior (time on task, correct responding), and decreasing inappropriate behaviors (self-aggression, self-injury) (104). Moreover, recent meta-analyses of the effect of exercise interventions on children with ASD report moderate-to-large effects from interventions targeting the development of motor skills, skill-related fitness, social functioning, and muscular strength and endurance (106,107). It is evident that exercise addresses ASD symptomology and comorbidities and provides health-enhancing benefits. However, youth with ASD tend to be less active and less likely to meet the PA guidelines compared to children without ASD (108). This is unsurprising when we consider that the nature of PA — typically a physical, social, sensory, and dynamic experience — may directly conflict with the characteristics of ASD. Therefore, special attention is warranted for exercise testing and prescription among this population.

Exercise Testing

Aside from possible risks associated with PA and exercise that exist for the general population, as outlined in *Chapter 1*, exercise testing is safe for populations with ASD. Therefore, preparticipation health screening for exercise and exercise testing should follow the general recommendations in *Chapter 2*. However, one should ensure the testing procedures and environments are understood, motivating, and comfortable for the individual with ASD. There exists tremendous heterogeneity within the population diagnosed with ASD; for example, individuals vary within cognitive, social, behavioral, sensory, and motor domains. This heterogeneity means that providing recommendations for exercise testing for individuals with ASD is not a "one size fits all" task. The exercise test administrator should, however, consider how the evidenced-based practices (EBPs) identified for individuals with ASD, including visual schedules, social narratives, task analysis, prompting, and reinforcement, may be used to assist with testing procedures (*Table 11.1*). EBPs are frequently used in combination with one another.

TABLE 11.1 • Exercise Testing Recommendations for Individuals with Autism Spectrum Disorder (ASD)

Recommendation	Elaboration/Example
1. Understand the individual's strengths, abilities, and preferences.	• Does the individual . . . ▪ have sensory issues? ▪ use tools to support communication? ▪ take medications with side effects such as fatigue or sedation?
2. Choose an appropriate test depending on the individual's attributes.	• A cycle ergometer may be preferred over a treadmill for an individual with poor balance or coordination. • Tests that are familiar to the individual may be preferred for an individual with intellectual disability or an anxiety disorder.
3. Provide routine and predictability.	• Many individuals with ASD have an "insistence on sameness" and "inflexible adherence to routines." • Be consistent with routines, equipment, and organization. • Visual schedules may help to reinforce routine by providing a graphic representation of scheduled tasks and activities.
4. Prepare the individual for exercise testing.	• Gradually expose the individual to the testing procedures and environment. • Use social narratives (109). Social narratives describe new social situations for individuals with ASD by providing relevant cues and descriptions of appropriate behavior expectations.

5. Use task analysis (110), the process of breaking a skill or task down into smaller, more manageable components.	• Task analysis of an exercise test, and the subsequent teaching of its "parts," may be necessary before testing an individual with ASD who is not familiar with the activity and/or may find the activity challenging.
6. Use prompting (111) to assist the individual in the testing procedures.	• Prompting procedures include any help given to learners that assist them in using a specific skill. • Prompting procedures may include verbal (keep concise and concrete), gestural, and physical. • Prompts are typically provided in conjunction with other evidence-based practices. A variety of prompting procedures exist, including using least-to-most prompts, simultaneous prompting, and graduated guidance. For an overview of these procedures, see Neitzel and Wolery (112).
7. Use modeling (113) and/or video modeling (114) to provide a visual model of the testing procedures.	• Modeling involves the demonstration of an activity or skill by the instructor to initiate imitation of the behavior/skill by the learner/exerciser. • Video modeling involves using video recordings and display equipment to provide a visual model of the behavior or skill (114) to the learner/exerciser. • Types of video modeling include basic video modeling, video self-modeling, point-of-

	view video modeling, and video prompting (114).
8. Use reinforcements to increase the probability that the individual will complete the movement (104,115).	• Reward the individual with ASD for completing an exercise test (*e.g.*, with preferred activities, verbal praise, tangible items). • Ask the parent/guardian or the individual with ASD about their preferred reinforcers.

Exercise Prescription

It is recommended that children and adults with ASD are prescribed exercise to gradually progress to a frequency, intensity, and time of that recommended for children and adults without ASD. As various types of PA have shown to be beneficial for individuals with ASD (100,106,107), the exercise type prescribed should depend on factors such as the individual's interests and the goal of the exercise program (*e.g.*, a goal of social skill development vs. fitness). Activities of type A (*e.g.*, walking, slow cycling) or B (*e.g.*, jogging, running, rowing, elliptical exercise) may be preferable for the development of cardiorespiratory endurance among individuals with ASD with motor deficits. Furthermore, due to the social deficits associated with ASD, it is recommended that an exercise program with individuals with ASD begins with a focus on these "type A" individual activities. However, the development of more advanced skills required for type C (*e.g.*, swimming, skiing) and type D activities (*e.g.*, soccer, basketball, racquet sports) should not be neglected to ensure that the individual with ASD can choose to participate in a range of activities. The latter type of activities (type D) are particularly pertinent for individuals with ASD as they inherently involve the use of social and communication skills thereby offering opportunities for the cardinal features of ASD to be improved on (see Activity Types, *Table 5.4*). Importantly, this also means that participation in these types of activities may be socially demanding and, thus, perhaps anxiety-inducing for the participant with ASD. Adequate supports should therefore be provided to individuals with ASD when organizing group activities, including providing opportunities for them to play in small-sided type D activities and the provision of regular breaks.

Making specific FITT recommendations for exercise interventions is hampered by the large variability that exists within the interventions studied among individuals with ASD (106). For example, a host of interventions have been demonstrated to positively affect social skills among children with ASD, using exercise types ranging from yoga to multisport camps, at varying doses ranging from 6.5 to 150 h (116). Similarly, the muscular strength and endurance of children with ASD has been shown to be positively impacted by a host of exercise types ranging from exergaming to equine therapy, at varying doses ranging from 20 to 60 h (106). Although the evidence does not lend itself to making specific exercise programming decisions for this population, it does strongly support the benefit of exercise of varying types and doses for individuals with ASD.

Exercise Training Considerations

Table 11.2 highlights considerations regarding the exercise environment and exercise programing for individuals with ASD. It should be noted that approximately one-third of individuals with ASD have an intellectual disability (ID) (117); therefore, readers may also find the information in the chapter related to those *with intellectual disability* useful.

TABLE 11.2 • Exercise Training Recommendations for Individuals with Autism Spectrum Disorder (ASD)

Exercise Training Components	Challenges and Strategies
The exercise environment	• Hypersensitivity issue. Learn about and prepare for sensory processing issues that the individual may have. For example, consider the noise and light in the gymnasium and modify the environment if necessary. • Predictability. Organize the space in a predicable manner for each training/testing session. • People. Consider the social environment: The individual with ASD may prefer individual, parallel, or small group activities. • Anxiety. New environments may cause anxiety in some individuals with ASD; slowly transition to new environments and give ample time for the individual to become accustomed to the new space.
Exercise programming	• Desire for "sameness." Maintain a predictable structure in your exercise program and communicate it via a visual schedule. • Motor deficits. Adapt equipment and activities to cater for possible motor

deficits (*e.g.*, coordination, balance, muscular strength).

- Fatigue. Offer breaks throughout the exercise period. Be aware that the individual may require breaks from sensory input and social interaction, in addition to physical fatigue.
- Apply evidence-based practices (individually or in combination with other practices) for the promotion of exercise behaviors and skills: See *Table 11.3* for a summary of evidence-based practices such as task analysis, modeling, video modeling, prompting, and reinforcements. See Wong et al. (104) for a comprehensive overview of evidence-based practices for individuals with ASD.

Future Directions

To understand how to most efficiently conduct exercise testing and prescription for individuals with ASD, research is needed with larger, more homogeneous samples using rigorous research designs to determine what, if any, modifications are needed to the FITT principles for this population. The FITT principles that correspond to particular outcomes of relevance to individuals with ASD (*e.g.*, repetitive behaviors, social skills) also require investigation. Moreover, two populations vastly understudied include younger children (<4 yr) and adults with ASD. Due to the importance of early intervention for this population (103), how exercise can be used to benefit young children with ASD, including being incorporated into other ASD interventions, is an avenue ripe for research. A focus on adults is also warranted; despite the increasing number of adults with ASD and the greater health disparities they experience (118), exercise interventions for this population are sparse.

ONLINE RESOURCES

ACSM/Exercise Connection Autism Exercise Specialist Course: http://acsm.ideafit.com/acsm/autism-exercise-specialist-certificate
Autism Society: http://www.autism-society.org
Autism Speaks: https://www.autismspeaks.org
Evidence-Based Practices: https://autismpdc.fpg.unc.edu/evidence-based-practices
National Autism Association: http://nationalautismassociation.org
The National Professional Development Center on Autism Spectrum Disorder: https://autismpdc.fpg.unc.edu/national-professional-development-center-autism-spectrum-disorder

CEREBRAL PALSY

Cerebral palsy (CP) is defined as "a group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain" (119). As such, CP encompasses a variety of motor disorders, which may be accompanied by disturbances of sensation, cognition, behavior, and communication (119). CP is the most common motor disability in childhood. The severity of motor impairment can vary considerably from person to person. An individual with severe motor impairment may be unable to maintain head and trunk postures and may require a wheelchair to mobilize. Someone with mild CP may present with impaired speed, balance, and coordination and not need any type of special assistance, or device, to walk. Individuals with CP also often experience associated conditions, including epilepsy and musculoskeletal disorders (119). Typically, CP is diagnosed between 12 and 24 mo of age, using a combination of standardized motor assessments, neuroimaging, and a medical history (120). Risk factors for CP include low birth weight, children born in multiple births, placental abnormalities, birth asphyxia, maternal obesity (121), and neonatal infections (122). However, the causal pathway to CP is poorly understood. The prevalence rate of CP is 1.5–3.8 per 1,000 live births in Europe, Australia, and the United States (123–125).

The core features of CP are abnormal fine and gross motor functioning (119), which manifests as abnormal motor tone, weakness, and loss of motor control and coordination (126). The main type of motor abnormality experienced by people with CP is spasticity (85%–91%), followed by dyskinesia (4%–7%) and ataxia (4%–6%) (119,127); however, a hallmark symptom of CP is muscle weakness and reduced muscle mass (128). Although it is recommended that the dominant type of motor abnormality be described in a clinical context, many people with CP will experience a mixed of impairment types (*i.e.*, spasticity with ataxia and/or dyskinesia). People with spastic CP have increased muscle tone and pathological reflexes (*e.g.*, hyperreflexia). Spasticity is characterized by an increased resistance that is velocity dependent (129). People with dyskinetic CP have involuntary movements and fluctuating muscle tone. Dyskinesia may be further divided as dystonia and choreoathetosis (119). People with ataxic CP experience a loss of muscular coordination and typically present with low tone, trunk and gait ataxia, and tremor. As well as experiencing abnormal muscle tone, those with CP experience reduced muscle strength, poor ability to selectively activate muscles, and reduced joint range of motion (ROM) (130–132), which result in difficulties performing activities (133,134).

CP was historically categorized according to a distribution of motor abnormalities, including diplegia, hemiplegia, quadriplegia, and tetraplegia. However, since 2007, it has been recommended that the terms unilateral and bilateral CP be used to describe the distribution of motor abnormality, as they acknowledge the involvement of the head and trunk. It also has been acknowledged that categorization of individuals with CP according to their functional ability is more useful for describing, comparing, and predicting future needs. The Gross Motor Function Classification System (GMFCS) is a widely used 5-point classification system to describe people with CP according to their functional mobility (135) (*Table 11.3*). Distinctions between GMFCS levels are based on functional abilities, the need for assistive technology, including handheld mobility devices (walkers, crutches, or canes) or wheeled mobility (levels III–V), and to a lesser extent, quality of movement and independent ambulation (levels I/II). A full description of each GMFCS level is in *Table 11.3*.

TABLE 11.3 • Gross Motor Function Classification System

Level I	Walks without restrictions, with limitations in more advanced gross motor skills
Level II	Walks without assistance, with slight community ambulation limitations
Level III	Walks with the assistive mobility devices, with community ambulation difficulties
Level IV	Self-mobility with limitations; wheeled mobility used in most settings but may transfer with physical assistance and walk short distances with physical assistance or in a body support walker
Level V	Severely limited mobility, even with appliances and adaptations; transported in wheelchair in all settings, but powered mobility may be used with extensive adaptations

Exercise Testing

Exercise testing may be done in individuals with CP to uncover challenges or barriers to regular PA, to determine the functional capacity of the individual, and to prescribe the appropriate exercise dose for aerobic and strengthening exercises. However, a symptom-limited graded exercise test

(GXT) is not required for those with CP to begin an exercise training program. Medical clearance should be sought prior to exercise testing (see *Chapter 2*). It is also recommended to review an individual's medical history and list of medications prior to exercise testing, as well as to consider potential existing comorbidities, and assess functional capacity. A high proportion of people with CP experience pain and fatigue, which may impact their performance on exercise testing (136). Assessment of functional capacity, including ambulatory ability, will facilitate the choice of exercise testing equipment, protocols, and adaptations. In the case of athletes, testing mode will also be guided by the desired sport.

A core set of exercise tests for children and adolescents with CP has been identified by an expert group, which includes the 10-m shuttle run tests for GMFCS levels I and II, the 7.5-m shuttle walk/run test for GMFCS level III, the muscle power sprint test, and the 20/30-s Wingate cycle or arm cranking test (137). Further information on these tests is provided in *Table 11.4*.

TABLE 11.4 • Exercise Tests for Children with Cerebral Palsy (CP)

Exercise Test	Physical Fitness Component Assessed	Further Comments
30-s Wingate arm cranking test	Anaerobic fitness and agility	Reliable measure in children with CP in Gross Motor Function Classification System (GMFCS) levels III and IV (138)
20-s Wingate cycle test	Anaerobic fitness and agility	Feasible and reliable measure in children with CP in GMFCS levels I–III (139)
Muscle power sprint test	Anaerobic fitness	Has been adapted to assess anaerobic fitness during self-propelling in a wheelchair in children in GMFCS levels III and IV and found to be valid and reliable (140) Walking/running muscle power sprint test has been found to be valid, reliable, and feasible in children in GMFCS levels I and II (138,141). Normative values for children with CP have been published (142).
10-m	Cardiorespiratory	Two shuttle run tests have been

shuttle run tests (SRT-I and SRT-II)	fitness	developed specifically for children in GMFCS levels I and II, respectively. Feasible, reliable, and valid in comparison to treadmill testing for assessing cardiorespiratory fitness among children with CP (143). Normative values for children with CP have been published for these tests (142).
7.5-m shuttle run/walk test	Cardiorespiratory fitness	Developed for children who require a mobility aid (GMFCS level III) and is a reliable measure of cardiorespiratory fitness (137)
10-m shuttle ride test	Cardiorespiratory fitness	Feasible, valid, and reliable test of cardiorespiratory fitness for children who use a manual wheelchair (144)

Exercise Testing Considerations

Choice of exercise mode and use of adaptive equipment is important when conducting exercise tests with those with CP. When necessary, testing should be conducted using appropriate adaptive equipment such as straps and holding gloves, to guarantee safety and optimal testing conditions for mechanical efficiency. Treadmill testing may be used to assess CRF among high-functioning ambulatory individuals (GMFCS levels I and II). Although graded arm ergometry tests are often used to assess CRF in people with mobility impairments, the cardiorespiratory demand during an arm ergometry test has been shown to be significantly lower compared to a wheelchair shuttle ride test in individuals with CP. Therefore, a 10-m wheelchair shuttle ride test may provide a more accurate indication of CRF (138). Submaximal single-stage exercise tests, such as the 6-MWT, provide information about walking capacity but are not validated methods of measuring CRF in persons with CP (145). Such tests may be appropriate to use in more severely impaired people to monitor distance walked, HR, gait efficiency, or rating of perceived exertion (RPE), where true maximal CRF testing is not appropriate or accurate.

When assessing isokinetic muscle strength, it may not be feasible to use an isokinetic dynamometer in those with CP (146). Handheld dynamometers may be used to assess isometric muscle strength in those with CP in GMFCS levels I–III, but assessors should be cognizant that reliability of this method may be poor, particularly for assessing hip extension, knee extension, and ankle plantar- and dorsiflexor muscle strength (147). Moreover, one repetition maximum (1-RM) testing may be difficult to perform in individuals with CP because of difficulties identifying appropriate methods of adding resistance, difficulties with coordination and balance, and lack of experience of working to maximal exertion. Therefore, it may be more appropriate to use submaximal tests such as multiple RM testing (*e.g.*, 8-RM) to predict maximal strength and/or prescribe progressive resistance training programs. Such tests require trialing multiple exercises and forms of resistance (*e.g.*, free weights, exercise machines, resistance bands) in order to identify exercises that allow people with CP to activate the required muscle group and provide adequate overloading of the muscle group. If using multiple RM tests, attempts should be made to ensure the person cannot perform more than 10 repetitions, as prediction of maximal strength declines with higher RMs. Tests of functional strength, such as the number of sit-to-stands performed in 30-s are reliable for people in GMFCS levels I and II (148) but may not be sensitive to changes in maximal muscle strength.

Special Considerations

- Joint pain is prevalent among people with CP (149) and may be exacerbated by joint loading. A mode of exercise test that minimizes joint pain should be chosen.
- Positioning and level of comfort during exercise testing need to be considered to avoid unintended increases in muscle tone or facilitation of primitive reflexes, which can also cause pain.
- Fatigue in the latter stages of exercise testing may reduce coordination and balance, and care should be given to prevent falls and injuries.
- People with CP often have reduced aerobic and anaerobic exercise responses as compared to those with typical development (150).
- Prediction of maximal HR using standard equations may not be accurate for individuals with CP. It is recommended that an HR of >180 beats $\cdot$ min^{-1} is used as an indication that maximal exertion is achieved during shuttle tests (143).

Exercise Prescription

Individuals with CP have decreased physical fitness levels compared to peers without disability (132,151). Interventions associated with CP, such as orthopedic surgery, can have a detrimental short-term effect on muscle strength and CRF (152,153); further deterioration in physical fitness also often occurs with age. Although CP is a nonprogressive condition, between 20% and 50% of adults with CP report a deterioration in mobility in young- to midadulthood (154), which may result from loss of ROM, reduced balance, reduced muscle strength, reduced aerobic capacity, or pain (155). The combination of low muscle mass, low muscle strength, and loss of physical function observed in people with CP has prompted comparison with sarcopenia in older adults with typical development (128).

People with CP should maintain a high level of physical fitness to offset the decline in function associated with both aging and the effects of CP.

Exercise participation should be promoted for people with CP from a young age in order to prevent chronic disease, optimize function, and promote quality of life. Training to develop muscular strength and aerobic endurance could be specifically valuable for people with CP in hindering the functional deterioration and the associated physical dependence that adults with CP experience (156). However, investigation in the area of Ex R_x focuses almost entirely on children and adolescents and individuals with minimal or moderate involvement (*i.e.*, those who are ambulatory) (157). Also, although exercise appears to be safe for those with CP, effects on functional outcomes are inconclusive (157).

Individuals with CP who are not able to meet the PA guidelines recommendations of 150 min of moderate intensity per week should engage in regular PA, according to their abilities, with support from health care providers. Generally, the FITT principle of Ex R_x recommendations for the general population should be applied to individuals with CP (see *Chapter 5*) (158). It is important to note, however, that the FITT principle of Ex R_x recommendations for individuals with CP is based largely on expert opinion and with limited literature support. Thus, currently the FITT principle of Ex R_x needed to elicit health/fitness benefits in individuals with CP is unclear. One to two sessions of aerobic exercise per week may be sufficient to increase CRF in those with CP who are deconditioned. In individuals with CP, particularly those with significant limitation (GMFCS levels IV and V), minimal efforts may result in elevated energy expenditure. When prescribing PA, it is important to consider that activities considered to be light intensity may actually constitute light or even moderate-to-vigorous intensity activity, respectively, in individuals with moderate-to-severe motor impairment (159). The combination of reduced CRF and increased walking energy cost also result in a higher physical strain of walking, and nearly half of ambulatory people may walk at or above their anaerobic threshold (150).

Even though the design of exercise training programs to enhance health/fitness benefits should be based on the same principles as the general population, modifications to the training protocol may be required based on the individual's functional mobility level, number and type of associated conditions, and degree of involvement of each limb (158). For this reason, recommendations regarding the FITT principle of Ex R_x are included in the following "Special Considerations" section.

Special Considerations

- Individuals with CP have a higher risk of osteoporosis and fractures compared to individuals without CP (160,161). Leg ergometry and hand cycling may be used to minimize risk of falls and fractures, particularly among people with balance deficits.
- Training sessions may be more effective for individuals with high muscle tone, if (a) several short training sessions are conducted rather than one longer session, (b) relaxation and stretching routines are included throughout the session, and (c) new skills are introduced early in the session (162,163).
- Resistance exercises should be performed over the full ROM, involving concentric and eccentric muscle contraction, at slow contraction speeds. Eccentric training may decrease cocontraction and improve net torque development (164).
- Single-joint and unilateral exercises may be more effective than multijoint and bilateral exercises for people who are very weak or with poor selective motor control, as they prevent compensation with other muscle groups.
- Different resistance exercises and methods (*e.g.*, free weights, resistance bands, weights machines) should be tried to activate the appropriate muscle group and appropriate resistance to overload the muscle.
- Before initiating open kinetic chain strengthening exercises using free weights, always check the impact of primitive reflexes on performance (*i.e.*, position of head, trunk, and proximal joints of the extremities) and whether the individual has adequate neuromotor control to exercise with free weights.

- Good positioning of the head, trunk, and proximal joints of extremities to control persistent primitive reflexes is preferred to strapping. Inexpensive modifications that enable good position such as Velcro gloves to attach the hands to the equipment should be used whenever needed.
- Individuals with CP may be more susceptible to overuse injuries because of their higher incidence of inactivity and associated conditions (*i.e.*, abnormal muscle tone, contractures, and joint pain).
- Strong support for sport participation is suggested because elite athletes with CP do not show associated lower neuromuscular fatigue (165).

Future Directions

The evidence base supporting exercise for CP is limited by small studies that are at high risk of bias (157). Many studies also fail to describe the exercise intervention in sufficient detail that allows for replication in practice. As well as improving reporting of exercise interventions, studies need to include additional information on fidelity to the content and delivery of interventions. Individuals with CP may not be able to perform all exercises as prescribed, and understanding fidelity to the intervention is important for identifying if exercise interventions are ineffective for people with CP or simply not feasible to perform as prescribed. The evidence for exercise in CP is largely limited to children with mild-to-moderate CP (GMFCS levels I–III). There is very little research focusing on the effect of exercise for adults with CP or people with moderate-to-severe CP. These subgroups need to be included in future studies as the effects of exercise for CP may be dependent on age and motor function. Finally, the effect of exercise for individuals with CP has also only been examined on a relatively small number of outcomes. There are a lack of studies examining the effect of aerobic exercise on aerobic capacity. Very few studies have explored the effect of exercise on participation or quality of life. Future studies are needed to investigate the long-term effects of exercise on function and health for people with CP, including pain, fatigue, falls, cardiovascular disease, osteoarthritis, and depression. Exercise may be particularly beneficial to maintain function and prevent development of chronic disease among adolescents and young adults with CP. Future studies with long-term follow-up are needed to examine this.

ONLINE RESOURCES

American Academy for Cerebral Palsy and Developmental Medicine Fact Sheets: https://www.aacpdm.org/UserFiles/file/fact-sheet-fitness-083115.pdf

"Learn more about Cerebral Palsy (CP)" from the Centers for Disease Control and Prevention Web site: https://www.cdc.gov/ncbddd/cp/index.html

National Institute of Neurological Disorders and Stroke. Cerebral palsy: http://www.ninds.nih.gov/disorders/cerebral_palsy/cerebral_palsy.htm

Peter Harrison Centre for Disability Sport. Educational toolkit: http://www.lboro.ac.uk/research/phc/educational-toolkit

Physical Activity Guidelines for Americans. Chapter 10: https://health.gov/sites/default/files/2019-09/16_F-10_Individuals_with_Chronic_Conditions.pdf

INTELLECTUAL DISABILITY AND DOWN SYNDROME

ID or intellectual developmental disorder(s) are diagnosed before the age of 18 yr as either mild, moderate, severe, or profound limitations in the areas of adaptive functioning (difficulty acquiring daily life skill) and/or intellectual functioning (knowledge acquisition, problem solving, logic reasoning) (69,166). ID has an estimated global prevalence of 1% (167), and, although etiology is not known for all cases, there have been established risk factors related to parental health (*i.e.*, maternal diabetes, drug exposure, alcohol exposure, infection) (168), genetic factors (*i.e.*, Down syndrome [DS], fragile X syndrome, phenylketonuria) (168), and nonphysiological factors related to health care access, socioeconomic status, and education status (169–171). ID includes a wide range of intellectual and adaptive functioning, with individuals divided into mild (IQ 55–70), moderate (IQ 40–55), severe (IQ 25–40), or profound (IQ <25) (69). Whereas most individuals with ID fall in the mild classification, individuals with DS have an IQ range from mild to severe (IQ 30–70) (172).

Life expectancy rates for individuals with ID can be up to 20 yr less than that of the general population, with main causes of death being related to respiratory illness and circulatory diseases (173). For individuals with DS, causes of death are slightly different, with congenital heart anomalies and respiratory illness being the leading causes (173). Mortality rates for individuals with ID have been shown to be inversely related to severity of ID (174). However, the life expectancy rates for individuals with ID have been increasing, as is also true for individuals with DS (175). Individuals with ID or DS are at a heightened risk for conditions that can severely impact long-term health, such as obesity (176–178), metabolic syndrome (179,180), epilepsy (181,182), and visual impairment (181). These comorbidities, taken with the main causes of death in this population, highlight the need to increase PA levels for all individuals with ID. ID, as well as its related comorbidities, provides unique challenges for implementing exercise programs. This is true for individuals living independently with the aid family caregivers as well as people living in group-home settings.

Exercise Testing

In general, exercise testing is feasible for individuals with ID or DS (183). It is recommended that individuals with ID or DS receive a physical evaluation prior to engaging in any kind of exercise testing or subsequent training (184). For individuals without DS, physician clearance and normal levels of exercise supervision will be sufficient. In addition to this, individuals with DS should be assessed for factors related to joint instability and cardiovascular impairments prior to any exercise participation. If an individual with DS has a history of these comorbid conditions, additional supervision during exercise testing should be considered.

Familiarity of an individual with testing protocol should be considered prior to testing, as test-retest reliability studies of walking and running protocols show that there is an improvement in performance on second trial among individuals with ID (185–187). Choosing the right testing protocol for a participant is critical and can differ among participants based on previous experience, participant preference, or medical appropriateness, including consideration of other comorbidities. Therefore, familiarization sessions are recommended as these could aid exercise professionals to obtain reliable data and decrease the likelihood of injury during testing. A minimum of two familiarization sessions for laboratory protocols and one familiarization session for field tests are recommended for participants with ID (188). However, each testing protocol should have its own familiarization session (188). Selecting a strength testing protocol for individuals with DS should be carefully considered to avoid exercise-induced injury (*e.g.*, assuring the exercise equipment fits the participant's body appropriately) considering the potential of limb length differences among individuals with DS (189) (*Table 11.5*).

TABLE 11.5 • Recommended Exercise Testing Protocols for Intellectual Disability (144,190–194)

Type of Exercise	Recommended Test Protocol(s)
Cardiorespiratory	• 6-min walk test (6-MWT) • Shuttle run test • Rockport One-Mile Fitness Walking Test • Discontinuous maximal treadmill protocol
Muscular strength/endurance	• 6-RM or 12-RM using machines • 1-RM (if appropriate) • Functional Strength Measurement in children with intellectual disability (FSM-ID) • Isometric maximal voluntary contraction (MVC) • Isokinetic testing
Flexibility	• Goniometry at specific joints
Balance and motor skill	• Bruininks-Oseretsky Test of Motor Proficiency-Second Edition (BOT-2) • Modified Berg Balance Scale (mBBS) • Test of Gross Motor Development for youth (all variations) • Static balance protocols
Anthropometrics and body composition	• Body mass index (BMI) • Waist circumference (WC) • Skinfold measurements (use of Slaughter equation) • Air displacement plethysmography • Dual-energy x-ray absorptiometry

1-RM, one repetition maximum; 6-RM, six repetition maximum; 12-RM, twelve repetition maximum.

It is important to evaluate perceived effort during maximal or submaximal exercise testing and encourage the participant to provide maximal effort when appropriate. Some work in the area of perceived exertion has indicated that individuals with ID/DS are able to accurately assess perceived exertion when compared to HR on both the Borg scale and a modified version of the Children's OMNI 1–10 walk/run scale (195); however, more evidence is needed to validate these scales in this population (196). Determining test endpoints based on HR may be difficult, as maximum HR calculations for individuals with ID are different than the general population. Maximal HR calculation for DS and ID could be estimated using the formula [$HR_{max} = 210 - 0.56(\text{age}) - 15.5(\text{DS})$], where DS = 2 and all other IDs = 1 (197).

Selection of an aerobic testing protocol can be dependent on individual abilities and preferences as well as available resources. Laboratory testing for aerobic fitness has been shown to be valid and reliable for children and adolescents with ID, including the use of maximal aerobic treadmill testing (198). Discontinuous maximal treadmill protocols might also be useful for this population (199), as they could provide relief from fatigue and adjustment of facial equipment, which could be helpful with testing compliance (199). Field tests for this population can be useful for those without laboratory testing equipment or for participants who are unsteady or unfamiliar with treadmill testing; however, there are several issues to keep in mind with the use of field tests to evaluate CRF with these individuals. For example, the Rockport One-Mile Fitness Walking Test could be better suited for children or adolescents with mild-to-moderate ID (200). Additionally, population-specific formulas have been developed predicting $\dot{V}O_{2max}$ using the Rockport One-Mile Fitness Walking Test for individuals with ID, but there is disagreement as to the accuracy of this estimation (201), and thus, these estimates should be used with caution. The 20-m shuttle run test has also been found as a reliable tool to estimate CRF in adolescents (202) and children (203) with mild-to-moderate ID. The 16- and 10-m adaptations of this test have also been shown to be reliable in children with ID (203) and adults with severe ID (187). However, limitations exist to the level of their level of accuracy (204). The 6-MWT has shown concerns with reliability, reproducibility, and validity in individuals with ID and DS (186,190,205,206).

For strength testing, the use of a 6-RM or 12-RM could be considered for individuals with little strength training experience. While a 1-RM is typically used, the 6-RM or 12-RM may provide inexperienced individual with less risk of injury, as well as less soreness (207,208), although this protocol has not been validated in individuals with ID or DS. Weight machines are recommended for all strength protocols to minimize risk of injury that may arise with joint laxity in individuals with DS. There is evidence that individuals with ID have reduced muscle activation (209), which may result in resistance and load that appears to be less than expected as compared to similarly fit nondisabled individuals. Therefore, exercise professionals should keep this in mind when selecting resistances and weights for strength testing protocols. The Functional Strength Measurement in children with ID (FSM-ID) is another option for strength testing. It is an eight-item functional strength assessment that scores individuals based off the ability to complete functional tasks, such as a sit to stand and stair climbing. While shown to be a reliable and valid tool, familiarization sessions or practice sessions of each task within the FSM-ID might be required in this population group (191).

Individuals with ID have been shown to have difficulty integrating sensory information along with motor issues (210) that can lead to an increase in fall and injury risk (211). Therefore, addition of balance and flexibility testing to an exercise testing battery could be particularly useful in this population group. Flexibility testing could be particularly useful due to its importance in preventing injury and maintaining range of motion to allow for ADL in healthy adults, although this has not been specifically shown in ID/DS (212). However, because falls are common among individuals with ID, extra care should be taken to ensure that participants are comfortable and are able to perform any balance test without increasing fall risk (213). Level of ID could impact overall performance in exercise testing, and particularly in tests that require higher cognitive or perceptual function, such as balance assessments (183). Older age can also impact performance in testing because of decreased muscular fitness associated with age in the untrained (183). During testing, careful observation by the test administrator is imperative, especially watching for unsteadiness.

Assessment of body composition and anthropometrics in ID is important because of issues related to obesity in this population group. Air displacement ple–thysmography and dual-energy x-ray absorptiometry (DXA) methods have been performed with reliable results (214,215). It is recommended that these methods be used when available, although some considerations should be made with regard to accuracy. In some populations with disability, DXA has been shown to overestimate muscle mass when fat-free muscle mass is used to estimate muscle mass (216,217); however, this has not been shown specifically for individuals with ID or DS. BMI and waist circumference have been shown to be reliable measures in the ID and DS populations. Skinfold measurements could present accuracy issues because of participant noncompliance and tester error (218); however, the skinfold measurement prediction equation for individuals with DS provided by Slaughter et al. (219) has been shown to agree with air displacement plethysmography results (*Table 11.6*).

TABLE 11.6 • Skinfold Equations in Youth and Adolescents (219)

Males:	PFDWB = .735 (triceps + calf) + 1.0
Females:	PFDWB = .610 (triceps + calf) + 5.1
Prepubescent White males:	PFDWB = 1.21 (triceps + subscapular) − .008 (triceps + subscapular)^2 − 1.7
Prepubescent Black males:	PFDWB = 1.21 (triceps + subscapular) − .008 (triceps + subscapular)^2 − 3.2
Pubescent White males:	PFDWB = 1.21 (triceps + subscapular − .008 (triceps + subscapular)^2 − 3.4
Pubescent Black males:	PFDWB = 1.21 (triceps + subscapular) − .008 (triceps + subscapular)^2 − 5.2
Postpubescent White males:	PFDWB = 1.21 (triceps + subscapular) − .008 (triceps + subscapular)^2 − 5.5
Postpubescent Black males:	PFDWB = 1.21 (triceps + subscapular) − .008 (triceps + subscapular)^2 − 6.8
All females:	PFDWB = 1.33 (triceps + subscapular) − .013 (triceps + subscapular)^2 − 2.5
For a sum of triceps and subscapular greater than 35 mm,	All males PFDWB = .783 (triceps + subscapular) + 1.6

the following equation should be applied:	All females PFDWB = .546 (triceps + subscapular)

PFDWB, percent fat body density, water, and bone mineral.

Exercise Prescription

In general, the Ex R_x for an individual with ID is uncomplicated, and recommending daily PA as encouragement toward healthy behavior and behavior change could be beneficial to efforts for weight loss and reduction of comorbidities for individuals with IDs (220). Comorbidities, such as hypertension, diabetes, or joint pain, can affect exercise behavior and practitioners should be cognizant of these factors. Energy expenditure can vary between individuals with ID with more severe versus less severe physical disability, as well as between genders (221). Slower paced walking ($3.0\ km \cdot h^{-1}$) has been shown to mimic energy expenditure of moderate paced walking in individuals with IDs, potentially because of differences in biomechanical efficiency (221).

FITT	FITT EXERCISE PRESCRIPTION FOR INTELLECTUAL DISABILITY (184)		
	Aerobic	**Resistance**	**Flexibility**
Frequency	$\geq$3 $d \cdot wk^{-1}$ of moderate-to-vigorous exercise	2–3 $d \cdot wk^{-1}$	Preferred daily but at least 2–3 $d \cdot wk^{-1}$
Intensity	40%–80% $\dot{V}O_{2max}$ progressive pattern	Begin with 10–12 reps of 60%–70% of one repetition maximum (1-RM); progress to 10–12 reps of 70%–80% 1-RM	To the point of slight discomfort
Time	30–60 $min \cdot d^{-1}$; intermittent bouts of 10–15 min alternative	2–3 sets	Static stretches 10–30 s; repeat two to four times per exercise
Type	Walking-based activities, swimming, ergometry (arm and leg)	Machine/cable-controlled protocols preferred	Static stretching

Studies evaluating the CRF of individuals with ID have shown significant deficits in CRF as compared to individuals without ID, especially individuals with DS having greater deficits (190). One explored mechanism for this reduction in CRF in this population is autonomic dysfunction. In DS, autonomic dysfunction is demonstrated in both sympathetic (low catecholamine response to maximal exercise) (222) and parasympathetic (low basal vagal function when compared to controls) (223) dysfunction. Together, this autonomic dysfunction results in difficulty of HR modulation for participants with DS. This is exemplified in a reduced HR response to exercise (chronotropic incompetence) (224,225), typically 25–30 beats $\cdot$ min^{-1} below age-matched maximum HR in those without disabilities (224). Evidence of chronotropic incompetence has also been found in individuals with ID with submaximal exercise (226). However, evidence of chronotropic incompetence in ID is not conclusive, as there is also evidence of adequate cardiac response to exercise (227).

Integrative and innovative Ex R_x can be created for this population group. Combined exercise regimens that use aerobic, balance, and strength training have been shown to be effective for improving cardiovascular fitness, strength, and body weight for adults with ID (228). Integration of new technologies could also be an area to expand within Ex R_x for this population. Common virtual reality devices combined with exercise programming focused on game-like activity have also been shown to enhance physical fitness in individuals with ID as evaluated by functional assessments (229).

Both aerobic interval training (230) and continuous aerobic training at higher intensities (231) have been shown to decrease body weight and BMI in adults with DS, with a slightly greater effect in interval training (230). In addition, there is evidence that HIIT can be used to increase aerobic capacity in individuals with DS (230). Given these findings, and evidence that people with DS have attention deficits, interval training could be used in DS Ex R_x, although the need exists for more research in this area. The interval training protocol that elicited these benefits consisted of a 1:3 work:rest ratio with intensity of the work being “all out” through the exercise session (230). However, as with healthy adults, participants with DS should become familiar with proper movement (*i.e.*, form) before engaging in interval training. Exercise professionals working with individuals with DS who are engaging in interval training should also familiarize themselves with ways in which their participant communicates pain or other exercise-related sensations.

Special Considerations for Individuals with Intellectual Disability

- Individuals with ID can be on a variety of medications; some that could present difficulties with weight gain or loss, such as antihypertensives, anticonvulsants, antidepressants, or diabetes medications (232).
- Directions should be concise, and demonstrations should be as accurate as possible.
- Balance and gait capabilities can be affected in individuals with ID, as compared to age-matched controls (213); therefore, fall risk must be considered when prescribing and performing exercise.
- Correlates of symptoms of ADHD were found in children with ID, including attention deficit (233). Reducing distractions will allow for greater concentration during exercise. Care should be taken to create an exercise environment with minimal distraction, particularly during more skilled movements such as resistance or balance training.
- Individuals with ID and DS have deficits in short-term memory (234), so simple language and repetition of direction is recommended. Demonstrations of movements could be needed.
- Providing a variety of exercise modalities for people with ID could be helpful to promote enjoyment, although this is not well-studied. Also, sport programs such as Special Olympics could offer enjoyable exercise, although participation in Special Olympics does not guarantee changes in fitness (235).
- Exercising as a group, or with familiar people, could be beneficial to facilitate enjoyment and promotion of exercise (236).

- Encouragement to exercise is crucial for this population group. Individuals with ID need higher levels of encouragement to exercise, potentially because of characteristics of personality that dispose them to less than average enjoyment from problem solving and lower levels of expected success when presented with a new task (237). This encouragement could come in many forms, such as verbal affirmation, goal setting, or relationship building.
- Accessibility is a large barrier to PA in adults with ID, including access to indoor or outdoor recreation facilities (238). Exercise professionals should be aware of environmental factors, such as built environment inside and around the individual's living area that could impact an individual's PA choice and behavior (239). Engaging with this population and having conversations about what is or is not available to the individual in the built environment could aid in creating better long-term exercise outcomes and behavior.
- To encourage individuals with ID to exercise outside of the regularly scheduled training, Ex R_x could include exercises to be performed independently. These exercises could be quite effective if they are familiar, and participants have the necessary resources and experience to accomplish them, such as video demonstration and minimalist equipment (240).
- Family members and caregivers can be facilitators to exercise in people with ID or DS outside of regularly scheduled training and provide valuable insight into exercise behavior of their loved one. However, family members and caregivers can also provide barriers to exercise in people with ID or DS, such as lack of provision of home-based activity (241). Understanding the home structure of individuals with ID and DS could aid exercise professionals in creation of a more holistic Ex R_x.
- Providing a comfortable setting for exercise is very important, including factors such as controlling the number of people in a given space, the playing of preferred music, exercise equipment to select from, etc. These environmental factors could play a role in creating initial participation

and maintaining participation over time (242). Asking participants what they are comfortable with can also aid in creating a proper environment.

- Individuals with ID or DS could have personality dispositions that lead to uneasiness around unfamiliar people (237). For this reason, participants should be familiar and comfortable with the personnel that they will be testing with, including effective channels of communication during exercise testing and training.

Special Considerations for Individuals with Down Syndrome

- Individuals with DS often have other comorbidities, such as heart disease, obesity, leukemia, Alzheimer's disease, dementia, and other infections, such as fungal skin infection, severe bacterial infection, and ear infection (243–245). These conditions can impact one's ability to exercise and motivation to do so.
- Facial features that impact ability to breathe, such as smaller nose, flat nasal bridge, and smaller mouth, should be taken into consideration when exercising at higher intensities. Making sure that the participant is able to keep an open airway due to structural facial differences will aid in exercise performance and safety. This may include taking breaks and keeping communication open with the participant during the exercise session.
- Joint laxity and skeletal muscle hypotonia could also affect the exercise choice for individuals with DS. Individuals with DS can experience atlanto-occipital instability (movement between the C1 vertebrae and the occiput), atlantoaxial instability (excessive movement between the C1 and C2 vertebrae), and cervical instability (general laxity between cervical vertebrae) (246). Because of these conditions, exercises that place pressure on the neck (such as abdominal crunches) are cautioned.
- Knee joints and hip joints can come under increased pressure due to overweight or obese status as well as several gait and biological factors

(247,248). Special consideration should be used when asking individuals with DS to engage in exercise that could stress these joints. Providing alternative exercises, particularly for weight-bearing exercises, could be helpful in reducing joint stress. In healthy athletic populations, multicomponent training, which includes resistance, agility, plyometric, flexibility, and balance training, has been shown to reduce lower limb joint injury (249), although this is not DS-specific. Further research on this is needed in DS.

- Lower work capacity is consistently seen in individuals with DS when compared to healthy control individuals. Careful consideration of HR should be taken during exercise as well as careful monitoring of participant's perceived exertion.
- There is also evidence that individuals with DS have lower mitochondrial function than individuals without DS, as measured by the rate of phosphocreatine resynthesis, which may contribute to the lower rates of PA in the DS population (250).

Whereas care needs to be taken when prescribing and executing exercise programming with this population group, the rewards of exercise programming for people with ID and DS can be great. Acute exercise has been shown to significantly increase mood and self-confidence in this population (251), whereas prolonged exercise programming has been shown to increase self-efficacy (252) and improve life satisfaction (253) in individuals with ID and DS. The effects of exercise in this population could even extend further into caregiver and family networks (254). Overall, exercise can provide a positive and potentially health-enhancing experience for people with ID or DS.

Future Directions

Additional research is needed to better understand how people with ID and DS respond to exercise and to determine the intensities and modes of exercise that are optimal for both prevention and reduction of chronic disease associated with ID and DS. This information could be used to improve exercise guidelines for people with ID and DS as well as inform the choices of exercise professionals to create optimal Ex R_x. In practice, increased efforts need to be made to get people with ID and DS into effective, evidence-based exercise programs that are designed to produce meaningful changes in activity-induced health benefits.

ONLINE RESOURCES

American Association on Intellectual and Development Disabilities: http://www.aamr.org
Center for Parent Information & Resources.
Intellectual disability: http://www.parentcenterhub.org/intellectual
National Association for Down Syndrome: http://www.nads.org
TASH: http://www.tash.org
The Arc of the United States: http://www.thearc.org

PARKINSON'S DISEASE

Parkinson's disease (PD) is the second most common neurodegenerative disease after Alzheimer's disease, and it is estimated that nearly 700,000 individuals in the United States age 45 yr and older are living with PD, with this number projected to double by 2030 (255). It is uncommon for PD to be diagnosed before 50 yr of age, but the incidence increases 5- to 10-fold from ages 60 to 90 yr (256). The global estimate of PD prevalence is currently 6.1 million individuals (257). PD is a chronic, progressive neurological disorder characterized by signs of bradykinesia, resting tremor, rigidity, postural instability, and gait abnormalities (*Box 11.1*). PD is a form of parkinsonism, a clinical syndrome including other neurodegenerative parkinsonian disorders, such as multiple systems atrophy, progressive supranuclear palsy, and corticobasal degeneration. They are collectively referred to as atypical parkinsonian disorders and have similar core features yet varying clinical signs that lead to differential diagnoses (259). The motor features of PD are the result of degeneration of the dopaminergic nigrostriatal pathway of the midbrain, which results in a reduction in the neurotransmitter dopamine in the striatum. The cause of PD is unknown; however, aging, genetic susceptibility, and environmental factors likely all play a role. Inflammation and mitochondrial dysfunction may also contribute to the disease process (260–263).

Box 11.1	Common Movement Disorders in Individuals with Parkinson's Disease (258)
Bradykinesia	Reduced movement speed and amplitude; at the extreme, it is known as *hypokinesia*, which refers to "poverty" of movement.
Akinesia	Difficulty initiating movements
Episodes of freezing	Motor blocks/sudden inability to move during the execution of a movement sequence
Impaired balance and postural instability	Difficulty maintaining upright stance with narrow base of support in response to a perturbation to the center of mass or with eyes closed; difficulty maintaining stability in sitting or when transferring from one position to another; can manifest as frequent falling
Dyskinesia	Overreactivity of muscles; can manifest as dystonia; wriggling/writhing movements; chorea or rarely athetosis
Tremor	Usually resting tremor; more rarely postural or action tremor
Rigidity	Hypertonicity and hyperreflexia in agonist and antagonist muscle groups in a given limb
Adaptive responses	Reduced activity, muscle weakness, reduced muscle length, contractures, deformity, reduced aerobic capacity

The progression of the stages of the disease is described by the Hoehn and Yahr (HY) scale (264) (*Box 11.2*). The key point to notice in the HY scale is that people in stages 1–2 do not have postural instability.

Box 11.2 The Hoehn and Yahr Staging Scale of Parkinson's Disease (265)

Stage 1 = Unilateral involvement only, usually with minimal or no functional impairment.

Stage 2 = Bilateral or midline involvement, without impairment of balance.

Stage 3 = First sign of impaired righting reflexes. This is evident by unsteadiness as the individual turns or is demonstrated when pushed from standing equilibrium with the feet together and eyes closed. Functionally, this person is somewhat restricted in activities but may have some work potential depending on the type of employment. Individuals are physically capable of leading independent lives, and their disability is mild to moderate.

Stage 4 = Fully developed, severely disabling disease; the person is still able to walk and stand unassisted but is markedly incapacitated.

Stage 5 = Confinement to bed or wheelchair unless aided.

The standard clinical scale for assessing PD is the Movement Disorder Society Unified Parkinson's Disease Rating Scale (MDS-UPDRS). The MDS-UPDRS is a valid and reliable comprehensive clinical rating scale used to monitor the burden and extent of PD (266,267). The MDS-UPDRS consists of 65 items and covers four different domains: Part I assesses the nonmotor experiences of daily living such as cognition, depression, sleep, fatigue, and hallucinations; part II assesses the individual's perception of their ability to engage in ADL such as eating, dressing, hobbies, and walking; part III covers the motor evaluation, which includes ratings for rigidity (stiffness), bradykinesia (slowness), gait, postural stability, and tremor; and part IV assesses the motor complications including ratings for dyskinesias (involuntary movements), dystonia (painful cramps), and motor fluctuations (irregular responses to PD medication) (235,265). Each item is rated on a 0–4 scale (0 = normal; 1 = slight; 2 = mild; 3 = moderate; 4 = severe), with higher scores indicating a greater impact of PD symptoms (266). Individuals with PD may have difficulty performing ADL and suffer from reduced quality of life (268). The primary feature of PD is bradykinesia, which refers to slowness in movement and reduced movement amplitude. It is characterized by a fatiguing and decrement of fast movements such as finger tapping. Clinically, it causes a reduction in dexterity manifest by micrographia, reduced arm swing, and difficulty with fine motor tasks. Resting tremor is present in some individuals with PD (269) and is typically a larger amplitude, rhythmic shaking of the distal limbs, most commonly occurring in the hand or arm. Usually, it is asymmetric and can be suppressed by voluntary activity, sleep, and complete relaxation of axial muscles. Stress and anxiety increase resting tremor (270). Rigidity is an increase in tone, often with a ratchet-like quality called cogwheeling, which can lead to an increase in the individual’s perception of movement effort and may be related to feelings of fatigue (271). These three signs of the disease (microphagia, reduced arm swing, difficulty with fine motor tasks) can occur in HY stages 1–2.

Postural instability refers to “the impairment in balance that compromises the ability to maintain or change posture such as standing and walking” (272). This is a feature of more advanced stages of the disease (HY stages 3–5) and can lead to falls. Individuals with more advanced PD may have a stooped posture (rounded shoulders, forward head, increased flexion of the trunk and knees) and a reduced stride length when walking such that the gait appears to be shuffling, with decreased arm swing, and may have poorer walking economy when compared to persons without PD (273,274). Difficulty and slowness in performing turns, getting up, transfers, and ADL are common as PD advances (275). Other problems include excessive salivation or drooling; soft, slurred speech; and a variety of nonmotor features, including cognitive impairment, mood disorders, and sleep disorders that impact quality of life. Individuals with PD also suffer from autonomic nervous system dysfunction including cardiovascular dysfunction, especially in advanced stages (276,277). Autonomic dysfunction in PD may result in orthostatic hypotension, cardiac arrhythmias, sweating disturbances, and urinary problems (276,277).

It is important to note that people may have had PD for several years before they are given the diagnosis of the disease. This is referred to as the prodromal stage of the disease and is characterized by rapid eye movement sleep disorder, constipation, depression, loss of smell (hyposmia), anxiety, and excessive daytime sleepiness (256). Exercise can help all of these symptoms, which can precede the disease by many years.

Treatment of PD is complex due to the progressive nature of the disease, the vast range of motor and nonmotor symptoms, and the different side effects associated with therapeutic interventions (278). One key point about the disease is that it is relentlessly progressive. Different signs and symptoms progress at different rates, and progression is often fastest early on in the disease. The progression of the motor signs can be as much as 3–6 points per year or more when measured by the Unified Parkinson's Disease Rating Scale (279). Treatments include drug therapy, surgery, physical rehabilitation, and exercise programming. With respect to drug therapy, levodopa is a dopamine precursor that is converted to dopamine in the brain. Carbidopa is added to levodopa in order to prevent the breakdown of levodopa in the blood, allowing the maximum amount of medication to get to the brain while limiting potential adverse effects caused by dopamine in the body, such as nausea and vomiting (280). Levodopa + carbidopa is the most commonly prescribed class of drug for the management of PD and is the single most effective drug available to treat all cardinal features of PD, with the possible exception of rest tremor (278,280). As PD progresses, the effect of levodopa may wane. Long-term use is associated with motor complications including motor fluctuations and dyskinesias in about 50% of individuals within 5 yr (281). Other side effects include nausea, sedation, orthostatic hypotension, and psychiatric symptoms such as hallucinations, confusion, and paranoia (282). Other medications that are used to treat PD symptoms are illustrated in *Table 11.7*. These drugs may be used as a monotherapy or adjunct therapy to provide symptomatic relief in PD and may have side effects that are important to consider when prescribing exercise to those with PD. Exercise professionals working with individuals with PD are advised to become familiar with these medications (see *Table 11.7*).

TABLE 11.7 • Common Medications for Treatment of Motor Symptoms of Parkinson's Disease

Medication Class	Medication Name	Adverse Effects	Indication
Levodopa-PDDI	Levodopa-carbidopa Levodopa-benserazide	Nausea, orthostatic hypotension, dyskinesia, hallucinations	All motor symptoms
Dopamine agonists	Pramipexole Ropinirole Rotigotine	Nausea, orthostatic hypotension, hallucinations, ICDs, edema, increased sleepiness	All motor symptoms
MAOBIs	Selegiline	Stimulant effect, dizziness, headache, confusion, exacerbation of levodopa adverse effects	Early, mild symptoms, and motor fluctuations
	Rasagiline	Headache, arthralgia, dyspepsia, depression, flulike syndrome,	

		exacerbation of levodopa adverse effects, constipation	
COMTIs	Entacapone	Dark-colored urine, exacerbation of levodopa adverse effects	Motor fluctuations
	Tolcapone	Dark-colored urine, exacerbation of levodopa adverse effects, hepatotoxicity	
Unspecified	Amantadine	Hallucinations, confusion, blurred vision, ankle edema, livedo reticularis, nausea, dry mouth, constipation	Gait dysfunction, dyskinesia
Anticholinergic	Trihexyphenidyl Benztropine	Hallucinations, cognitive impairment, nausea, dry mouth, blurred vision, urinary retention, constipation	Tremor

COMTIs, catechol-O-methyltransferase inhibitors; ICDs, impulse control disorders; MAOBIs, monoamine oxidase type B inhibitors; PDDI, peripheral dopa decarboxylase inhibitor.
Table adapted from (194).

Individuals with advanced PD whose motor complications are inadequately managed with medication may choose to undergo deep brain stimulation (DBS). DBS stimulates the brain at high frequencies and thus replaces abnormal high and variable neuronal firing with a consistent pattern (283). DBS is more effective than drug therapy in advanced PD in reducing dyskinesias, improving motor function, and increasing quality of life (284).

Alongside drug therapy and surgery in the treatment and management of PD is exercise, which is a vital component of managing the signs and symptoms of the disease. Regular exercise will decrease or delay secondary sequelae affecting musculoskeletal and cardiorespiratory systems that occur as a result of reduced PA. Because PD is a chronic progressive disease, sustained exercise is necessary to maintain benefits. Evidence suggests that exercise can reduce disease severity (285) and slow down the progression of the signs of the disease (286). Exercise also improves strength (285,287–289), aerobic capacity (286,290,291), gait performance (291–293), and quality of life (292) in individuals with PD.

Exercise Testing

Exercise testing can be used to determine current fitness levels, physiological response to a given exercise bout, and any functional limitations prior to prescribing exercise so that the program can be specified to the individual's particular needs. Most individuals with PD have impaired mobility and problems with gait, balance, and functional ability, which vary from individual to individual. Many individuals with PD experience fluctuations of their motor symptoms from day to day, even from moment to moment. These fluctuations are sometimes attributed to the timing and dosage of their medication and can vary within the same individual and among different individuals. This is important to take into account during exercise testing and programming, as the variability of motor fluctuations may influence testing outcomes (294) and also daily exercise performance. As an attempt to control for the variability in testing outcomes due to symptom fluctuations, and to help document accurate changes in performance, it may be helpful to utilize a graded symptom checklist on days of pre- and posttesting (294). The impairments of PD are often accompanied by low levels of physical fitness (*e.g.*, CRF, muscular strength and endurance, core stability, and flexibility).

There are several special considerations that should be taken into account prior to performing exercise testing for individuals with PD. Because many individuals with PD are older and have reduced PA levels, assessment of cardiovascular risk (see *Chapter 2*) may be warranted prior to beginning an exercise test. Autonomic nervous system dysfunction can occur with these individuals (295), thereby increasing the risk of developing BP abnormalities (296), which can be further affected by medications (297). Additionally, individuals with PD may experience orthostatic hypotension. The occurrence of orthostatic hypertension is directly related to the duration and severity of the disease and can also be induced by any of the dopaminergic drugs that are used to manage PD symptoms (298). Tests of balance, gait, general mobility, ROM, flexibility, muscular strength, core stability, and aerobic capacity are recommended before exercise testing is performed. Results of these tests can guide how to safely exercise test the individual with PD. Static and dynamic balance evaluation and physical limitations of the individual should be used in making decisions regarding testing modes for test validity and safety.

For individuals with PD, clinical balance tests include the functional reach test (299), Berg Balance Scale (300), Mini-BESTest (301), tandem stance (302), single limb stance (303), and pull tests (302–304). Functional mobility can be assessed with the Timed Up and Go test (305,306) and chair sit-to-stand test (307). Gait observation can be done during the 10-m walk test at a comfortable walking speed (308,309). Meanwhile, strength can be evaluated by manual muscle testing, arm curl tests, RM assessment using weight machines, dynamometers, and chair rise tests just as it is in older adults (310). Flexibility can be assessed with goniometry, the sit-and-reach test, and the back-scratch test (311). Aerobic capacity can be assessed submaximally with the 6-MWT (312).

Decisions regarding submaximal and maximal exercise testing protocols may be influenced by the stage of PD (see *Box 11.2*) or physical limitations of the individual. Use of a cycle ergometer alone or combined with arm ergometry may be more suitable for individuals with severe gait and balance impairment or with a history of falls (263). However, use of leg/arm ergometers may preclude individuals with PD from achieving a maximum cardiorespiratory response because of early muscular fatigue before the maximal cardiorespiratory levels are attained (313). Treadmill protocols can be used safely in individuals with early-stage PD, or HY stage 1–2 (286,314). Submaximal tests may be most appropriate in advanced cases (HY stage ≥3) or with severe mobility impairment. For individuals with very advanced PD (HY stage ≥4) and those unable to perform a GXT for various reasons, such as inability to stand without falling, severe stooped posture, and deconditioning, may require a radionuclide stress test or stress echocardiography. Moreover, for an individual who is deconditioned, demonstrates lower extremity weakness, or has a history of falling, care and precautions should be taken, especially at the final stages of the treadmill protocol when fatigue occurs and the individual's walking may deteriorate. A gait belt should be worn, and a technician should stand by close to the subject to guard during the treadmill test. For people with advanced symptoms, symptom-limited exercise testing should be considered as an alternative to heart-rate limited exercise testing, although this recommendation may be modified in certain situations (315). Symptoms include but are not limited to fatigue, shortness of breath, abnormal BP responses, and signs of discomfort. The Borg RPE scale is a valid tool that can and should be utilized as an aid during exercise testing to monitor physical exertion levels and assess fatigue (314,316). Antiparkinsonian medication intake should be noted prior to performing the exercise test due to the individual's susceptibility to experiencing orthostatic hypotension as a side effect of dopaminergic medication. If possible, GXT should be conducted when antiparkinsonian medication is at its peak effect. In addition, it is important to practice walking on a treadmill prior to testing and to use the modified Bruce protocol (see *Figure 4.1*). Although the Bruce protocol is the most commonly used protocol for exercise testing on a treadmill (317), this protocol may be too strenuous for some individuals with PD (295).

For individuals with DBS, the signal from the DBS pulse generator interferes with the ECG recording. Therefore, clinicians should consult with a neurologist prior to performing the exercise test in these individuals, and deactivation of the DBS should be done by a trained clinician or neurologist. HR monitoring can be used when DBS is not activated. RPE should be used to monitor physical exertion levels during exercise testing.

In addition to the aforementioned concerns, standard procedures, contraindications to exercise testing, recommended monitoring intervals, and standard termination criteria are used to exercise test individuals with PD (see *Chapters 3* and *4*). There have been no known serious adverse effects exacerbated by the interaction of PD medications and exercise. A few episodes of systolic blood pressure (SBP) drops of >20 mm Hg during treadmill training sessions have been reported (318). However, no association between medication usage and drop in SBP during exercise was found. Cognitive impairment is frequently observed in individuals with PD, although not all individuals with PD will experience cognitive deficits. This may present as feeling distracted, forgetful, slower thinking and information processing, and difficulty concentrating or managing complex tasks. It is recommended that all testing instructions be explained slowly, concisely, and repeated as necessary.

Exercise Programming

The main goal of the Ex R_x for individuals with PD should ultimately be to slow down the rate at which the signs of the disease progress, reduce the signs of the disease, reduce comorbidities, prevent secondary complications from muscle disuse, and improve functional ability, independence, and quality of life. The FITT principle of Ex R_x should address CRF, muscular strength and endurance, flexibility, neuromotor training, and motor control. The ability to rigorously quantify, measure, and prescribe aerobic, resistance, and flexibility exercises has resulted in FITT principles of exercise design that focus predominantly on these three domains. However, the importance of incorporating neuromotor training and exercises that enhance motor control should not be overlooked or undervalued, regardless of the difficulty associated with determining a precise prescription for these types of exercises. As a general rule, neuromotor training should progress exercise motor complexity and quantitative training parameters (*i.e.*, FITT principles). Exercise motor complexity refers to the coordinative and control requirements of the motor activity. Thus, exercise motor complexity and quantitative training parameters should not be prescribed simultaneously, as the former impairs the progression of the latter, but instead should be done sequentially.

Also, the importance of identifying exercise modalities that an individual enjoys should not be underestimated because adherence is a key ingredient to gaining maximal benefit from exercise. Because PD is a chronic and progressive disorder, an exercise program should be prescribed early when the individual is first diagnosed and continue on a regular, lifetime basis. The Ex R_x should be reviewed and revised as PD progresses because different physical problems occur at different stages of the disease.

The primary key health outcomes of an exercise program designed for individuals with PD are improved (a) aerobic capacity, (b) muscle strength and endurance, (c) gait mechanics, (d) balance, (e) physical function, and (f) flexibility (319). Because the FITT principle of Ex R_x recommendations for individuals with PD is based on a smaller literature, the Ex R_x for healthy adults generally applies to those with PD (212); however, the limitations imposed by the disease process should be assessed, and the Ex R_x should be individually tailored accordingly.

FITT	FITT RECOMMENDATIONS FOR INDIVIDUALS WITH PARKINSON'S DISEASE (285–288)			
	Aerobic	**Resistance**	**Flexibility**	**Neuromotor**
Frequency	3–4 d · wk^{-1}	2–3 d · wk^{-1}	≥2–3 d · wk^{-1} with daily being most effective	2–3 d · wk^{-1}
Intensity	High intensity (80%–85% maximum heart rate [HR_{max}]) for mild-to-moderate Parkinson's disease (PD); Moderate intensity (60%–65% HR_{max}) for deconditioned individuals or those with more advanced PD; progress to 80%–85%	30%–60% of one repetition maximum (1-RM) for individuals beginning to improve strength; 60%–80% 1-RM for more advanced exercisers	Full extension, flexion, rotation, or stretch to the point of slight discomfort	N/A

	HR_{max} is possible.			
Time	30 min of continuous or accumulated exercise	1–3 sets of 8–12 repetitions, beginning with 1 set and working up to 3 sets	Hold static stretch for 10–30 s; 2–4 repetitions of each exercise	30–60 min
Type	Prolonged, rhythmic activities using large muscle groups (*e.g.*, walking, running, cycling, swimming, dancing)	For safety, avoid free weights for individuals in more advanced stages of the disease; focus on weight machines and other resistance devices (*e.g.*, bands, body weight).	Slow static stretches for all major muscle groups	Exercises involving motor skills (*e.g.*, balance, agility, coordination, gait, dual tasks) such as tai chi, yoga, multidirectional step training and instability training

It is important to note that the FITT principle of Ex R_x recommendations for resistance training in individuals with PD is based on literature with variable objectives with respect to study design and outcomes (320). Resistance training is well tolerated in individuals with mild-to-moderate PD (320) and should be progressive (285). Physical parameters, such as muscle strength and power (288), movement speed (285), and dynamic balance, along with quality of life parameters such as fatigue, are improved with resistance training in individuals with PD (320,321), with strength improvements being similar compared to neurologically normal controls (285,293). Therefore, recommendations for resistance exercise in neurologically healthy older adults may be applied to individuals with PD (293). A recent modification to progressive resistance training that has proven beneficial for individuals with PD is the incorporation of unstable devices into the resistance exercises (322). Results from this type of training have shown improved mobility, motor signs, neuromuscular outcomes, balance, reduced cognitive impairment, reduced fear of falling, and improved quality of life, which may be attributed to the progression of exercise motor complexity (*i.e.*, degree of instability) and quantitative training parameters (*i.e.*, frequency, intensity, and time) (322–324).

Accumulating evidence suggests that long-term aerobic exercise may attenuate PD progression (325,326). General aerobic training at a moderate intensity may improve aerobic fitness, fatigue, mood, executive function, and quality of life in those with mild-to-moderate PD (327,328). High intensity endurance exercise (80%–85% HR_{max}) can be safely prescribed to individuals with early-stage PD (HY stages 1–2) and has been shown to attenuate the worsening of motor signs (286). Individuals should be encouraged to exercise at high intensity to the extent that they are willing to do this. Individuals at HY stages ≥3 should also consider high intensity aerobic exercise, but check with their physician if they have autonomic dysfunction.

Recommendations for Neuromotor Exercise for Individuals with Parkinson's Disease

Endurance exercise, resistance exercise, and stretching will benefit posture and balance (329,330), but there are also benefits to performing exercises specifically for posture, balance, and mobility. Balance impairment and falls are major problems in individuals with PD, with approximately 61% of people with PD experiencing at least one fall and 39% of people suffering from recurring falls (331). Balance training is a crucial exercise in all individuals with PD. Postural instability and balance performance in individuals with mild-to-moderate PD can be improved with PA and exercise (332). Static, dynamic, and balance training during functional activities should be included. Clinicians should take steps to ensure the individual's safety (*e.g.*, using a gait belt and nearby rails or parallel bars and removing clutter on the floor) when using PAs that challenge balance. Training programs may include a variety of challenging PAs (*e.g.*, multidirectional step training, step up and down, reaching forward and sideways, obstacles, turning around, walking with suitable step length, standing up and sitting down) (258,333,334). When external cueing in the form of rhythmic auditory stimulation is utilized during multidirectional step training, individuals with PD show improvements in functional gait parameters, including balance, and maintain these improvements longer than when external cueing is not utilized (258). Tai chi, Tango, and Waltz are other activities to improve balance in PD (335–337). Incorporating unstable devices, such as balance pads, dyna discs, balance discs, BOSU balls, or Swiss balls, into a resistance training regimen has also been shown to improve balance in PD (322).

Exercise Training Modalities and Considerations

The selection of the exercise type is dependent on the individual's clinical presentation of PD severity and personal preference. In addition to treadmill exercise, stationary cycles, recumbent cycles, ellipticals, rowers, and arm ergometers are safe and effective modalities for aerobic training.

Additionally, water exercises and robotic gait training are effective for some people living with PD (338). Virtual reality training, mental practice, boxing, and Nordic walking have a small amount of evidence supporting their use in PD (338). Dance programs, especially ones that include visual and auditory cues and rhythmic tasks, have been shown to improve some of the motor characteristics of the disease and improve functional mobility (335–339). Tai chi has been shown to be effective in improving motor function, balance, and quality of life in individuals with PD, with limited evidence also showing improvements in fall risk and depression (340). However, research behind the optimal dose and specific protocols for the varying PD subtypes and symptom burdens is limited (340).

Free weights may be utilized for individuals with mild-to-moderate PD. However, free weights may become unsafe at more advanced stages and in those with increased severity of tremor, especially during exercises that involve overhead lifting (341). Weight machines and other resistive devices such as resistance bands or body weight are safe alternatives to free weights. It may be necessary to modify certain exercises due to decreased ROM associated with PD (341). During resistance training, emphasize extensor muscles of the trunk and hip to prevent faulty posture. Train all major muscles of the lower extremities to maintain mobility.

Flexibility and ROM exercises should include slow static stretches and passive ROM exercises for all major muscle groups and joints, with an emphasis on the upper extremities and trunk (263,341). Spinal mobility and axial rotation exercises are recommended for all severity stages (309). Neck flexibility exercises should be emphasized because neck rigidity is correlated with posture, gait, balance, and functional mobility (342). In addition, functional exercises such as the sit-to-stand, step-ups, turning over, and getting out of bed as tolerated should be incorporated in an exercise program to improve neuromotor control, balance, and maintenance of ADL.

The Lee Silverman Voice Training (LSVT) BIG program is an exercise-based behavioral treatment conducted by a certified therapist consisting of specific exercises involving large amplitude, exaggerated movement patterns (343). The exercises are performed with high intensity and effort that become progressively more difficult and complex, with the overall goal of restoring normal movement amplitude in real life situations and ADL (344). LSVT BIG has been effective at improving motor function in people with PD (345). Incorporating the concepts of this program into functional exercise may be beneficial.

Special Considerations

- Some medications used to treat PD further impair autonomic nervous system functions (296). Levodopa/carbidopa may produce exercise bradycardia and transient peak dose tachycardia and dyskinesia. Caution should be used in testing and training an individual who has had a recent change in medications because the response may be unpredictable (263). Several nonmotor symptoms may burden exercise performance (*Box 11.3*) (345,346).
- The outcome of exercise training varies significantly among individuals with PD because of the complexity and progressive nature of the disease (263).
- Cognitive decline and dementia are common nonmotor symptoms in PD and may burden the training and progression (347). It is recommended that instructions be explained slowly, clearly, concisely, and repeated as necessary. Exercises should be demonstrated and broken down into a series of short, simple steps. Utilize verbal, visual, and tactile cues while instructing the individual.
- Fall history should be recorded. Individuals with PD with more than one fall in the previous year are likely to fall again within the next 3 mo (348). Precautions should be taken to prevent falls whenever possible, such as avoiding narrow and/or uneven walkways, avoiding sharp turns and pivots, and removing any obstacles on the floor.

- Incorporate and emphasize fall prevention/reduction and education into the exercise program. Instruction on how to break falls should be given and practiced to prevent serious injuries. Most falls in PD occur during multiple tasks or long and complex movement (348,349). If the exercise professional has any concerns, they should suggest that the individual should seek a referral for fall prevention training from a physical therapist.
- Balance training should be emphasized in all individuals with PD (350).
- Use dual tasking or multitasking with novice exercisers with great care. Individuals with PD have difficulty paying full attention to multiple tasks. Dual task performance during gait has been correlated with increased risk of falling and diminished quality of life (351). Dual task training has been shown to significantly increase stride length and cadence in individuals with PD (352) and may also better prepare an individual with PD for responding to a balance perturbation (353). Dual task training can be incorporated into training once the individual is able to perform well in a single task.
- Visual and auditory cueing can be used to improve gait in persons with PD during exercise (354).
- Some individuals with PD experience freezing of gait (FOG), which is an intermittent feeling that their feet are "frozen" or stuck to the floor when trying to walk. While resistance and balance training do not seem to improve FOG in individuals with PD (355), utilizing both visual and auditory cues will help during, but will not necessarily alleviate freezing episodes (356). Utilizing exercise regimens that limit the opportunity for freezing episodes such as stationary cycling and resistance exercises alongside auditory cues are additional ways to handle FOG.
- Although no reports exist suggesting resistive exercise may exacerbate symptoms of PD, considerable attention must be paid to the development and management of fatigue (357).

Box 11.3 **Nonmotor Symptoms in**

Parkinson’s Disease (345)	
Domains	**Symptoms**
Cardiovascular	Symptomatic orthostasis, fainting, light-headedness
Sleep/fatigue	Sleep disorders, excessive daytime sleepiness, insomnia, fatigue, lack of energy, restless legs
Mood/cognition	Apathy, depression, loss of motivation, loss of interest, anxiety syndromes and panic attacks, cognitive decline
Perceptual problems/hallucinations	Hallucinations, delusion, double vision
Attention/memory	Difficulty in concentration, forgetfulness, memory loss
Gastrointestinal	Drooling, swallowing, choking, constipation
Urinary	Incontinence, excessive urination at night, increased frequency of urination
Sexual function	Altered interest in sex, problems having sex
Miscellaneous	Pain, loss of smell/taste and appetite/weight, excessive sweating, fluctuating response to medication

Future Directions

Exercise might play a neuroprotective role in individuals with PD; however, the direct evidence is limited to animal models (358–361). The data from animal models is very encouraging both in terms of deficits directly linked to dopamine depletion such as slowness of movement (358,360) and also in terms of deficits not linked to dopamine depletion but which affect those with PD such as hyposmia, anhedonia, lack of novelty-seeking behavior, depression, and anxiety (359). Although some studies do suggest promising findings with respect to changes in the brain of those with PD (362), and exercise-induced increases in blood brain-derived neurotropic factor (BDNF) levels in human with PD (363), none of these changes relate to the growth of new neurons or the protection of neurons. Therefore, there are grounds for cautious optimism that exercise will be shown to be neuroprotective once techniques are developed to address this question in humans. Future studies should be carried out to elucidate whether exercise is in fact neuroprotective, determine the influence of different types of exercise on neurogenesis and neuroplasticity, and establish the combination of interventions that have the most beneficial effect on both the motor and nonmotor symptoms of PD. These studies will provide clarity on the most advantageous ways to modify disease progression and the biological mechanisms behind it.

ONLINE RESOURCES

American Parkinson Disease Association: http://www.apdaparkinson.org
Davis Phinney Foundation: http://www.davisphinneyfoundation.org
European Parkinson's Disease Association: http://www.epda.eu.com
National Institute of Neurological Disorders and Stroke: http://www.ninds.nih.gov/parkinsons_disease/parkinsons_disease.htm
National Parkinson Foundation: http://www.parkinson.org/
Parkinson's Disease Foundation: http://www.pdf.org
The Michael J. Fox Foundation for Parkinson's Research: http://www.michaeljfox.org
The Parkinson Alliance: http://www.parkinsonalliance.org/

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Behavioral Theories and Strategies for Promoting Exercise

CHAPTER 12

INTRODUCTION

The purpose of this chapter is to provide exercise and health care professionals a basic understanding of how to assist individuals to adopt and adhere to the exercise prescription (Ex R_x) recommendations that are made throughout the *Guidelines*. *Chapter 1* of the *Guidelines* focuses on the public health recommendations for a physically active lifestyle, yet most of the public remain unaware of these recommendations (1). Furthermore, most adults in the United States do not engage in the recommended amounts of physical activity (PA) (2). Simply providing knowledge and promoting awareness of Ex R_x recommendations may be insufficient to produce behavior change (3); therefore, a better understanding of behavioral strategies that can be used to promote a physically active lifestyle is warranted.

Research has identified consistent correlates of engaging in regular exercise. Numerous demographic factors (*e.g.*, age, gender, socioeconomic status, education, ethnicity) are consistently related to the likelihood that an individual will exercise on a regular basis (4,5). Although these factors are not amenable to intervention, they do suggest who might benefit most from exercise intervention. This chapter focuses on (a) the role of modifying the Ex R_x on exercise adoption and maintenance, (b) behavioral theories and models that have been applied to enhance exercise adoption and maintenance, (c) behavioral strategies and approaches that can be used to increase PA behaviors, and (d) unique behavioral considerations for special populations.

MODIFYING THE EXERCISE PRESCRIPTION

Given the flexibility in the *F*requency, *I*ntensity, *T*ime, and *T*ype (*FITT*) principle of Ex R_x for the targeted population, it is important to first understand what impact variations in the Ex R_x might have on adoption or maintenance of a habitually active lifestyle.

Frequency/Time

Ex R_x recommendations allow for flexibility in the different combinations of frequency and time to achieve them. However, reviews of randomized trials have not identified differences in exercise adherence when different combinations of frequency and time are used to achieve the same total volume of PA (6,7), although these studies assigned individuals to different combinations. Allowing individuals to self-select frequency and time may differentially influence adherence to exercise interventions through its impacts on autonomy (see "Reinforcement" and "Self-Determination Theory" sections).

Intensity

Although previous studies of the effects of exercise intensity on adherence suggest that individuals are more likely to adhere to lower intensity exercise programs (8,9), there is some evidence that this inverse relationship is not particularly strong and may be moderated by prior exercise behavior (7). There is evidence that individuals with more exercise experience fare better with higher intensity programs (65%–75% heart rate reserve [HRR]), whereas those adopting exercise for the first time may be better suited to, and self-select, moderate intensity programs (45%–55% HRR) (10). As discussed in *Box 12.1*, these findings may have important implications for high intensity interval training.

Box 12.1 High Intensity Interval Training

High intensity interval training (HIIT) consists of short bouts of high intensity anaerobic exercise alternating with very short bouts of less intense recovery. HIIT has gained popularity, both in the fitness industry and in research. The *2018 Physical Activity Guidelines Advisory Committee Scientific Report* found that HIIT is an efficient method for increasing cardiorespiratory fitness, and there is moderate evidence that it can effectively improve insulin sensitivity, blood pressure, and body composition in adults (11). However, the scientific report found that the unpleasant affective response associated with increased intensity is greatest above the lactate and ventilatory thresholds (11). Thus, caution should be used in implementing HIIT among people with little exercise experience and those who have been sedentary (12).

Type

In the FITT principle of Ex R_x, “Type” universally refers to the mode or kind of exercise. Most of the research that has examined exercise adherence has investigated aerobic activity, often with a focus on walking, yet there is no compelling evidence that exercise mode is related to adherence (7). To date, little is known about the characteristics of those who adopt and maintain resistance training and flexibility-exercise programs. When discussing exercise promotion, Type has an additional context, focusing more on program/delivery type (*i.e.*, home-based, supervised). Studies have shown comparable or greater adherence to home-based, or lifestyle, programs within certain populations (*e.g.*, older adults) that include the provision of remotely delivered support compared to structured, center-based programs (13,14). Interventions delivered entirely or predominantly via telephone have been shown to be effective in increasing PA in a range of populations (15). Technology-delivered interventions such as internet-based programs also hold promise for promoting PA, with greater reach and lower implementation costs compared to face to face interventions (16). PA apps are widely available and, as discussed in the "Self-Monitoring" section, can be an important adjunct to other interventions. However, some apps may lack the inclusion of evidence-based behavior change strategies, principles, and theories to guide their users appropriately. Therefore, fitness professionals should understand which apps and wearables can work best for individuals given these potential limitations (17–19).

THEORETICAL FOUNDATIONS FOR UNDERSTANDING EXERCISE BEHAVIOR

Theories and models provide frameworks for understanding exercise participation and the factors that may facilitate or impede being physically active. Using appropriate theories can guide exercise and health professionals in determining appropriate strategies to assist individuals to adopt and maintain regular PA. The purpose of this section is to provide an understanding of the most widely used theories and models to promote PA. These theories share similar concepts and have similar ideas about how to understand PA behavior but use different combinations of constructs to explain why people are or are not active. Many theories share a common, conscious decision-making basis focused on individual's expectancies and values. That is, people will intend to engage in a behavior in which they think they can expect to succeed and have a valued, positive result. Newer theories have also begun to incorporate an understanding of the role of nonconscious processes such as emotion, enjoyment, and affect. *Table 12.1* outlines the conceptual overlap between these theories and the strategies that can be used to target each of the shared concepts. Later sections in this chapter describe more specific applications of strategies that result from these theories and models.

TABLE 12.1 • Overarching Theoretical Constructs, Associated Theories, and Change Strategies (20–22)

Theoretical Construct	Theories	Behavior Change Strategy
Intentions	• TPB: intentions • TTM: stages of change	• Goal setting • Implementation intentions
Knowledge	• SCT • TTM • HBM • SDT • TPB • SEM • Dual processing theories	• Brief counseling/motivational interviewing • Stage of change tailored counseling
Self-regulation	• SCT • Dual processing theories	• Self-monitoring • Reinforcement • Relapse prevention • Problem solving • Affect regulation • Social support
Social influences and subjective norms	• SCT • SDT • TPB • SEM	• Social support • Reinforcement • Vicarious experience • Brief counseling/motivational interviewing • Stage of change tailored counseling
Environmental	• SCT	• Brief

context and resources	• SEM	counseling/motivational interviewing • Stage of change tailored counseling • Problem solving
Beliefs about consequences *(i.e., outcome expectancies, decisional balance)*	• SCT • TTM • TPB • HBM	• Brief counseling/motivational interviewing • Stage of change tailored counseling • Vicarious experience • Physiological feedback • Problem solving
Beliefs about capabilities *(i.e., self-efficacy, perceived behavioral control)*	• SCT • TTM • TPB • HBM	• Mastery experience • Vicarious experience • Verbal persuasion • Physiological feedback • Problem solving • Relapse prevention
Skills	• SCT • SDT	• Mastery experience
Reinforcement	• SCT • SDT • TTM • Dual process theories	• Reinforcement • Social support • Affect regulation

HBM, health belief model; SCT, social cognitive theory; SDT, self-determination theory; SEM, social ecological model; TPB, theory of planned behavior; TTM, transtheoretical model.

Social Cognitive Theory

Social cognitive theory (SCT) is a comprehensive theoretical framework that has been extensively employed in understanding, describing, and changing exercise behavior. The theory and strategies derived from SCT have been successfully applied in exercise interventions across diverse populations (23–25). SCT is based on the principle of reciprocal determinism; that is, the individual (*e.g.*, emotion, personality, cognition, biology), behavior (*e.g.*, past and current achievement), and environment (*i.e.*, physical, social, and cultural) all interact to influence behavior (26). It is important to recognize that these are dynamic factors that influence each other differently over time. For example, an individual who begins an exercise program may feel a sense of accomplishment, encouraging even more exercise, which leads to making the environment more conducive to subsequent exercise (*e.g.*, buying home exercise equipment). Conversely, another individual may start an exercise program, work too hard and feel fatigued, lose motivation, and move the exercise equipment to the basement to make the environment less conducive to exercising. SCT posits that individuals learn from external reinforcements and punishments, by observing others, and through cognitive processes (27).

Central to SCT is the concept of self-efficacy, which refers to one's beliefs that they are capable of successfully completing a course of action such as exercise (4,26). There are two salient types of self-efficacy when considering exercise behavior. Task self-efficacy refers to an individual's belief he or she can actually do the behavior in question, whereas barriers self-efficacy refers to whether an individual believes he or she can regularly exercise in the face of common barriers such as lack of time and poor weather. The higher the sense of efficacy, the greater the effort, persistence, and resilience an individual will exhibit, particularly when faced with barriers or challenges. For example, an older adult who does not believe he or she can lift weights would not even consider enrolling in a program that included resistance training. This individual would have to work on increasing his or her confidence in his or her capability to perform resistance training (task self-efficacy) prior to worrying about their ability to resistance train in the face of challenges (barriers self-efficacy). For strategies on enhancing self-efficacy, see *Table 12.2*.

TABLE 12.2 • Strategies for Enhancing Self-Efficacy

Source of Self-Efficacy Information	Description	Strategies
Mastery experiences	Have individual successfully perform the behavior.	• Set realistic goals that can be achieved. • Progress gradually over time. • Provide proper instruction and demonstration. • Use physical activity logs to track progress.
Vicarious experiences	Have individual watch others with similar background perform tasks.	• Have appropriate group exercise leaders that individual can identify with. • Use videos to model behavior. • Discuss/show “success” stories of individuals with similar backgrounds and characteristics.
Verbal persuasion	Have others tell the individual that he or she can be successful.	• Give frequent feedback (*e.g.*, encouragement, compliments) and express confidence in the individual’s abilities. • Prompt discussion of previous successful attempts at behavior change. • Discuss existing skills and knowledge, which can help with behavior change.

Physiological feedback	Communicate the meaning of symptoms associated with the behavior change.	• Provide appropriate instruction and reassurance. • Discuss how physical activity makes the individual feel. • Provide education about the possible discomfort associated with physical activity. • Encourage using music, scenery, etc. to make physical activity pleasurable.

Outcome expectations and expectancies are key concepts of SCT, and are anticipatory results of a behavior and the value placed on these results (28). If specific outcomes are seen as likely to occur and are valued, then behavior change is more likely to occur (28). For example, an overweight adult who wants to lose weight and believes that walking will help is more likely to start and maintain such a program. Conversely, a woman who believes that resistance training will lead to looking muscular or masculine will be unlikely to start a resistance training program if these traits are perceived as undesirable (26).

Another important concept in SCT is self-regulation or self-control. Self-regulation/self-control is an individual’s ability to set goals, monitor progress toward those goals (or self-monitor), problem solve when faced with barriers, and engage in self-reward. A meta-analysis found that exercise interventions were most effective when self-monitoring was combined with at least one other technique within the self-regulation/self-control construct, such as prompting goal setting, providing feedback on behavior or outcomes, and reviewing goal progress (25). See “Self-Monitoring” and “Goal Setting” sections for more information on how to best implement those strategies.

Transtheoretical Model

The transtheoretical model (TTM) was developed as a framework for understanding behavior change and is one of the most popular approaches for promoting exercise behavior (29–31). The popularity of the TTM stems from the intuitive appeal that individuals are at different stages of readiness to make behavioral changes and thus require different interventions to help them progress. The TTM includes five stages of change: precontemplation (*i.e.*, no intention to be regularly active in the next 6 mo), contemplation (*i.e.*, intending to be regularly active in the next 6 mo), preparation (*i.e.*, intending to be regularly active in the next 30 d), action (*i.e.*, regularly active for <6 mo), and maintenance (*i.e.*, regularly active for ≥6 mo). As individuals attempt to change their behavior, they may move linearly through these stages, but repeated relapse and successful change after several unsuccessful attempts may also occur. Stage-based interventions, across various groups and populations, have been effective in helping individuals make progress toward and/or actually becoming regularly active (29,32).

Associated with the five stages of change are the constructs of *processes of change*, *decisional balance*, and *self-efficacy*. The processes of change, 10 in all, illustrate the strategies used by individuals in attempting to advance through the five stages of change. Emphasizing experiential or cognitive processes of change (*e.g.*, understanding the risks of inactivity) is recommended in earlier, pre-action stages of change, whereas promoting behavioral processes of change (*e.g.*, rewarding oneself) is most helpful in later stages of change (see "Stage of Change Tailored Counseling" section for more examples). Decisional balance involves weighing the pros and cons of changing exercise behavior. For example, during preaction stages of change, the cons typically outweigh the pros, whereas during action and maintenance, the pros typically outweigh the cons (31). Evidence suggests that individuals need to increase their pros of exercising twice as much as they decrease the cons of exercising as they progress through the stages

(33). Practically, this means that if an individual can only think of a few reasons to exercise, he or she may view the time required for exercise as a major barrier; however, if that same individual can endorse 10 or 15 reasons to exercise, then time may be less of a barrier. Self-efficacy is lowest in the earliest stages of change and highest in the latest stages of change. There are specific processes of change and pattern in decisional balance and self-efficacy that have been shown to be most useful to facilitate progression through each of the stages of change for exercise (29,34).

Health Belief Model

The health belief model (HBM) theorizes that an individual's beliefs about whether or not they are susceptible to disease, and individual perceptions of the benefits of trying to avoid said disease, influence an individual's readiness to act. In order to evoke readiness to change, an individual needs to believe he or she is susceptible to a disease and believe that the benefits of taking action outweigh the perceived barriers (35). Together, the six constructs of the HBM suggest strategies for motivating individuals to change their exercise behavior because of health issues (*Table 12.3*). Although it is not as widely studied as other theories, the HBM may be most suitable for understanding and intervening with populations that are motivated to be physically active primarily for health reasons (36). Thus, the HBM has been applied to cardiac rehabilitation and diabetes mellitus (DM) prevention and management (37,38). As the field moves toward implementing more medical referrals to exercise specialists in Exercise is Medicine, this theory may gain added utility.

TABLE 12.3 • Health Belief Model Constructs and Strategies (35)

Construct	Exercise-Specific Definition	Change Strategy
Perceived susceptibility	Beliefs about the chances of getting a disease/condition if do not exercise	• Explain risk information based on current activity, family history, other behaviors, etc.
Perceived severity	Beliefs about the seriousness/consequences of disease/condition as a result of inactivity	• Refer individual to medically valid information about disease. • Discuss different treatment options, outcomes, and costs.
Perceived benefits	Beliefs about the effectiveness of exercising to reduce susceptibility and/or severity	• Provide information on benefits of exercise to preventing/treating condition or disease. • Provide information regarding all of the other potential benefits of exercise (*e.g.*, quality of life, mental health).
Perceived barriers	Beliefs about the direct and indirect costs associated with exercise	• Discuss Ex R_x options to minimize burden.

		• Provide information on different low-cost activity choices.
Cues to action	Factors that activate the change process and get someone to start exercising	• Help individual look for potential cues. • Ask the individual what it would take for him or her to get started.
Self-efficacy	Confidence in ability to exercise	• Assess level of confidence for different types of activity. • Use self-efficacy building techniques to enhance exercise confidence.

Ex R_X, exercise prescription.

Self-Determination Theory

Self-determination theory (SDT) has a focus on understanding the dynamics of an individual's motivation determinants (39–41). The underlying assumption of SDT is individuals have three primary psychosocial needs that they are trying to satisfy: (a) *self-determination or autonomy*, (b) demonstration of *competence or mastery*, and (c) *relatedness* or the ability to experience meaningful social interactions with others. The theory proposes that motivation exists on a continuum from amotivation to intrinsic motivation. Individuals with amotivation have the lowest levels of self-determination and have no desire to engage in exercise. Individuals with intrinsic motivation have the highest degree of self-determination and are interested in engaging in exercise simply for the satisfaction, challenge, or pleasure it brings. Between amotivation and intrinsic motivation lies the continuum of levels of extrinsic motivation; that is, when individuals engage in exercise for reasons that are external to the individual and different than satisfaction and pleasure, such as being physically active to make oneself more attractive to others, out of sense of obligation, to pursue rewards, or out of fear of punishment (40,41).

SDT suggests that the use of rewards to get individuals to start exercising may have limited long-term effectiveness because they promote extrinsic motivation (42). This deserves special attention given the increasing propensity of health insurers and employers to consider financial incentives to promote behavior change (43). Rather, programs should be designed to enhance autonomy by promoting choice and incorporating simple, easy exercises initially to enhance feelings of competence and enjoyment. Interventions that target strategies to increase autonomy have been effective at enhancing PA levels (44–46). Increasing opportunities for social interactions can also impact on relatedness (see "Group Leader Effectiveness" section).

Theory of Planned Behavior

The theory of planned behavior (TPB) consistently explains exercise intentions and behavior (47,48); however, there is less evidence that interventions based on the TPB are effective at increasing PA levels (49,50). According to the TPB, intention to perform a behavior is the primary determinant of actual behavior (51). Intentions reflect an individual's perceived probability or likelihood that he or she will exercise but do not always translate directly into behavior because of issues related to behavioral control (52). Attitudes are the degree to which an individual has a favorable or unfavorable evaluation of behavioral outcomes. Subjective norms are the social component and are about whether an individual believes important people in their life value a behavior. Finally, perceived behavioral control is the perceived ease or difficulty in engaging in a behavior. Thus, an individual intends to be physically active if they believe exercise would lead to desired outcomes, is valued by someone whose opinion they value, and is within the individuals own control.

Although intentions are the primary predictor of behavior, there is also a hypothesized direct link between perceived behavioral control and behavior (*Figure 12.1*). An individual's subjective norms may lead them toward healthier behavior, and a more positive attitude, but powerful barriers outside of the individual's control may act directly to limit exercise participation. For example, if an individual perceives low control over their ability to engage in exercise when the weather is poor, they are more likely to skip an exercise session if it is raining.

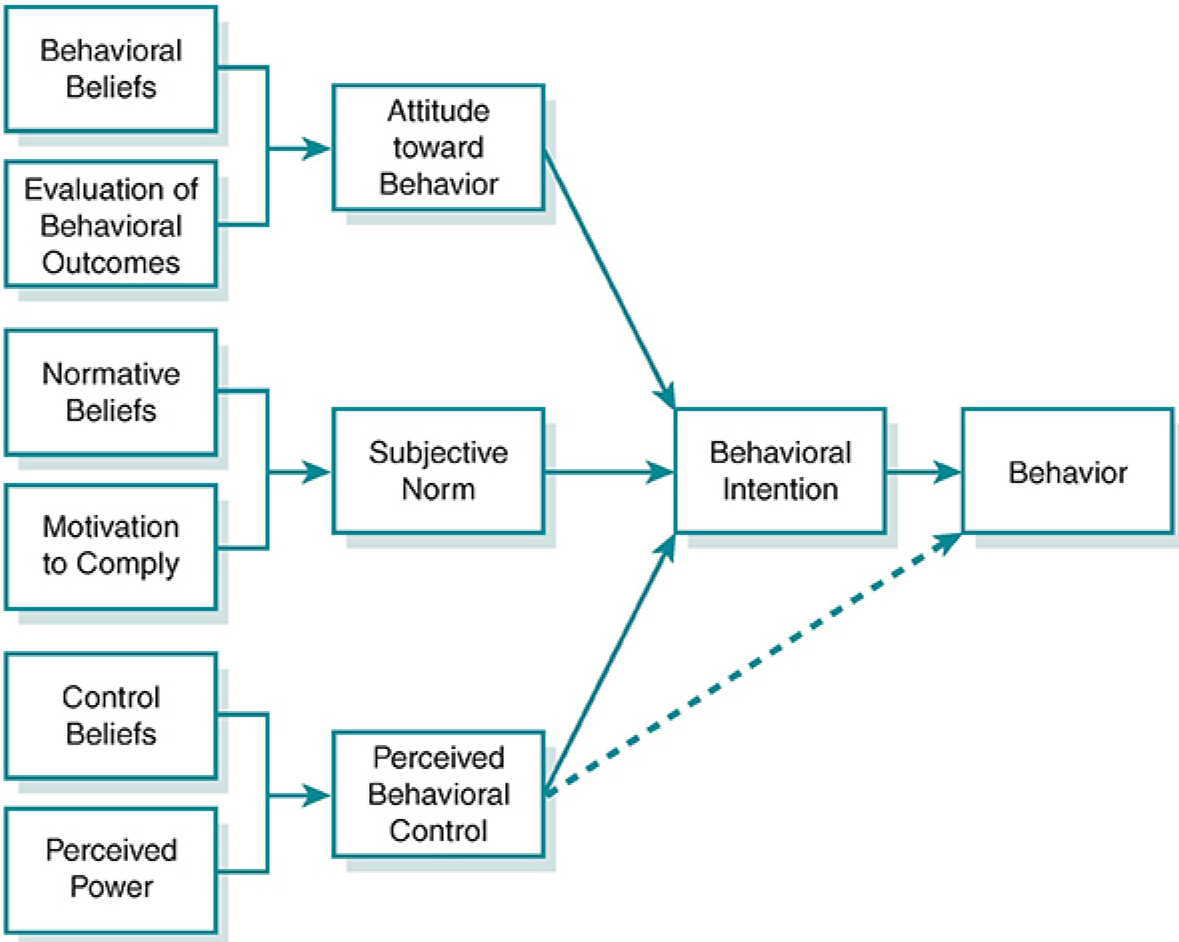

Figure 12.1 Theory of planned behavior. Based on information from (51).

Social Ecological Models

The defining feature of social ecological models is the explicit recognition of relations between individuals and their physical environments (53,54). Ecological models posit that behavior results from influences at multiple levels (*Table 12.4*). Importantly, environmental factors influence behavior directly and indirectly through an individual's perceptions. Targeting aspects of the individual are important, but if a physical environment is not conducive to changing one's lifestyle, then the exercise intervention will not be successful. A key belief is that interventions are most likely to be effective when they target multiple levels (53,54). For example, adding a walking path in a park is most likely to be effective in increasing PA when there is a campaign to promote awareness of the path, perhaps combined with an intervention that targets individual beliefs and motivations about walking. Although research examining the impact of interventions based on ecological models is limited in part because of the complexity of delivering these multilevel interventions, results examining the impact of interventions based on ecological models is promising (54).

TABLE 12.4 • Levels of Social Ecological Model and Potential Physical Activity Intervention Strategies

Social Ecological Level	Components	Potential Change Strategies
Intrapersonal factors	• Knowledge, attitudes, behaviors, beliefs, perceived barriers, motivation, enjoyment • Skills and self-efficacy • Demographics (age, sex, education, and socioeconomic and employment status)	• Focus on changing individual's knowledge, skills, and attitudes. • Use theories and approaches such as social cognitive theory, the transtheoretical model, theory of planned behavior, and self-determination theory. • Use demographic information to identify subgroups at risk or subgroups that require different approaches to intervention.
Interpersonal factors/social environment	• Family, spouse, or partner • Peers • Coworkers	• Use community education, support groups, and peer programs.

	• Access to social support • Influence of health professionals • Community norms • Cultural background	• Social marketing campaigns may promote positive community attitudes and awareness toward participation in physical activity. • Use consistent, accurate, and encouraging messages to promote physical activity.
Organizational factors	• Schools, workplaces, faith-based settings, and community organizations	• Create opportunities for organizations, at both the individual and group level, to adopt or increase physical activity.
Physical environment	• Natural factors such as weather or geography • Availability and access to exercise facilities • Aesthetics or perceived qualities of facilities or the natural environment • Safety such as crime rates and traffic • Community design • Public transportation options	• Create walking trails or parks. • Enhance existing environments (*e.g.*, park/neighborhood cleanups). • Help individuals become more aware of opportunities for physical activity in their communities (*e.g.*, parks, trails, community centers).
Policy	• Urban planning policies	• Align physical

	• Education policies such as physical education classes • Health policies • Environmental policies • Workplace and other organizational policies	activity participation with priorities such as reducing reliance on fossil fuels and the reduction of greenhouse gas emissions. • Emphasize the importance of regular physical education. • Require workplaces to provide support for physical activity. • Vote for politicians who advocate for increased physical activity.

Dual Processing Theories

Dual processing theories refer to a class of theories that focus on both the conscious and nonconscious aspects of behavior (55,56). For example, many people will state a desired motivation to exercise (conscious motivation) at the same time that they experience dread of exercise (nonconscious motivation). The dread component is part of hedonic motivation, an automatic association between a behavior and previous affective responses to the behavior (57). *Affective response* describes how an individual's affect changes as a result of engaging in a behavior. Affect is a neurobiological state that encompasses (often involuntary) physiological reactions and subjective evaluations of experiences, to characterize how an individual feels about a given situation, experience, or behavior. Hedonic motivation suggests that people will tend to seek out experiences that are pleasurable and enjoyable and avoid those which bring displeasure. The key distinction between this type of motivation and conscious motivation (*e.g.*, intentions) is that it is automatic, it happens without thinking, and it does not consider the pros and cons, goals, or intentions. The more we have positive experiences surrounding a behavior, the greater our hedonic desire becomes for the behavior. Likewise, the more we have negative experiences surrounding a behavior, the greater our hedonic dread becomes for a behavior. When people struggle to start or continue an exercise program, it can be a result of their hedonic dread of exercise influencing their behavior despite their conscious desire to exercise.

How an individual feels during a single exercise session — the affective response — is predictive of exercise behavior 6 and 12 mo later, and negative affective responses to exercise are typically associated with exercise avoidance (58,59). Because cumulative positive experiences can shape automatic associations with behavior, it is important to understand which exercise scenarios promote positive affective responses. At a low intensity, affective response to exercise is typically positive. At moderate intensity, affective response is also typically positive; however, for those who do not exercise regularly, this is less often the case. At higher intensities, affective response can be positive; however, as people approach their maximum threshold, affective response during exercise is typically aversive (60). Emerging evidence on affective response to high intensity interval training suggests that some individuals, including those who are overweight, obese, and/or inactive will respond positively, whereas others may find this type of exercise aversive. At longer intervals or intensities close to the lactate threshold, perceived enjoyment and affective response decline (61–63).

STRATEGIES AND APPROACHES FOR INCREASING PHYSICAL ACTIVITY

Enhancing Self-Efficacy

Self-efficacy, the confidence in one's ability to carry out actions necessary to perform certain behaviors (26), is a central component of most of the theories previously discussed (*i.e.*, SCT, TTM, HBM, and TPB). Increased self-efficacy is related to PA behavior change (23). Individuals draw on various sources of efficacy information to increase exercise behavior. *Table 12.2* describes the sources of efficacy and strategies that can enhance personal exercise efficacy.

Self-Monitoring

Self-monitoring, an important component of SCT and TTM, involves observing and recording behavior and has been shown to be important in exercise behavior change (23,25). Self-monitoring of exercise can be in the form of a paper-and-pencil log, a heart rate monitor, pedometer, or wearables such as a smart watch. Technology devices and apps can provide the individual with detailed feedback that includes minutes of exercise, exercise intensity, distance travelled, or step counts. Visual documentation (*e.g.*, workout log) can be useful for tracking progress toward goals, identifying barriers to changing behavior, and as a reminder to exercise. Self-monitoring is most effective when paired with other strategies, such as goal setting, as merely monitoring behavior by itself may only have limited, short-term effects (64).

Goal Setting

Goal setting is a powerful tool for behavior change that leads to positive changes in exercise behavior when used as part of process that involves setting, monitoring, and altering goals (23). The exercise professional can work with individuals to help develop, implement, measure, and revise goals on a consistent basis to provide direction to their efforts; enhance persistence; and learn new strategies. The SMARTS principle can be used to guide effective goal setting:

- **S**pecific: Goals should be precise.
- **M**easurable: Goals should be quantifiable.
- **A**ction-oriented: Goals should indicate what needs to be done.
- **R**ealistic: Goals should be achievable.
- **T**imely: Goals should have a specific and realistic time frame.
- **S**elf-determined: Goals should be developed primarily by the individual.

It is important for individuals to set both short- and long-term goals that allow for measurement and assessment on a regular basis. Individuals often focus on long-term goals; however, when attempting to initiate a new behavior, setting short-term achievable goals (*i.e.*, daily or weekly) is important for increasing self-efficacy (65). The exercise professional should regularly monitor progress, provide feedback, and discuss successes and struggles with the individual. Setting proper goals is an important part of numerous PA studies; however, because goal setting is incorporated into many theories and interventions (*e.g.*, SCT, TPB, TTM), there is limited evidence on its sole contribution to changing exercise behavior (66–68). The expansion of wearable monitoring devices allows for greater ease in tracking behavior, which is essential to the goal setting process, but care must be taken that the goals are being set appropriately by the individual or app (19).

Implementation Intentions

The formation of implementation intentions may enhance the link between exercise intentions and behavior (69). Implementation intentions reflect an individual's specific and detailed plans to exercise, such as where they will exercise, when they will exercise, and with whom they will exercise. Implementation intentions are analogous to the setting of specific strategies that will be discussed in the goal setting process (70). Evidence has supported that the addition of implementation intentions improves exercise behavior outcomes beyond standard motivational interventions (71,72). This model has been applied most frequently to clinical populations, including cancer patients (73), cardiac rehabilitation participants (74), and pregnant women (75).

Reinforcement

The use of positive reinforcement (*i.e.*, rewards) is emphasized in SCT, SDT, and TTM, and dual process theories. Individuals should be encouraged to reward themselves for meeting behavioral goals. Extrinsic rewards include tangible, physical rewards such as money, a new pair of shoes, or a new book, and are often used to initiate behavior change (76). There is evidence that this can be effective, at least in the short term, for initiating PA (42). Social reinforcement, such as praise from an exercise professional or family member, is also an extrinsic reinforcer. Intrinsic rewards are intangible rewards that come from within, such as a feeling of accomplishment, confidence, or enjoyment. Individuals are more likely to adhere to regular exercise over the long term if they are doing the activity for intrinsic reasons (41,77). It may be difficult to give intrinsic reinforcers to individuals, but it may be possible to develop an environment that can promote intrinsic motivation. These environments focus on the autonomy of the individual and have been shown to lead to higher levels of PA (44). Environments promoting intrinsic motivation focus on (a) providing positive feedback to help the individual increase feelings of competence, (b) acknowledging individual difficulties within the program, and (c) enhancing sense of choice and self-initiation of activities to build feelings of autonomy. The development of apps that reward or provide praise has also been shown to be an effective strategy to help people increase their PA (78).

Social Support

Social support is a powerful motivator to exercise for many individuals and important in SCT, TTM, TPB, and social ecological models, and can come from an instructor, family members, workout partners, coworkers, neighbors, as well as exercise and other health professionals. Social support can be provided to individuals in various ways including (a) instrumental, (b) emotional, (c) informational, (d) companionship, and (e) validation (79).

Providing social support in the form of guidance is most common when working with individuals. Individuals beginning an exercise program need to feel supported in times of stress or times when continuing to exercise is difficult (80,81). Moreover, individuals beginning an exercise program may have feelings of incompetence. Increasing one's beliefs about their capabilities can be done through mastery experiences, social modeling, and providing praise; all practical ways to increase acknowledgment of one's competence (26).

Implementing ways to increase an individual's attachment and feelings of being part of a group are also important. The exerciser needs to feel comfortable, and one method to accomplish this is to establish buddy groups. In group settings, exercisers can benefit from watching others complete their exercise routines and from instructors and fellow exercisers giving input on proper technique and execution. Creating supportive exercise groups within communities has been linked with greater levels of exercise behavior (3).

Aspects of social support are present in most PA apps and wearable devices (82). Technology allows for social rewards through praise, for social support through various social networking features, and for monitoring of behavior by others via automatic or user-generated features to share activity progress. Using these features can help change behavior, but it is important that the social support provided through technology is matched to the individual's need for support and is not the only form of social support for that individual.

Problem Solving

Individuals face a number of personal, social, and environmental-related barriers in both the adoption and maintenance of PA (83,84). The behavioral theories discussed above help us to understand an individual's behavior, and *Table 12.5* shows common challenges expressed in the adoption and maintenance of exercise, connecting them to appropriate theories and constructs. Problem solving can assist individuals in identifying strategies to reduce or eliminate barriers and includes four main steps: (a) identify the barrier, (b) brainstorm ways to overcome the barrier, (c) select a strategy generated in brainstorming viewed as most likely to be successful, and (d) analyze how well the plan worked and revise as necessary (85). Solutions to barriers should ideally be generated by the individual and not by the exercise professional. For example, if lack of time is a barrier to engaging in exercise, the individual, in conjunction with the exercise professional, can identify possible solutions for overcoming this barrier (*e.g.*, schedule exercise appointments, incorporate PA into existing activities).

TABLE 12.5 • Most Common Exercise Barriers (83), Relevant Theories, and Potential Strategies

Common Problem	Applicable Theories	Example Strategies
"I don't have enough time."	SCT, TPB, SEM	• Discuss modifications to FITT principles. • Examine priorities/goals. • Brief counseling/motivational interviewing
"I don't have enough energy."	SCT, HBM, SEM, TPB	• Discuss modifications to FITT principles. • Brief counseling/motivational interviewing • Discuss affect regulation techniques for setting exercise intensity.
"I'm just not motivated."	SCT, HBM, TPB, TTM, SEM, SDT	• Discuss attitudes and outcome expectations. • Determine stage of change and provide stage-tailored counseling. • Examine perceived susceptibility and severity. • Discuss potentially effective reinforcements.
"It costs too much."	HBM, TTM, SEM	• Examine exercise alternatives to meet goals. • Evaluate exercise opportunities in the environment.

"I'm sick or hurt."	**TTM**	• Discuss maintenance/relapse prevention. • Discuss alternative exercises to keep progressing toward goals.
"There's nowhere for me to exercise."	**SEM**	• Evaluate exercise opportunities in the environment. • Discuss different types of activities for which there are resources.
"I feel awkward when I exercise."	SCT, TPB	• Examine self-efficacy. • Examine alternative settings.
"I don't know how to do it."	SCT, HBM, TTM, TPB	• Build task self-efficacy using appropriate strategies.
"I might get hurt."	SCT, HBM, TPB	• Evaluate exercise prescription. • Determine task-specific self-efficacy.
"It's not safe."	**SEM**	• Evaluate exercise opportunities in the environment.
"No one will watch my child if I exercised."	SCT, SEM	• Develop social support structures. • Examine opportunities for exercise in which childcare may be provided.
"There is no one to exercise with me."	SCT, TPB, TTM	• Develop social support and exercise buddy system. • Identify different types of activities one can do on his or her own.

FITT, *F*requency, *I*ntensity, *T*ime, and *T*ype of exercise; HBM, health belief model; SCT, social cognitive theory; SDT, self-determination theory; SEM, social ecological model; TPB, theory of planned behavior; TTM, transtheoretical model.

Affect Regulation

Individuals are often advised to pick an exercise activity they enjoy. This is supported by hedonic theory, which suggests that by picking an enjoyable form of PA, people are more likely to adopt and maintain PA (86). Engaging in enjoyable forms of PA is also a key component to establishing intrinsic motivation as described by SDT (87); intrinsic motivation is predictive of long-term adherence to recommended levels of PA (41). Affective response varies between individuals, and some exercise intensities and exercise types may be more enjoyable for certain individuals. To address this variability and promote a positive affective response to exercise, self-ratings of affect or of the pleasantness/unpleasantness of an experience, can be used as a marker of the transition from aerobic to anaerobic metabolism and may be useful for Ex Rx. Specifically, exercisers can use feelings of increasing displeasure to be a sign that exercise intensity may be too high, and they should decrease exercise intensity to reduce these feelings.

Self-selecting the intensity of exercise can be helpful for individuals to start and maintain a program of exercise, particularly those who are overweight or obese (88–90). When self-selecting an intensity, individuals can also be instructed to exercise at an intensity that feels good. When choosing their own intensity, and particularly intensities that feel good, individuals typically still end up working at a moderate intensity, despite the lack of focus on targeted heart rate zones (91). Other strategies to promote positive affect in the context of exercise include the following:

- Exercising in an enjoyable context (*e.g.*, with friends or in a location that is pleasing to the individual) (92)
- Maintaining variety in types of exercise, trying new activities (93)

- Establishing a reward system for exercise (78)

Relapse Prevention

Regularly active individuals will occasionally encounter situations that make sticking with their exercise program difficult or nearly impossible. Therefore, an important part of helping individuals maintain their PA levels is the development of strategies to overcome setbacks (94). Although it is not unusual to have a brief lapse from exercise, preparing for situations which may result in an elongated lapse, or relapse, is critical. Relapse prevention can be implemented across all behavioral approaches once individuals adopt and try to maintain exercise (95). Relapse prevention strategies include being aware of and anticipating high-risk situations (*e.g.*, travel, vacation, holidays, illness, competing family obligations, and poor weather) and having a plan to ensure that a lapse does not become a relapse (94). For some individuals, it may be important to vary exercise routines and create new exercise goals to avoid boredom and potentially a relapse. It is also important that individuals do not get discouraged when they miss a session of planned activity, as missing planned exercise is unavoidable. Therefore, individuals should avoid “all-or-nothing” thinking, and relapse prevention strategies can help an individual to stay on track or to get back on track once the situation has passed.

Brief Counseling and Motivational Interviewing

A proven technique for increasing exercise adoption is through the use of brief counseling, often conducted by health care professionals such as certified exercise professionals (96). These brief counseling approaches can be based on any of the theories previously discussed; however, it is imperative that they be more thorough than simply asking about PA levels and advising the individual to increase exercise behavior. A motivational interviewing approach explores why people aren’t active, asks open-ended questions, uses empathic responses and reflective listening skills, and recognizes that individuals may be resistant.

Motivational interviewing has evolved over the past several decades and has been successfully applied to many health behaviors in a variety of settings (97), including PA (98,99) and weight loss (100). Motivational interviewing is an individual-centered, directive method of communication where the professional and the individual work collaboratively to explore and resolve ambivalence about behavior change. The professional's approach should be nonjudgmental, empathic, and encouraging. The approach respects individual autonomy and views the individual as fully responsible for change rather than persuading individuals to change, proving they should exercise, and arguing with individuals.

A major focus of motivational interviewing is to help the ambivalent individual realize the different intrinsic motivators that can lead to positive change. Ambivalence about behavior change occurs when an individual has conflicting viewpoints about changing his or her behavior, for example, "I know I should exercise to stay healthy, but I don't like the way I feel when I'm exercising." The primary goal is to help resolve ambivalence and increase motivation for change, which is also the initial phase of motivational interviewing, when change talk can occur. Change talk refers to an individual's mention or discussion of a desire or reason to change, making it more likely the change will occur (*Table 12.6*) (101). The use of personal rulers can evoke change by examining whether an individual is ready, willing, and able to make a change. The use of these rulers prior to goal setting strategies can facilitate setting realistic, achievable, short- and long-term goals. Motivational interviewing can be adapted and used in combination with most existing theories to help motivate change and confidence among individuals who are seeking to adopt or maintain an exercise program. Because of theoretical similarities between motivational interviewing and SDT (*e.g.*, intrinsic motivation, autonomy), there is a growing interest to combine these in intervention development (103).

TABLE 12.6 • Methods for Evoking Change Talk

Approach	Description	Examples
Ask evocative questions.	Ask the individual questions regarding: ● Disadvantages of the status quo ● Advantages of change ● Optimism about change ● Intention to change ● Explore and resolve ambivalence	"What do you think will happen if you don't change anything?" "What are some benefits of becoming more physically active?" "What changes would work best for you?" "What do you intend to do?"
Use the importance ruler.	Ask simple questions to assess how important physical activity is to the individual and what might make it more important.	"How important would you say it is for you to be physically active? (After response) "Why do you believe that?" "What would it take for you to increase the importance of exercise?"
Use the confidence ruler.	Ask simple questions to assess the individual's confidence and what might increase his or her confidence.	"How confident are you that you can engage in regular physical activity? (After response) "What makes you feel that way?"

		"What would it take for you to feel more confident about this?"
Explore pros and cons.	Encourage individual to discuss the positive and negative aspects of his or her present behavior. Help explore and resolve ambivalence.	"Are there things that you like about being physically inactive?" "Are there disadvantages of being physically inactive?"
Elaborate.	When health professional hears any arguments for change, encourage the individual to elaborate to reinforce change talk.	"You said exercise might make you feel better. Can you tell me more about that?"
Query extremes.	When the individual has little desire for change, encourage him or her to consider extreme consequences of not changing and best consequences of changing.	"Suppose you continue on as you have, with no physical activity in your life. What do you imagine are the worse things that might happen to you?" "What might be the best results you could imagine if you make a change?"
Look back.	Help the individual remember a time in his or her life when he or she was physically active.	"You mentioned that you used to walk regularly. What was that like?"
Look forward.	Help the individual envision a changed future.	"If you don't like what you see in the future

		about yourself, how would you like things to be different?"
Explore values and goals.	Ask the individual to tell you what things are most important in his or her life and then ask if being inactive fits with this picture.	"What in life is most important to you?" (After a response) "Does being physically active or inactive matter to this?"

Adapted from (101,102).

Stage of Change Tailored Counseling

The TTM is predicated on the notion of stages of change and that progression through the stages can be facilitated by the use of stage-specific strategies and processes of change that result in tailoring interventions. *Box 12.2* provides examples of how one might use specific strategies within each stage to tailor the intervention to an individual to help them progress to the next stage. Intervention studies have consistently found stage-tailored interventions that include all of the components of the TTM are appropriate for many different populations and are effective at enhancing PA levels (32,104).

Box 12.2 Example Strategies to Facilitate Stage Transitions

Precontemplation → Contemplation

- Provide information about the benefits of regular physical activity.
- Discuss how some of the barriers they perceive may be misconceived such as "It can be done in shorter and accumulated bouts if they don't have the time."
- Have them visualize what they would feel like if they were physically active with an emphasis on short-term, easily achievable benefits of activity such as sleeping better, reducing stress, and having more energy.
- Explore how their inactivity impacts individuals other than themselves such as their spouse and children.

Contemplation → Preparation

- Explore potential solutions to their physical activity barriers.
- Assess level of self-efficacy and begin techniques to build efficacy.

- Emphasize the importance of even small steps in progressing toward being regularly active.
- Encourage viewing oneself as a healthy, physically active individual.

Preparation → Action

- Help develop an appropriate plan of activity to meet their physical activity goals and use a goal setting worksheet or contract to make it a formal commitment.
- Use reinforcement to reward steps toward being active.
- Teach self-monitoring techniques such as tracking time and distance.
- Continue discussion of how to overcome any obstacles they feel are in their way of being active.
- Encourage them to help create an environment that helps remind them to be active.
- Encourage ways to substitute sedentary behavior with activity.

Action → Maintenance

- Provide positive and contingent feedback on goal progress.
- Explore different types of activities they can do to avoid burnout.
- Encourage them to work with and even help others become more active.
- Discuss relapse prevention strategies.
- Discuss potential rewards that can be used to maintain motivation.

Group Leader Effectiveness

Separate from attempts to implement individual behavior change is the concept of group interventions to improve exercise adoption and adherence. Exercising in a group, where the instructor purposefully creates group dynamics and goals, has consistently been shown superior to exercising in a usual exercise class (where each individual functions autonomously) or exercising at home with or without contact. These outcomes highlight the value of group-based PA interventions (105).

Exercise leaders have an influence on PA participation and the psychological benefits that occur as a result of PA (80). The exercise leader and group play significant roles in SCT and SDT. An exercise leader with a socially supportive leadership style is one that provides encouragement, verbal reinforcement, praise, and interest in the individual (81). When an exercise leader has a socially supportive leadership style, individuals report greater self-efficacy, more energy, more enjoyment, stronger intentions to exercise, less fatigue, and less concern about embarrassment (106). In addition to the exercise leader, aspects of the exercise group may also influence PA participation. One such aspect is that of group cohesion, that is, a dynamic process reflected in the tendency of a group to stick together and remain united in the pursuit of its instrumental objectives and/or satisfaction of member affective needs. Five principles have been successfully used to improve cohesion and lower dropout rates among exercise groups (107,108):

- Distinctiveness — creating a group identity (*e.g.*, group name)
- Positions — giving members of the class responsibilities and roles for the group
- Group norms — adopt common goals for the group to achieve
- Sacrifice — individuals in the group giving up something for the greater good of the group
- Interaction and communication — the belief that the more social interactions that are made possible for the group, the greater the cohesion

SPECIAL POPULATIONS

An important area of exercise promotion is the proper tailoring of interventions to promote exercise behavior across diverse populations that present unique challenges. Proper tailoring requires an understanding of potential unique beliefs, values, environments, and obstacles within a population or individual. Although every individual is clearly unique, the following sections discuss behavioral considerations of some of the more common special groups with whom exercise professionals may work.

Cultural Diversity

In order to provide culturally competent care to exercisers, it is necessary to be exposed to and understand the cultural beliefs, values, and practices of the desired population. This includes but is not limited to housing, neighborhood characteristics, religion, access to resources, crime, race, ethnicity, age, ability level, and social class. Although there is homogeneity among groups, there is heterogeneity as well. For example, people of the same race may have cultural ties to another country, which may impact how their perception of and participation in physical activity. Higher levels of physical inactivity among racial/ethnic groups may be caused not only by environmental constraints but also by cultural beliefs (109). For example, African American women have cited lack of PA exposure and thus lack of role models, family responsibilities (*i.e.*, need to be the caregiver), issues related to body size (*i.e.*, larger body sizes and curves tend to be appreciated, and thus, lower perceived need for PA), and hairstyles as barriers to PA (110). Various groups may share barriers and facilitators, thus it is important to know about the individual one is working with. Including strategies that address cultural barriers may be essential in interventions focusing on a particular population. PA choices and resources are also inextricably linked to neighborhood characteristics and access to resources and can be influenced by religious and other sociodemographic factors.

Perhaps the most important characteristic of exercise interventions that target different cultures is being culturally sensitive and tailored. One common, erroneous assumption people make when culturally tailoring approaches is that they only need to translate the materials used in an intervention, such as brochures or public service announcements, into another language (109). Such superficial tailoring is not adequate. There should be an in-depth knowledge and understanding of the individual and the population that can be best achieved through meaningful involvement of community members and through research conducted by representatives of the culture. This in-depth understanding of the target population can lead to better, more appropriate recommendations.

Older Adults

There are several challenges when working with promoting the adoption and adherence of exercise among older adults (see *Chapter 6* and or *ACSM's Behavioral Aspects of Physical Activity and Exercise*) (111,112). Older adults may lack knowledge about the benefits of PA or how to set up a safe and effective exercise program; therefore, the exercise professionals need to provide some initial education (113). Although typically viewed as beneficial, social support is not necessarily positive, especially in older adults (114). Family and friends may exert negative influences by telling them to "take it easy" and "let me do it." The implicit message is that they are too old or frail to be physically active (114).

Although older adults experience many of the commonly reported barriers to PA (*e.g.*, lack of time, motivation) (84,112), there are several barriers that may take on special significance, including lack of or indifferent social support; increased social isolation; fear of falling/safety; and physical ailments such as injury, chronic illness, and poor health (84,115). Quite possibly, the largest barrier to exercise participation in older adults is the fear that exercise will cause injury, pain, and discomfort, or exacerbate existing conditions (84). In addition, older women in particular may have had little early-life exposure to PA due to social norms that were less accepting of this behavior in women. These unique barriers can be significant and require careful consideration when promoting PA and developing interventions for this population. Recommendations include finding enjoyable activities, start low and go slow if the individual lacks a history of exercise, and being aware of chronic conditions that might be present.

Individuals with Mental Illness

Approximately 20% of the U.S. adult population lives with some form of mental illness (116). Although adults with diagnosed mental health disorders are not at increased risk of harm due to exercise (see *Chapter 11*), many cite similar barriers to exercise as the general population, but depending on the disorder, may experience additional barriers as a result of their psychological and psychosomatic health. The barriers, which may be exacerbated in this population, include perceived or actual lack of resources and social support, confidence (self-efficacy), fear, motivation, and affect, in addition to side effects associated with psychiatric medications (117). Strong evidence exists to support the role of exercise in reducing both state and trait anxiety, depression, depressive symptoms in adults, and moderate evidence exists to support the benefits of exercise for adults with schizophrenia and attention deficit hyperactivity disorder (11). In adults with severe mental illnesses like major depressive disorder and schizophrenia, evidence suggests that exercise improves symptoms, cognition, and quality of life (118). Individuals with a mental illness often have trouble working up the energy or motivation to exercise, and therefore can benefit from help in finding personally enjoyable activities and setting small, realistic goals. Other recommendations include being active with others, which can improve mood and reduce sadness or anxiety, and exercising outside, as being outside has been shown to have positive effects on mood.

Youth

When working with children (see *Chapter 6*), it is important to recognize whether they are engaging in an exercise program because their parents wish them to, implying an extrinsic motivation, and thereby likely requiring tangible forms of social support (*e.g.*, transportation, payment of fees) (84). However, to help children maintain exercise behavior over their lifetime, they need help shifting toward a sense of autonomy (119) and to feel a sense of self-efficacy and behavioral control. Establishing a sense of autonomy and intrinsic motivation through the creation of a supportive environment should therefore be a high priority when fostering PA among children and youth (44). An appropriately engaged family can be important for the promotion of PA (120).

Schools are an appealing setting for implementing PA interventions, as they reach a majority of youth. Simple modifications to physical education classes (119,121), small changes during recess (122), and promoting structured PA within the classroom can increase PA (123). Physical education, recess, and classroom-based PA interventions either enhance or do not take away from academic achievement, academic behavior, and cognitive skills and attitudes (124).

Individuals with Obesity

PA decreases across body mass index categories, with individuals who are obese being the least active group (125). Although concerns about excess weight is the primary reason why many individuals with obesity adopt an exercise program (126), they may face additional, unique, weight-related barriers to engaging in PA, such as feeling physically uncomfortable while exercising, being uncomfortable with their appearance, and not wanting to exercise in front of others (127). Individuals with obesity may have had negative mastery experiences with exercise in the past and will need to enhance their self-efficacy so they believe that they can successfully exercise (128,129). Furthermore, they may be quite deconditioned and perceive even objectively moderate intensity exercise as challenging, so keeping activities fun and at an intensity that feels good may be particularly important to promote positive perceptions of PA (130). Although goals should remain self-determined, individuals with obesity may need help setting realistic weight loss goals and identifying appropriate levels of PA to help them reach those goals (131).

Individuals with Chronic Diseases and Health Conditions

PA improves symptoms associated with a number of chronic diseases and health conditions. A concern when working with individuals with many chronic diseases and health conditions is their ability to even do the exercise. This requires a focus on enhancing task self-efficacy to ensure that individuals believe that they can do what is being asked of them. Often, this may require appropriate modifications to the activity or exercise to ensure that it is safe and appropriate for the individual's current disease state and capabilities. Once individuals possess task self-efficacy, they often face barriers specifically related to their condition (84). For example, individuals with arthritis report pain, fatigue, and mobility limitations as barriers to PA participation (132,133). Those with neurological conditions (*i.e.*, muscular dystrophy, multiple sclerosis, motor neuron disease, and Parkinson disease) cite fatigue, fear of falling or losing balance, and safety due to the progression of disease as barriers (134). Being aware of the unique barriers and fears of individuals with chronic diseases and health conditions can help assure the physical activities chosen are appropriate and foster the individuals' self-efficacy.

ONLINE RESOURCES

Exercise is Medicine: http://exerciseismedicine.org
National Cancer Institute Behavioral Research Program Theories Project: http://cancercontrol.cancer.gov/brp/research/theories_project/index.html
National Physical Activity Plan: http://www.physicalactivityplan.org/
The Guide to Community Preventive Services, Behavioral and Social Approaches: http://www.thecommunityguide.org/pa

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APPENDIX

A

Common Medications

LIST OF COMMON MEDICATIONS

Appendix A is a table listing common medication categories that exercise and health care professionals are likely to encounter among individuals who are soon to be, or are, physically active. This table is not intended to be exhaustive or all-inclusive and is not designed for the determination of pharmacotherapy/medication prescription for individuals by clinicians/physicians. Rather, this listing should be viewed as a resource for exercise professionals to assist in understanding how typical hemodynamic responses to exercise may be impacted by certain medications. For a more detailed informational listing, the reader is referred to the online resources of the American Hospital Formulary Service (AHFS) Drug Information or the U.S. Food and Drug Administration and U.S. Department of Health and Human Services.

Table A.1 lists the common categories of medications with available published data regarding their influence on the response to exercise, specifically hemodynamics, the electrocardiogram (ECG), and exercise capacity. Exercise data are presented by drug category. The influence of common medications during rest and/or exercise is presented with the directional relationships when specified in the literature. *Exercise capacity* is a generic term that often was used and not defined by a specific measure in the literature. In instances in which measures of exercise capacity were reported, they are listed, that is, maximal volume of oxygen consumed per unit time ($\dot{V}O_{2max}$), endurance, performance, and tolerance, often times with no clear distinctions among them provided by the author.

TABLE A.1

Effects of Medications on Hemodynamics, the Electrocardiogram (ECG), and Exercise Capacity (1–9)

Medications	Cardiac Output	Heart Rate (HR)	Blood Pressure (BP)	ECG Changes	Exercise Capacity
I. Cardiovascular medications					
β-Blockers (BB)	↓ or ↔ Exercise	↓ Rest and exercise ↓ Rest less by intrinsic sympathomimetic activity (ISA) + BB ↓ Exercise less by cardioselective BB	↓ Rest and exercise	↓ Rest ↓ Ischemia during exercise	↑ In those with myocardial ischemia
Angiotensin-converting enzyme inhibitors (ACE-I)	↔ Exercise	↔ Exercise	↓ Rest and exercise		↔ Performance; ↑ Tolerance individuals with heart failure (HF)
Angiotensin-neprilysin inhibitors (ARNI)	↑		↓ Rest and exercise	↓ Ventricular arrhythmias	↑ Performance
Angiotensin II receptor blockers (ARB)		↓ or ↔ Rest and exercise	↓ Rest and exercise		↔
Calcium channel blockers (CCB)					
Nondihydropyridines (non-DHP)			↓ Exercise		↔ Performance and endurance; responses can be variable.
Dihydropyridine	Nifedipine: ↔ Exercise ↓ Stroke volume	↔ Exercise	↓ Exercise (greater vs. non-DHP)		↔ Performance and endurance; responses can be variable.
II. Vasodilating agents					
Nitrates		↑ Rest ↑ or ↔ Exercise	↓ Rest ↓ or ↔ Exercise	↑ Rest HR ↑ or ↔ Exercise HR	↑ Individuals with angina

				↓ Exercise ischemia	↔ Individuals without angina ↑ or ↔ Individuals with HF
α-Blockers	↔ Exercise Doxazosin: ↑ exercise at 50% $\dot{V}O_{2max}$	↔ Exercise Doxazosin: ↑ exercise at 75% $\dot{V}O_{2}$ max	↓ Exercise systolic BP (SBP) (not diastolic BP [DBP])	↓ Exercise ischemia	↔ Performance
Central α-agonist	↔ Exercise	↓ Exercise except guanabenz	↓ Exercise		Clonidine: blunts the sympathetic response to exercise; consider avoiding if exercising.
III. Antiarrhythmic agents					
				All antiarrhythmic agents may cause new or worsened arrhythmias (*i.e.*, proarrhythmic effect).	
Class I					
Quinidine		↑ or ↔ Rest and exercise	↓ or ↔ Rest	↑ or ↔ Rest HR Exercise may result in false negative test results.	↔
Disopyramide			↔ Exercise	Rest may prolong QRS and QT intervals.	
Procainamide		↔ Rest and exercise	↔ Rest and exercise	Rest may prolong QRS and QT intervals. Exercise may result in false positive test results.	↔
Propafenone		↓ Rest ↓ or ↔ Exercise	↔ Rest and exercise	↓ Rest HR ↓ or ↔ Exercise HR	↔

Class II					
BB (see Cardiovascular medications)					
Class III					
Amiodarone	↔	↓ Rest and exercise	↔ Rest ↑ Exercise	↓ Rest HR	↑ or ↔
Sotalol				↔ Exercise	
Class IV					
CCB (see Cardiovascular medications)					
Others					
Digitalis		↓ Individuals with atrial fibrillation and possibly HF Not significantly altered in individuals with sinus rhythm	↔ Rest and exercise	Rest may produce nonspecific ST-T wave changes. During exercise, may produce ST-segment depression	↑ Individuals with atrial fibrillation or HF
IV. Respiratory					
Inhaled corticosteroids		↔ Rest and exercise	↔ Exercise	↔ Exercise	↔
Bronchodilators and anticholinergics		↔ Rest and exercise	↔ Rest and exercise	Bronchodilators: ↔ rest and exercise Anticholinergics: ↑ or ↔ HR	↑ or ↔ In individuals with chronic obstructive pulmonary disease (COPD) Bronchodilators: ↔ $\dot{V}O_{2max}$
Sympathomimetics (β_2-receptor agonists)		↔ Rest and exercise	↔		↔ Performance or $\dot{V}O_{2max}$; ↑ or ↔ In individuals with COPD
Albuterol		May ↑ exercise			↔ Performance and $\dot{V}O_{2max}$
Pseudoephedrine		↔ Rest and exercise May ↑ exercise	↔ Exercise May ↑ exercise SBP	May produce premature ventricular contractions (PVC)	↔ Performance

Xanthine derivatives				Rest and exercise may produce PVCs.	
Theophylline		↑ Rest ↔ Exercise			↔ Performance and $\dot{V}O_{2max}$
Caffeine	↔	↑ Resting ↑ or ↔ exercise	↑ Exercise		↑ Endurance
Antihistamines		↑ Rest ↔ Exercise			↔ Performance and endurance
V. Hormonal					
Human growth hormone		↔ Rest and exercise	↔	↔	↑ Performance and $\dot{V}O_{2max}$
Androgenic-anabolic		↔ Rest and exercise	↑ DBP		↔ or ↑ Performance and $\dot{V}O_{2max}$
Thyroid agents		↑ Rest and exercise	↑ Rest and exercise	↑ HR May provoke arrhythmias	↔ Unless angina worsens during exercise
Levothyroxine					↑ Cardiopulmonary reserve ↔ Recovery and performance
VI. Central nervous system					
Antidepressants		↑ or ↔ Rest and exercise	↓ or ↔ Rest and exercise	Variable rest	
Antipsychotics					
Lithium		↔ Rest and exercise	↔ Rest and exercise		
Antianxiety		↑ or ↔ Rest and exercise	↓ or ↔ Rest and exercise	Variable rest	
Stimulants		↑	↑		↑ or ↔ Endurance and performance
Nicotine replacement therapy		↑	↑		↔ or ↓
Nonsteroidal anti-inflammatory drugs (NSAIDs)					↔ Performance; combined with dehydration may

			cause acute renal failure

↓, decreased; ↑, increased; ↔, not changed; $\dot{V}O_{2max}$, maximal volume of oxygen consumed per unit time.

It is important to note that exercise may impact the pharmacokinetic (*i.e.*, what the body does to the medication) and pharmacodynamic (*i.e.*, what the medication does to the body) properties of a medication, necessitating a change in (a) dose, (b) dosing interval, (c) length of time the individual takes the medication, and/or (d) the exercise prescription.

The primary sources used to extract the information in *Table A.1* are *Pharmacology in Exercise and Sports* (1) and *Sport and Exercise Pharmacology* (2). In addition, a literature search by generic drug name or class and exercise response and/or capacity was performed using PubMed and Google Scholar on or before March 1, 2019.

ONLINE RESOURCES

American Hospital Formulary Service Drug Information:
http://www.ahfsdruginformation.com
U.S. Food and Drug Administration, U.S. Department of Health and Human Services:
http://www.accessdata.fda.gov/scripts/cder/drugsatfda/index.cfm?fuseaction=Search.Search_Drug_Name

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Electrocardiogram Interpretation

APPENDIX B

The tables in *Appendix B* provide a quick reference source for electrocardiogram (ECG) recording and interpretation, with a focus on normal expectations of the ECG. Each of these tables should be used as part of the overall clinical profile when making diagnostic decisions about an individual.

TABLE B.1

Limb and Augmented Lead Electrode Placement[a]

Lead	Electrode Location and Polarity	Heart Surface Viewed
Lead I	Left arm (+), right arm (−)	Lateral
Lead II	Left leg (+), right arm (−)	Inferior
Lead III	Left leg (+), left arm (−)	Inferior
aVR	Right arm (+)	None
aVL	Left arm (+)	Lateral
aVF	Left leg (+)	Inferior

[a]Exercise modifications: The limb leads are positioned over the left and right infraclavicular region for the arm leads and over the left and right lower quadrants of the abdomen for the leg leads. This electrocardiogram (ECG) configuration minimizes motion artifacts during exercise. However, torso-placed limb leads should be noted for all ECG tracings to avoid misdiagnosis of an ECG tracing. The most common changes observed are produced by right axis deviation and standing that may obscure or produce Q waves inferiorly or anteriorly and T wave or frontal QRS axis changes even in normal people (1,2).

TABLE B.2

Precordial (Chest Lead) Electrode Placement

Lead	Electrode Placement	Heart Surface Viewed
V_1	Fourth intercostal space just to the right of the sternal border	Septum
V_2	Fourth intercostal space just to the left of the sternal border	Septum
V_3	At the midpoint of a straight line between V_2 and V_4	Anterior
V_4	On the midclavicular line in the fifth intercostal space	Anterior
V_5	On the anterior axillary line and on a horizontal plane through V_4	Lateral
V_6	On the midaxillary line and on a horizontal plane through V_4 and V_5	Lateral

Adapted from (3).

TABLE B.3

Electrocardiogram (ECG) Interpretation Steps

1. Check for correct calibration (1 mV = 10 mm) and paper speed (25 mm · s^{-1}).
2. Verify the heart rate and determine if heart rhythm is regular.
3. Measure intervals (PR, QRS, QT).
4. Determine the mean QRS axis and mean T-wave axis in the limb leads.
5. Look for morphologic abnormalities of the P wave, QRS complex, ST segment, T wave, and U wave (*e.g.*, chamber enlargement, conduction delays, infarction, repolarization changes).
6. Interpret the present ECG.
7. Compare the present ECG with previous available ECGs.
8. Offer conclusion, clinical correlation, and recommendations.

TABLE B.4

Resting Electrocardiogram: Normal Limits (4–6)

Parameter	Normal Limits	Abnormal If	Possible Interpretation(s)[a]
Heart rate	60–100 beats · min^{-1}	<60 beats · min^{-1}	Bradycardia
		>100 beats · min^{-1}	Tachycardia
P wave	<0.12 s	Broad and notched (>0.12 s) in leads I, II, aVL, and V_4–V_6 and inverted in V_1	Left atrial hypertrophy
	<2.5 mm tall	Peaked (>2.5 mm tall) in leads II, III, and aVF and upright in V_1	Right atrial hypertrophy or enlargement
		Peaked and broad in leads I, II, III, aVL, aVF, and V_4–V_6 and	Combined atrial hypertrophy

		biphasic in V_1	
PR interval	0.12–0.20 s	<0.12 s	Preexcitation (*e.g.*, W-P-W or L-G-L)
		>0.20 s	Sinus delay (*e.g.*, AV block)
QRS duration	0.06–0.10 s	If ≥0.11 s	Conduction abnormality (*e.g.*, incomplete or complete bundle branch block, W-P-W, IVCD, or electronic pacer)
QT interval	Rate dependent	QTc long	Drug effects, electrolyte abnormalities, or ischemia
		QTc short	Digitalis effect, hypercalcemia, or hypermagnesemia
QRS axis	−30 to +110 degrees	<−30 degrees	Left axis deviation (*e.g.*, hemiblock, MI)
		>+110 degrees	Right axis deviation (*e.g.*, RVH, COPD, PE, hemiblock, MI)
		Indeterminate	All limb leads transitional
T wave	Upright in leads I, II,	Upright, inverted,	Can be a normal variant; ischemia,

	and V_3–V_6; inverted in aVR; flat, inverted, or biphasic in III and V_1–V_2	flattened, or biphasic alone or with ST-segment changes	LVH, or caused by physiologic conditions (posture changes, respiration, drugs)
T axis	Generally same direction as QRS axis	The T axis (vector) is typically deviated away from the area of “mischief” (*e.g.*, ischemia, bundle branch block, or hypertrophy).	Chamber enlargement, ischemia, drug effects, bundle branch blocks, or electrolyte disturbances
ST segment	Generally at isoelectric line (PR segment) or within 1 mm	Elevation of ST segment	Normal variant (early repolarization), injury, ischemia, pericarditis, or electrolyte abnormality
	The ST segment may be elevated up to 1–2 mm	Depression of ST segment 80 ms after the J-point	Injury, ischemia, electrolyte abnormality, drug effects, or normal variant

	in leads V_1–V_4.		
Q wave	<0.04 s and <25% of R wave amplitude (exceptions: leads III and V_1)	>0.04 s and/or >25% of R wave amplitude except leads III and V_1	MI or pseudoinfarction (as from chamber enlargement, conduction abnormalities, W-P-W, COPD, or cardiomyopathy)
Transition zone	Usually between V_2 and V_4	Before V_2	Counterclockwise rotation (early transition)
		After V_4	Clockwise rotation (late transition)

[a]If supported by other electrocardiograms and related clinical criteria.

AV, atrioventricular; COPD, chronic obstructive pulmonary disease; IVCD, intraventricular conduction delay; L-G-L, Lown-Ganong-Levine syndrome; LVH, left ventricular hypertrophy; MI, myocardial infarction; PE, pulmonary embolism; QTc, QT corrected for heart rate; RVH, right ventricular hypertrophy; W-P-W, Wolff-Parkinson-White syndrome.

ONLINE RESOURCES

Jenkins D, Gerred SJ, editors. *ECGs by Example*. 3rd ed. London (United Kingdom): Churchill Livingstone; 2011 [cited 2019 Mar]. 238 p. Available from: https://ecglibrary.com/axis.html

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APPENDIX C

American College of Sports Medicine Certifications

INTRODUCTION

Exercise practitioners are becoming increasingly aware of the advantages of maintaining professional credentials. In efforts to ensure quality, reduce liability, and remain competitive, more and more employers are requiring professional certification of their exercise staff. Additionally, in efforts to improve public safety, mandates for certification by state and/or regulatory agencies (*e.g.*, licensure), as well as third-party payers, now exist. The American College of Sports Medicine (ACSM) offers four primary and four specialty certifications for exercise professionals (1).

ACSM Primary and Specialty Certifications

Primary Certifications

- ACSM Certified Group Exercise InstructorR-ball (ACSM-GEI)
- ACSM Certified Personal TrainerR-ball (ACSM-CPT)
- ACSM Certified Exercise PhysiologistR-ball (ACSM-EP)
- ACSM Certified Clinical Exercise Physiologist® (ACSM-CEP)

Specialty Certifications

- Exercise is Medicine Credential®
- ACSM/NCHPAD Certified Inclusive Fitness TrainerSM
- ACSM/ACS Certified Cancer Exercise TrainerSM
- ACSM/NPAS Physical Activity in Public Health SpecialistSM

Performance domains, complete job tasks with assigned cognitive complexity, and knowledge and skills (KSs) statements for each certification for all four primary ACSM certifications and for the four specialty certifications and credentials can be found online at https://www.acsm.org/get-stay-certified. Because every question on each of the certification examinations must refer to a specific knowledge or skill statement within the associated job task analysis (JTA), these documents provide a resource for exam preparation. *Table C.1* is a quick glance at the ACSM primary certifications populations served, eligibility criteria, and necessary competencies.

TABLE C.1

American College of Sports Medicine’s (ACSM’s) Certifications at a Glance

Certification	Primary Population Served	Eligibility Criteria	Job Definition
ACSM Certified Group Exercise Instructor®-ball	Apparently healthy individuals and those with health challenges who are able to exercise independently	• ≥18 yr • High school diploma or equivalent • Current CPR and AED certifications (must contain a live skills component) — AED not required for those practicing outside of the United States and Canada	• Works in a group exercise setting with apparently healthy individuals and those with health challenges who can exercise independently to enhance quality of life, improve health-related physical fitness, manage health risk, and promote lasting health behavior change. • Develops and leads safe and effective exercise programs using a variety of leadership techniques to foster group camaraderie, support, and

			motivation to enhance muscular fitness, flexibility, cardiorespiratory fitness, body composition, and any of the motor skills related to the domains of health-related physical fitness.
ACSM Certified Personal Trainer[R-ball]	Apparently healthy individuals and those with health challenges who are able to exercise independently	• ≥18 yr • High school diploma or equivalent • Current CPR and AED certifications (must contain a live skills component such as the American Heart Association [AHA] or the American Red Cross) — AED not required for	• Works primarily with apparently healthy individuals to enhance fitness. • Also works with individuals who have stable health challenges and are cleared to exercise independently. • Conducts basic preparticipation health screenings, lifestyle inventories, and fitness assessments for health- and skill-related components of fitness. • Assesses behavior adaptation readiness and offers

	those practicing outside of the United States and Canada	guidance in the development of realistic, client-centered goals related to health, fitness, and wellness. • Develops and administers programs designed to promote optimal cardiorespiratory fitness, muscular fitness, flexibility, and body composition as well as agility, balance, coordination, power, speed, and reaction time. • Facilitates client motivation and adherence and honors client confidentiality. • Adheres to all agreed-upon terms with each client and stays within the scope of practice of the ACSM-CPT credential; makes referrals to appropriate allied

			health professionals when clients' needs exceed the ACSM-CPT's scope of practice.
ACSM Certified Exercise Physiologist[R-ball]	Apparently healthy individuals and those with medically controlled diseases	• Bachelor's degree in an exercise science, exercise physiology, kinesiology, or exercise science–based degree (One is eligible to sit for the examination if the candidate is in the last term of a degree program.) • Current CPR and AED certifications (must contain a live skills	• Works with apparently healthy clients and those with medically controlled diseases to establish safe and effective exercise and healthy lifestyle behaviors to optimize both health and quality of life. • Conducts preparticipation health screenings, submaximal graded exercise tests, strength, flexibility, and body composition assessments. • Develops and administers programs designed to enhance cardiorespiratory fitness, muscular fitness, balance,

		component such as the AHA or the American Red Cross) — AED not required for those practicing outside of the United States and Canada	and range of motion. • May be self-employed or employed in commercial, community, studio, worksite health promotion, university, and hospital-based fitness settings.
ACSM Certified Clinical Exercise Physiologist®	Apparently healthy individuals and those with cardiovascular, pulmonary, metabolic, orthopedic, musculoskeletal, neuromuscular, neoplastic, immunologic, and hematologic diseases	• Master's degree in clinical exercise physiology or equivalent and 600 h of hands-on clinical experience • OR bachelor's degree in exercise science, exercise physiology, or equivalent	• Utilize prescribed exercise, basic health behavior interventions, and promote physical activity for individuals with chronic diseases or conditions; examples include, but are not limited to, individuals with cardiovascular, pulmonary, metabolic, orthopedic, musculoskeletal, neuromuscular, neoplastic, immunologic, and

	and 1,200 h of hands-on clinical experience • Basic life support provider or CPR for the professional rescuer certification (with hands-on practical skills component); AED not required for those practicing outside of the United States and Canada	hematologic diseases. • Provides primary and secondary prevention strategies designed to improve, maintain, or attenuate declines in fitness and health in populations ranging from children to older adults. • Provides exercise screening, exercise and fitness testing, exercise prescriptions, exercise and physical activity counseling, exercise supervision, exercise and health education/promotion, and measurement and evaluation of exercise and physical activity–related outcome measures. • Works individually or as part of an

		interdisciplinary team in a clinical, community, or public health setting. • May receive referrals from a referring practitioner to implement exercise protocols. • Guided by published professional guidelines and standards and applicable state and federal laws and regulations.

ACSM-CPT, ACSM Certified Personal Trainer[R-ball]; AED, automated external defibrillators; CPR, cardiopulmonary resuscitation.

ONLINE RESOURCES

American College of Sports Medicine Certifications: https://www.acsm.org/get-stay-certified

American College of Sports Medicine Certifications Job Task Analysis: http://certification.acsm.org/exam-content-outlines

American College of Sports Medicine Code of Ethics for Certified and Registered Professionals: https://www.acsm.org/acsm-membership/membership/join/acsm-member-code-of-ethics

Clinical Exercise Physiology Association: https://www.acsm-cepa.org

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Metabolic Calculations and Methods for Prescribing Exercise Intensity

APPENDIX D

METABOLIC CALCULATIONS

Measuring oxygen consumption ($\dot{V}O_2$) requires equipment that is expensive and sophisticated and trained professional staff who can perform the test as well as interpret the data; it does not lend itself to large numbers of subjects or patients. When it is not possible or feasible to measure $\dot{V}O_2$, reasonable estimates of the $\dot{V}O_2$ during exercise can be made from regression equations derived from measured $\dot{V}O_2$ during exercise on ergometric devices and while walking and running. In this regard, the American College of Sports Medicine (ACSM) developed equations for estimating $\dot{V}O_2$ during *steady-state*, *submaximal* aerobic exercise as described in this Appendix (1). More recently, the Fitness Registry and the Importance of Exercise National Database (FRIEND) was created to meet the clinical need to establish normal standards for *maximal exercise capacity* (maximal volume of oxygen consumed per unit time [$\dot{V}O_{2max}$]) for a healthy (without known coronary vascular or pulmonary diseases) and diverse (age, sex, race, body mass, geographic distribution) population, composed of thousands of participants (2). Furthermore, this registry has been utilized to develop equations that provide an accurate estimate of $\dot{V}O_2$ at *maximal exercise capacity* ($\dot{V}O_{2max}$) (3-5). See *Table D.2*.

Estimation of Energy Expenditure: The ACSM Metabolic Calculations

Table D.1 presents the ACSM metabolic equations for the *gross* or total oxygen cost, expressed in $mL \cdot kg^{-1} \cdot min^{-1}$, of walking, running, leg ergometry, arm ergometry, and stepping. For each prediction equation, there are essential known physiologic constants, such as how much oxygen is required to move the body horizontally (walking on the flat) and vertically (walking up a grade or hill), or the oxygen cost of pedaling at no resistance (1). Detailed explanations, examples, and applications are reviewed elsewhere (*Figure D.1*) (1,6). Moreover, for exercise prescription purposes, these equations may be used to determine the required exercise intensity associated with a desired level of energy expenditure (1). When using these equations to determine caloric expenditure, $\dot{V}O_2$ should be used by subtracting the resting $\dot{V}O_2$, or 3.5 $mL \cdot kg^{-1} \cdot min^{-1}$. This value has been used for the resting metabolic rate (RMR) for many years (7,8) and has been termed a metabolic equivalent (MET). METs have been used as a tool in epidemiologic studies that easily reflect a standard intensity of a wide variety of activities by dividing the measured energy cost ($\dot{V}O_2$ [$mL \cdot kg^{-1} \cdot min^{-1}$]) of the activities by 3.5 $mL \cdot kg^{-1} \cdot min^{-1}$ (7). Recently, there has been concern that 3.5 $mL \cdot kg^{-1} \cdot min^{-1}$ overestimates measured RMRs and is influenced by age, body mass, and sex (8). Furthermore, an equation has been developed resulting in a "corrected MET" value (9). The corrected MET may be appropriate for exercise prescription and to estimate one's energy expenditure (7,9). However, it is unlikely that the value of 3.5 $mL \cdot kg^{-1} \cdot min^{-1}$ introduces meaningful error as used in the metabolic equations. The ACSM metabolic equations should *not* be used to predict $\dot{V}O_{2max}$, especially in a clinical setting where an accurate estimate of maximal exercise capacity is necessary for therapeutic and prognostic applications. These equations were not developed to equate to a value of $\dot{V}O_2$ measured during progressive, non–steady-state, maximal exercise tests (4,5). Additionally, these equations only utilized a limited number of rather homogeneous subjects that are not representative of the population undergoing cardiopulmonary exercise testing (CPX) (4,5).

TABLE D.1

Metabolic Calculations for the Estimation of Gross Energy Expenditure (■O_2 [mL · kg^{-1} · min^{-1}]) during Common Physical Activities

Sum of Resting + Horizontal + Vertical/Resistance Components				
Mode	**Resting component**	**Horizontal component**	**Vertical component/resistance component**	**Limitations**
Walking	**3.5**	0.1 × speed[a]	1.8 × speed[a] × grade[b]	Most accurate for speeds of 1.9–3.7 mi · h^{-1} (50–100 m · min^{-1})
Running	**3.5**	0.2 × speed[a]	0.9 × speed[a] × grade[b]	Most accurate for speeds >5 mi · h^{-1} (134 m · min^{-1})
Stepping	**3.5**	0.2 × steps · min^{-1}	1.33 × (1.8 × step height[c] × steps · min^{-1})	Most accurate for stepping rates of 12–30

				steps · min^{-1}
Leg cycling	**3.5**	**3.5**	(1.8 × work rate[d])/body mass[e]	Most accurate for work rates of 300–1,200 kg · m · min^{-1} (50–200 W)
Arm cycling	**3.5**	—	(3 × work rate[d])/body mass[e]	Most accurate for work rates between 150 and 750 kg · m · min^{-1} (25–125 W)

[a]Speed in m · min^{-1}.

[b]Grade is grade percentage expressed in decimal format (*e.g.*, 10% = 0.10).

[c]Step height in m.

Multiply by the following conversion factors:

lb to kg: 0.454; in to cm: 2.54; ft to m: 0.3048; mi to km: 1.609; mi · h^{-1} to m · min^{-1}: 26.8; kg · m · min^{-1} to W: 0.164; W to kg · m · min^{-1}: 6.12; $\dot{V}O_{2max}$ L · min^{-1} to kcal · min^{-1}: 4.9; $\dot{V}O_2$ MET to mL · kg^{-1} · min^{-1}: 3.5.

[d]Work rate in kilogram meters per minute (kg · m · min^{-1}) is calculated as resistance (kg) × distance per revolution of flywheel × pedal frequency per minute. Note: Distance per revolution is 6 m for Monark leg ergometer, 3 m for the Tunturi and BodyGuard ergometers, and 2.4 m for Monark arm ergometer.

[e]Body mass in kg.

MET, metabolic equivalent; $\dot{V}O_2$, volume of oxygen consumed per unit of time; $\dot{V}O_{2max}$, maximal volume of oxygen consumed per unit time.

Adapted from (1,6).

Using metabolic calculations (see Table D.1) to determine target work rate ($kg \cdot m^{-1} \cdot min^{-1}$) on a Monark leg cycle ergometer

Available data:

A woman 42 yr of age
Weight: 190 lb (86.4 kg)
Height: 70 inches (177.8 cm)

Desired $\dot{V}O_2$: 18 $kg \cdot m^{-1} \cdot min^{-1}$; determined from the exercise prescription
Formula: $\dot{V}O_2 = 7.0 + (1.8 \times \text{work rate}) / \text{body mass}$

1. Calculate work rate on cycle ergometer:
   $\dot{V}O_2 = 7.0 + (1.8 \times \text{work rate}) / \text{body mass}$
   $18\ mL \cdot kg^{-1} \cdot min^{-1} = 7.0 + (1.8 \times \text{work rate}) / 86.4\ kg$
   $11 = (1.8 \times \text{work rate}) / 86.4$
   $950.4 = 1.8 \times \text{work rate}$
   $528 = \text{work rate}$

   Work rate = $528\ kg \cdot m^{-1} \cdot min^{-1} = 86.6\ W$

Using metabolic calculations (see Table D.1) to determine % grade during walking on a treadmill

Available data:

A man 54 yr of age who is moderately physically active
Weight: 190 lb (86.4 kg)
Height: 70 inches (177.8 cm)

Desired walking speed: 2.5 $mi \cdot hr^{-1}$ (4 $km \cdot hr^{-1}$; 67 $m \cdot min^{-1}$)
Desired MET: 5 METs; determined from the exercise prescription
Formula: $\dot{V}O_2 = 3.5 + (0.1 \times \text{speed}) + (1.8 \times \text{speed} \times \%\ \text{grade})$

1. Determine target $\dot{V}O_2$:
   Target $\dot{V}O_2 = \text{MET} \times 3.5\ mL \cdot kg^{-1} \cdot min^{-1}$
   Target $\dot{V}O_2 = 5 \times 3.5\ mL \cdot kg^{-1} \cdot min^{-1} = 17.5\ mL \cdot kg^{-1} \cdot min^{-1}$

2. Determine treadmill grade:
   $\dot{V}O_2 = 3.5 + (0.1 \times \text{speed}) + (1.8 \times \text{speed} \times \%\ \text{grade})$
   $17.5\ mL \cdot kg^{-1} \cdot min^{-1} = 3.5 + (0.1 \times 67\ m \cdot s^{-1}) + (1.8 \times 67\ m \cdot s^{-1} \times \%\ \text{grade})$
   $14 = (0.1 \times 67\ m \cdot s^{-1}) + (1.8 \times 67\ m \cdot s^{-1} \times \%\ \text{grade})$
   $14 = 6.7 + (120.6 \times \%\ \text{grade})$
   $7.3 = 120.6 \times \%\ \text{grade}$
   $0.06 = \%\ \text{grade}$

   % grade = 6%

Determination of net energy expenditure (EE), in kcals, for 30 min of exercise

1. Determine net $\dot{V}O_2$:
   Net $\dot{V}O_2$ = gross $\dot{V}O_2$ − resting $\dot{V}O_2$
   Net $\dot{V}O_2 = 17.5\ mL \cdot kg^{-1} \cdot min^{-1} - 3.5\ mL \cdot kg^{-1} \cdot min^{-1} = 14\ mL \cdot kg^{-1} \cdot min^{-1}$

2. Convert relative rate of $\dot{V}O_2$ to absolute rate of $\dot{V}O_2$:
   Absolute rate of $\dot{V}O_2$ in $L \cdot min^{-1}$ = ($\dot{V}O_2$ in $mL \cdot kg^{-1} \cdot min^{-1}$) (body mass) / 1,000
   Absolute rate of $\dot{V}O_2$ in $L \cdot min^{-1}$ = (14.0) (86.4) / 1,000 = 1.21 $L \cdot min^{-1}$

3. Convert absolute rate of $\dot{V}O_2$ in $L \cdot min^{-1}$ to $kcal \cdot min^{-1}$:
   Net caloric expenditure in $kcal \cdot min^{-1} = 1.21\ L \cdot min^{-1} \times 4.9\ kcal \cdot L^{-1} = 5.9\ kcal \cdot min^{-1}$
   Net caloric expenditure for 30 min = $5.9\ kcal \cdot min^{-1} \times 30\ min = 177\ kcal$

Figure D.1 Examples of the application of selected metabolic equations. MET, metabolic equivalent; $\dot{V}O_2$, volume of oxygen consumed per unit time.

Estimating $\dot{V}O_{2max}$: The FRIEND Registry Prediction Equations

Participants in the FRIEND registry completed a CPX that directly measured maximal oxygen uptake ($\dot{V}O_{2max}$) (peak respiratory exchange ratio [RER] >1.0) by open-circuit spirometry in one of eight participating laboratories that used valid and calibrated equipment and testing procedures administered by experienced personnel (2-5). The prediction equations developed from the FRIEND registry to estimate $\dot{V}O_{2max}$ (*Table D.2*) are clinically relevant as they have demonstrated accuracy and a lower average error between directly measured $\dot{V}O_{2max}$ and predicted $\dot{V}O_{2max}$ when compared to commonly used equations (3-5).

TABLE D.2

Equations for Predicting Maximal Oxygen Uptake (■O_2 [mL · kg^{-1} · min^{-1}])

Activity	Equation	Standard Error of Estimate
Cycle ergometry (5)	Non–sex specific: $\dot{V}O_{2max}$ = 1.74 × [Watts × 6.12 / body weight (kg)] + 3.5 Men: $\dot{V}O_{2max}$ = 1.76 × [Watts × 6.12 / body weight (kg)] + 3.5 Women: $\dot{V}O_{2max}$ = 1.65 × [Watts × 6.12 / body weight (kg)] + 3.5 Formula for correcting the overestimation of METs by previously using the ACSM cycle formula. Non–sex specific: CORRECTED METs = ACSM-derived METs − 0.06 × [Watts × 6.12 / body weight (kg)] − 3.5	None provided
Treadmill (4) walking or running	Non–sex specific: $\dot{V}O_{2max}$ = speed (m · min^{-1}) × (0.17 + fractional grade × 0.79) + 3.5	None provided
Cycle ergometry and treadmill (3)	Gender specific: $\dot{V}O_{2max}$ = 45.2 − (0.35 × age) − [10.9 × sex (male = 1; female = 2)] − [0.15 × weight (lb)] + [0.68 × height (inches)] −	6.6 mL · kg^{-1} · min^{-1}

	[0.46 × exercise mode (treadmill = 1; cycle ergometer = 2)]	
Nonexercise (2)	Sex specific: gross $\dot{V}O_{2max}$ = 79.9 − (0.39 × age) − [13.7 × sex (0 = male; 1 = female)] − [0.127 × weight (lb)]	7.2 $mL \cdot kg^{-1} \cdot min^{-1}$

ACSM, American College of Sports Medicine; METs, metabolic equivalents $\dot{V}O_{2max}$, maximal volume of oxygen consumed per unit time.

APPLICATION OF VARIOUS METHODS FOR PRESCRIBING EXERCISE INTENSITY

Intensity is a fundamental element of the physical activity or exercise prescription. Intensity is measured as a percent of maximal capacity and more accurately, as a percent of $\dot{V}O_2$ reserve (6). Monitoring this requires the use of a surrogate measure that is more easily obtained such as heart rate, workload, or perceived exertion (6). With regard to the use of maximal heart rate (HR_{max}), when it is not determined from a maximal exercise test, it is more accurately estimated using equations found in *Table 5.3* rather than by using the traditional equation (HR_{max} = 220 − age). Also, the heart rate reserve method is a more accurate way of establishing a target heart rate rather than using a percent of HR_{max} (6). *Figure D.2* provides examples of methods used to monitor intensity.

Heart rate reserve (HRR) method

Available test data:

HR_{rest}: 70 beats · min^{-1}
HR_{max}: 180 beats · min^{-1}

Desired exercise intensity range: 50%–60%
Formula: target heart rate (THR) = $[(HR_{max} - HR_{rest}) \times \%\text{ intensity}] + HR_{rest}$

1. Calculation of HRR:
   $HRR = (HR_{max} - HR_{rest})$
   $HRR = (180\text{ beats} \cdot \text{min}^{-1} - 70\text{ beats} \cdot \text{min}^{-1}) = 110\text{ beats} \cdot \text{min}^{-1}$

2. Determination of exercise intensity as %HRR:
   Convert desired %HRR into a decimal by dividing by 100
   $\%HRR = \text{desired intensity} \times HRR$
   $\%HRR = 0.5 \times 110\text{ beats} \cdot \text{min}^{-1} = 55\text{ beats} \cdot \text{min}^{-1}$
   $\%HRR = 0.6 \times 110\text{ beats} \cdot \text{min}^{-1} = 66\text{ beats} \cdot \text{min}^{-1}$

3. Determine THR range:
   $THR = \%HRR + HR_{rest}$
   To determine lower limit of THR range:
   $THR = 55\text{ beats} \cdot \text{min}^{-1} + 70\text{ beats} \cdot \text{min}^{-1} = 125\text{ beats} \cdot \text{min}^{-1}$
   To determine upper limit of THR range:
   $THR = 66\text{ beats} \cdot \text{min}^{-1} + 70\text{ beats} \cdot \text{min}^{-1} = 136\text{ beats} \cdot \text{min}^{-1}$
   THR range: 125 beats · min^{-1} to 136 beats · min^{-1}

$\dot{V}O_2$ reserve ($\dot{V}O_2R$) method

Available test data:

$\dot{V}O_{2max}$: 30 mL · kg^{-1} · min^{-1}
$\dot{V}O_{2rest}$: 3.5 mL · kg^{-1} · min^{-1}

$\dot{V}O_{2rest}$: 3.5 mL · kg^{-1} · min^{-1}

Desired exercise intensity range: 50%–60%
Formula: Target $\dot{V}O_2 = [(\dot{V}O_{2max} - \dot{V}O_{2rest}) \times \%\text{ intensity}] + \dot{V}O_{2rest}$

1. Calculation of $\dot{V}O_2R$:

$\dot{V}O_2R = \dot{V}O_{2max} - \dot{V}O_{2rest}$
$\dot{V}O_2R = 30\text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1} - 3.5\text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$
$\dot{V}O_2R = 26.5\text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$

2. Determination of exercise intensity as $\%\dot{V}O_2R$:

Convert desired intensity ($\%\dot{V}O_2R$) into a decimal by dividing by 100
$\%\dot{V}O_2R = \text{desired intensity} \times \%\dot{V}O_2R$
Calculate $\%\dot{V}O_2R$
$\%\dot{V}O_2R = 0.5 \times 26.5\text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1} = 13.3\text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$
$\%\dot{V}O_2R = 0.6 \times 26.5\text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1} = 15.9\text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$

3. Determine target $\dot{V}O_2R$ range:

$(\%\dot{V}O_2R) + \dot{V}O_{2rest}$
To determine the lower target $\dot{V}O_2$ range:
Target $\dot{V}O_2 = 13.3\text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1} + 3.5\text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1} = 16.8\text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$
To determine upper target $\dot{V}O_2$ range:
Target $\dot{V}O_2 = 15.9\text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1} + 3.5\text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1} = 19.4\text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$
Target $\dot{V}O_2$ range: 16.8 mL · kg^{-1} · min^{-1} to 19.4 mL · kg^{-1} · min^{-1}

4. Determine MET target range (optional):

1 MET = 3.5 mL · kg^{-1} · min^{-1}

Calculate lower MET target:
1 MET / 3.5 mL · kg^{-1} · min^{-1} = X MET / 16.8 mL · kg^{-1} · min^{-1}
X MET = 16.8 mL · kg^{-1} · min^{-1} / 3.5 mL · kg^{-1} · min^{-1} = 4.8 METs

Calculate upper MET target:
1 MET / 3.5 mL · kg^{-1} · min^{-1} = X MET / 19.4 mL · kg^{-1} · min^{-1}
X MET = 19.4 mL · kg^{-1} · min^{-1} / 3.5 mL · kg^{-1} · min^{-1} = 5.5 METs

5. Identify physical activities requiring energy expenditure within the target range from compendium of physical activities (7,9).

$\%HR_{max}$ (measured or estimated) method:

Available data:

A man 45 yr of age

Desired exercise intensity: 70%–80%
Formula: THR = $HR_{max} \times$ desired %

Calculate estimated HR_{max} (if measured HR_{max} not available):
$HR_{max} = 207 - (0.7 \times \text{age})$
$HR_{max} = 207 - (0.7 \times 45)$
$HR_{max} = 207 - 32 = 175$ beats · min^{-1}

1. Determine THR range:

THR = Desired % $\times HR_{max}$

Convert desired % HR_{max} into a decimal by dividing by 100
Determine lower limit of THR range:
THR = 175 beats · min^{-1} × 0.70 = 123 beats · min^{-1}
Determine upper limit of THR range:
THR = 175 beats · min^{-1} × 0.80 = 140 beats · min^{-1}

THR range: 123 to 140 beats · min^{-1}

%$\dot{V}O_2$max (measured or estimated) method

Available data:

A woman 45 yr of age
Estimated $\dot{V}O_{2max}$: 30 mL · kg^{-1} · min^{-1}

Desired $\dot{V}O_2$ range: 50%–60%
Formula: $\dot{V}O_{2max}$ × desired %

Determine target $\dot{V}O_2$ range:

Target $\dot{V}O_2$ = Desired % × $\dot{V}O_{2max}$
Convert desired intensity (%$\dot{V}O_2$) into a decimal by dividing by 100
Determine lower limit of target $\dot{V}O_{2max}$ range
Target $\dot{V}O_2$ = 0.50 × 30 mL · kg^{-1} · min^{-1} = 15 mL · kg^{-1} · min^{-1}

Determine upper limit of target $\dot{V}O_{2max}$ range
Target $\dot{V}O_2$ = 0.60 × 30 mL · kg^{-1} · min^{-1} = 18 mL · kg^{-1} · min^{-1}

Target $\dot{V}O_2$ range: 15 mL · kg^{-1} · min^{-1} to 18 mL · kg^{-1} · min^{-1}

Figure D.2 Examples of the application of various methods for prescribing exercise intensity. HR_{max}, maximal heart rate; HR_{rest}, resting heart rate; MET, metabolic equivalent; $\dot{V}O_2$, volume of oxygen consumed per unit of time; $\dot{V}O_{2max}$, maximal volume of oxygen consumed per unit of time; $\dot{V}O_2R$, percentage of oxygen uptake reserve; $\dot{V}O_{2rest}$, resting volume of oxygen consumed per unit of time. Adapted from (1,6).

ONLINE RESOURCES

Compendium of Physical Activities: https://sites.google.com/site/compendiumofphysicalactivities/home
Youth Compendium of Physical Activities: https://www.nccor.org/nccor-tools/youthcompendium/

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APPENDIX

E

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