FUNDAMENTALS OF SPECIAL STRENGTH-TRAINING IN SPORT

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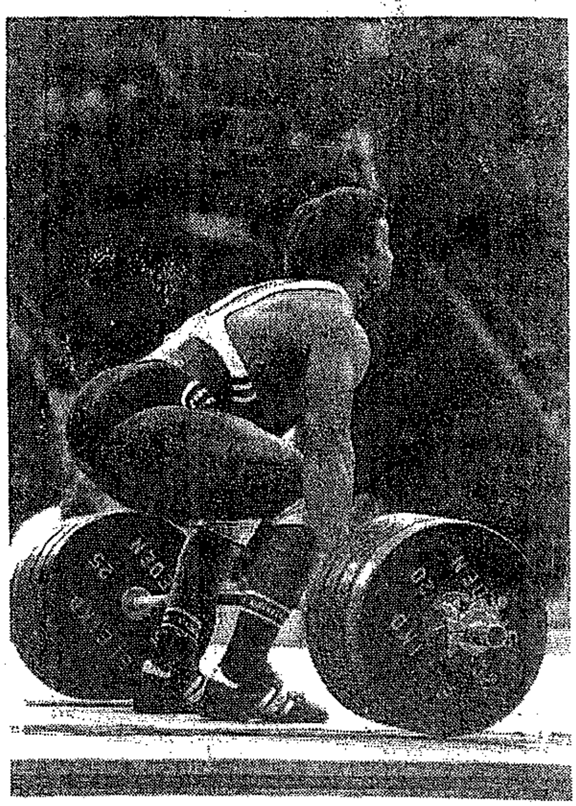
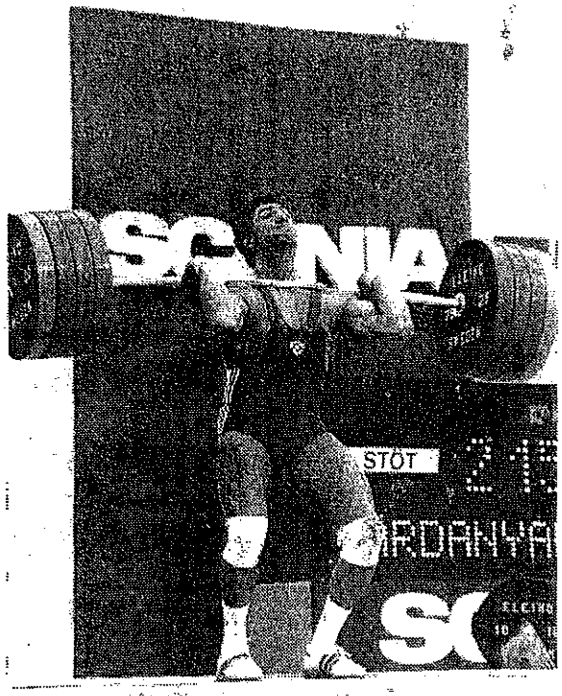
Основы специальной силовой подготовки в спорте

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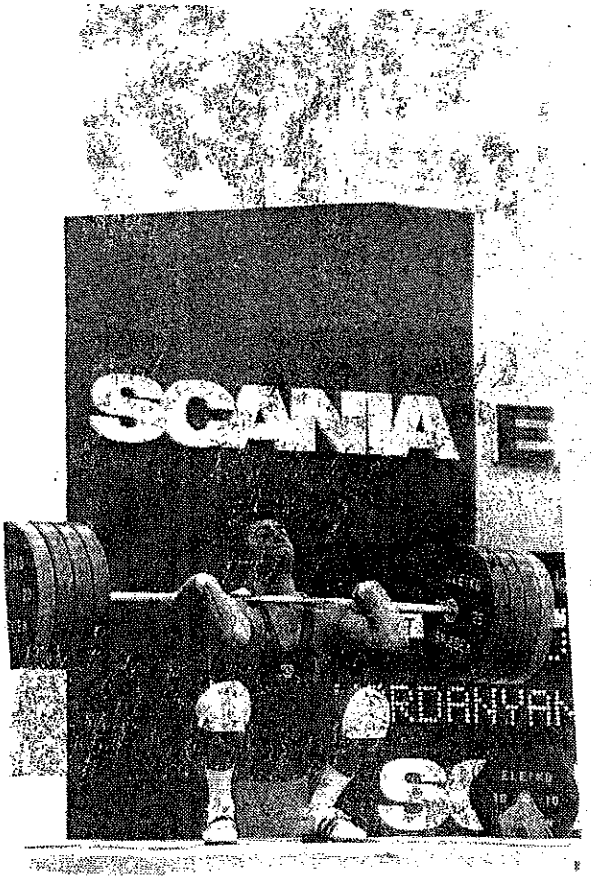
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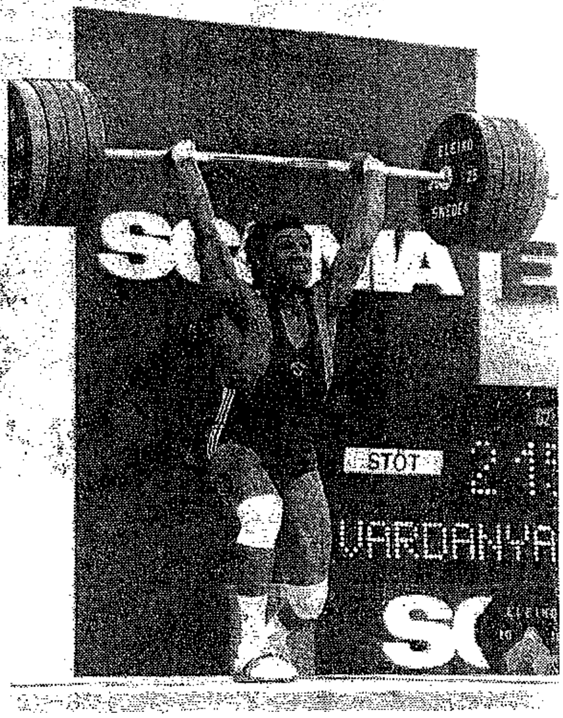
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Fundamentals of Special Strength-Training in Sport

by

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Table of Contents

Chapter I

The Role and Place of Special-Strength Training in the Process of Attaining Sport Mastery

Strength training is important for successful sport preparation. However, such an assertion remains only a declaration if a concrete methodical principle, specifying the role and place of strength-training in the training process is not formulated (in the yearly cycle and its separate stages as well as in the long-term).

In recent years considerable experience in the use of the means of special strength-training has been gained to be sufficiently analyzed and some general conclusions reached. However, it has not been that significant to form the basis for the methodological strength-training of athletes. The role and place of special strength-training can be objectively established only through a basic scientific search, specifically oriented in two directions: first, further study of the laws governing the training of man's organism and finding valid means of realizing his potential; second, an intensive study of the objective laws determining the long-term, developmental, process of attaining sport mastery (P.A.S.M.).

The first direction of scientific search already has found a wealth of factual material. Interest in the second direction has come quite recently. However, this material is still rather limited (that which has already been obtained), but it enables one to formulate important methodological principles concerning a sportsman's special strength-training.

In considering further some of the laws governing the process of attaining sport mastery we find an ingenious connection between the problem of an athlete's special strength and the determination of its role and place in the long-term process of training.

1.1 Regularities in the Functional Perfectioning of Movements

-- Movement -- this is that real phenomenon which is the basis for sport activity and its composition. Athletic tasks are resolved by means of movement. Movements are those objectives which are directly or indirectly managed by the complex of training influences in the course of the long-term preparation of athletes.

The functional perfectioning of athletic movements in the process of long-term training is realized primarily through raising the athlete's motor potential and the ability to fully utilize this potential for the solution of concrete motor tasks.

The development of motor potential is connected with the functional perfectioning of the organism as a whole, but there is a definite regularity in the manner in which its main organs and systems participate immediately in the resolution of motor tasks, during the functional perfectioning of the organism.

The ability to fully and effectively utilize one's motor potential for achieving success is the essence of sport-technical mastery. This ability is realized by means of a concrete system of movements and appropriate criteria, the composition and organization of which are determined by the type of athletic activity and the rules of competition. The process of attaining sport-technical mastery as a whole is a phenomenon of exceptional complexity. It is therefore appropriate to limit one's study only to those regularities in the perfectioning of movement which are connected with its energetic execution, mainly through muscular strength as well as from biomechanically appropriate spatial-time organization.

1.1.1 Raising the Working-Effect of Movement

The working-effect of an athletic movement is the result of man's active interaction with the objects in the external environment. The speed and direction of movement depends upon the character of the force developed.

If the form of movement is abstracted into its concrete direction, the working organs, its execution and finally the regime of muscular work, then the nature of the force developed can be graphically depicted F(t). In the overwhelming majority of athletic movements the beginning and end of the force developed lies on the abscissa (figure 1), because the movement begins and ends with zero velocity. The working-effect of the effort is determined by the impulse force (I=Ft) i.e., the area under the curve F(t), where the largest portion of the weight overcome (P) lies. An increase in the working-effect of the movement is realized in principle, by increasing this area which is, strictly speaking, the goal of the functional perfectioning of athletic movement.

As sport mastery increases the coordination structure of the expressed effort undergoes specific time and spatial changes which can be clearly displayed even within a relatively short period of training. For example, the F(t) and F(s), the explosive force (explosive leg movement in a seated position) obtained at the beginning and end of 6 months of training for one subject are graphically depicted in figure 2. Their coincidence on the ordinate corresponds to the instant when the magnitude of the force is equal to the weight of the load displaced. It is easy to see that the F(t) graph depicts a shortening of the time expended equal to the amount of weight displaced, an increase in the maximum effort; shows the instant maximum effort is displaced close to the beginning of working muscular tension; and finally a shortening of the general duration of the effort. The maximum effort is characteristically shifted to the beginning of the movement in graph F(s). The obvious reason for the increase in the area under the F(t) curve is the greater amount of weight (P) displaced.

The changes in the character of the graph is a reflection of the general regularities of the perfectioning of athletic movement which were revealed in a number of studies with athletes of different specialization and qualification; utilizing different regimes of muscular work as well as the same sportsman during the course of training for different lengths of time.

On the basis of the experimental data obtained, it can be assumed that in the process of long-term training the perfectioning of athletic movement proceeds in the following way (figure 3): initially there is a relatively uniform increase in force (in comparison with the initial level-1) over the course of the movement, i.e., timewise (figure 3,A; curve 2), with an insignificant decrease in its duration; then a significant increase in maximum force and a noticeable decrease in the duration of the movement (3); and finally there is an increase in the force developed at the beginning of the working-effort with some increase in its maximum, and a decrease in the time expended to achieve the latter.

The change in the dynamics of an athletic movement, relative to its working amplitude, observes a regular sequence (figure 3,b). The movement's dynamic mechanism initially is subject to the shifting changes in the magnitude of force over the entire working amplitude (1); which is associated first, with insufficient muscular strength and second, with the inability to utilize it rationally. Then, with exercise, maximum dynamic force increases and there is a tendency towards localization in the working amplitude (2); which can concern any part of the working amplitude depending upon the resolution of movement's tasks. In ballistic types of speed-strength movements where there is a relatively small resistance, the force is concentrated at the beginning portion of the working amplitude (3). The force at the beginning of the movement is expressed to a lesser degree when the resistance is significant. In this instance there is a tendency to develop force quickly. Then there is some increase in it until it reaches maximum in the middle of the second part of the working amplitude.

Thus, the perfectioning of the working-effect is associated with the display of a large maximum external force in a shorter period of time. This is the only means possible which previous argumentative, logical analysis (Y. V. Verkhoshansky, 1961, 1963) corroborated observation of variations in the dynamics of movements of athletes of different qualification (V. N. Papysheva, 1966; K. G. Gomberazde, 1970; V. G. Semyenov, 1970; V. V. Tatyan, 1974, and others). True, different regimes and external conditions of muscular work in athletics undoubtedly have an influence on the manifestation of this regularity. Thus, in movements associated with overcoming significant external resistance (gymnastic elements, wrestling, weightlifting) the perfectioning of the working-effect is realized primarily by the increase in the maximum external force developed and some shortening of time taken for its display (figure 4).

In ballistic movements, fencing, and some aspects of throwing) perfectioning of the working-effect is associated with the concentration of force at the beginning of the movement's amplitude, i.e., with a significant increase in maximum force it is shifted closer to the beginning of the movement and there is a shortening of the time expended for its achievement (figure 5).

In exercises with a clearly expressed combination of muscular work regimes, the active working force is preceded by a phase of muscular stretching (jumping in track and field, figure skating, acrobatics). Thus, the qualitative perfectioning of the movement is realized by improving the muscles' capacity to express great force at the instant there is a switching from yielding to overcoming work. The rapid switch from stretching to contracting causes some decrease in the magnitude of the working amplitude, i.e., there is a decrease in the angle of the working joint in flexion (figure 6).

The working-effect in cyclic exercises (running, swimming and rowing) is raised by improving the ability to quickly express maximum force during the deep and rapid muscular relaxation in the passive phase of the movement. There is a simultaneous increase in the relative duration of the relaxation phase and a shortening of the absolute duration of the cycle (figure 7).

Thus, in the course of atttaining sport mastery, the process of raising the work-effect of the movement is independent of the regime; and the external conditions of the working of the motor apparatus occurs with a specific regularity. This regularity is principally expressed by an increased maximum working force, displacement of the instant of achieving maximum force to the beginning of the working muscular tension, an increase in the working amplitude of the movement and a shortening of its time of execution. The magnitude of these changes are peculiar to the type of sport.

1.1.2 Functional Perfectioning of the Motor Structure of Athletic Movements

The effectiveness of movement is associated first of all with the appropriate utilization of the working mechanisms of a man's body, which are functional components of the motor apparatus; providing the output of mechanical energy and its effective utilization in accordance with external conditions. Such working mechanisms are complex and are inherited over a long period in the evolution of man's motor functions. Sport training adds nothing new to them. It only leads them to a high level of perfection, improves their coordinational relationships and increases energy potentials.

The working mechanisms of man's body include: the pulling force of muscles transformed into external force with bone leverage; the synergistic and antagonistic relationships of the muscle groups at the joints and the musculo-skeletal system as a whole; tonic and tendon-ligamentous reflexes; the elastic qualities of muscles allow the accummulation and the utilization of additional elastic energy; the dominance mechanism, contributing to the strengthening of a basic movement by drawing impulses from additional collateral movements; the rational, sequential inclusion of muscles into the work with different functional qualities; the tonus of the muscular system.

From a biomechanical standpoint, it is appropriate that one should consider a motor complex that is organized in with the anatomical-functional peculiarities of the body and permits (with maximum effectiveness) one to utilize the inherent working mechanisms under concrete conditions, to solve motor tasks.

The body's working mechanisms determine the form of the interaction during the process of solving this or that motor task; and as a result of systematic training, combine in a rational functioning system which secures a high working-effect.

It is convenient to study the functional properties of the body's working mechanisms and their basic tendencies toward perfectioning in the course of exercise at the level of the kinematic pair (the two actively combine adjacent links), the kinematic chain (sequential combination of a number of links) and the kinematic system (aggregate of kinematic chains).

The perfectioning of movement at the kinematic pair level is dependent upon its linking purpose; or with the development of the ability to express large motor force; or with the execution of movement with large angular speed; or with these and others simultaneously. The nature and direction of qualitative perfectioning of movement are determined by the anatomical pecularities of man's muscle-bone apparatus.

Facts accummulated from many studies indicate that in all of the diverse isolated single-joint movements, changes in strength are apparently dependent upon the role and functions of the joint mechanism and the relative disposition of the body's links (see the reviews of V. M. Zatsiorsky, 1966; Y. V. Verkhoshansky, 1970). Changes in joint angle change the conditions of muscular work: the length and angle of pull are changed. Muscular strength and leverage are altered, and consequently, so is the rotational moment force of the muscles. Therefore, the maximum external force developed by the muscles corresponds to a specific (in each concrete case) joint angle. Thus, maximum force is achieved at a joint angle of 90 for isolated elbow flexion, at 120 for extension at the elbow joint, at 60-70 for extension at the shoulder joint and at an angle of 60 for extension at the knee joint. Trained athletes can express maximum force at a number of angles close together (S. A. Kosilov, 1965; V. F. Dorofyev, 1966; T. Hansen, I. Lindhard, 1923; D. Wilkie, 1950).

The graphic dependence of strength on joint angle can be classified into 3 types: the ascending, descending (maximal and minimal forces corresponding to the extreme parts of the angular amplitude of joint movement, figure 8, curve F) and the ascending-descending (minimal force is at the extreme parts and maximal force at the middle of the angular amplitude).

A number of our studies have established that the ability to express explosive-strength (the ratio one-half the maximum isometric tension to the amount of time for reaching it) unidirectionally changes with the change in external muscular force (figure 8, curve Q). A decrease in the Q index along with the change in joint angle is associated simultaneously with a decrease in muscular tension and an increase in the expenditure of time for its expression (figure 9).

The force-angle graph does not fundamentally change with the increase in muscular strength as a result of training. However, a number of studies (V. M. Zatsiorsky, L. M. Raitsin, 1974; L. M. Raitsin, S. K. Sarsania, 1975) have established that the increase in strength over the entire amplitude of single-joint movements depends on the joint angle at which maximum muscular tension is expressed during training. If it is expressed at an angle corresponding to the muscle's greatest length (i.e., the smallest degree of flexion in the joint for active muscular flexion or the least extension for muscular extension), then the transfer of strength to the other joint angles is relatively uniform.

The reverse is true if maximum muscular force is expressed when the muscles are in a state of contraction (shortened length, Ed.) then the increase in strength is larger. However, the transfer of the training-effect to the other joint angles is comparatively small and the further from this angle the lesser the maximum strength transfer.

It is interesting to note that, at the joint angle at which maximum force is expressed in training; there is a relatively larger increase in strength than there is in the nearest joint angles.

The functional perfectioning of movement at the kinematic pair level is still associated with increasing the angular amplitude of movement through larger mobility in the joint. However, this applies primarily to kinematic pairs; those joint combinations which have two or three planes of movement (talo-crural, gleno-humeral, iliofemoral joints).

The working movements of man are realized by a system of links in a kinematic chain where the angles in each joint combination are simultaneously changed. The fundamental working functions of the kinematic chains in the motor apparatus consist of transforming rotational joint movements to rectilinear (by

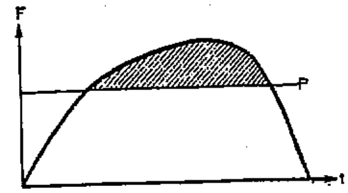

FIGURE 1 - Development of working-force (F) over time (t); P - weight of the resistance.

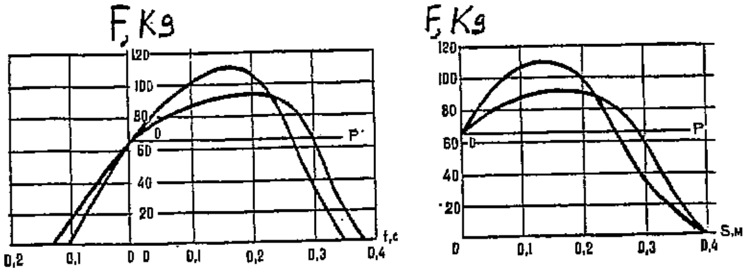

FIGURE 2 - Graph of F(t) and F(S) of explosive force (explained in text).

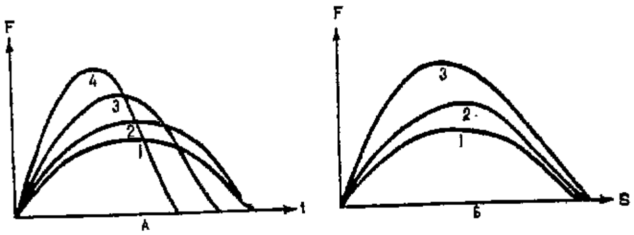

FIGURE 3 - Graphic changes in F(t) and F(S) during training.

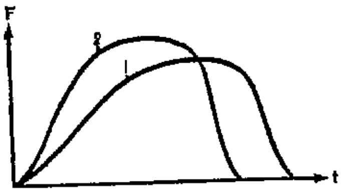

FIGURE 4 - Displacement in force during explosive isometric tension, 1) before training, 2) after training.

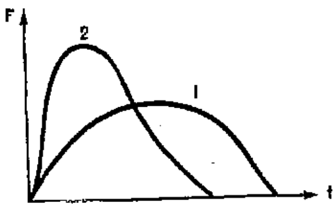

FIGURE 5 - Displacement in a ballistic movement, 1) before training, 2) after training.

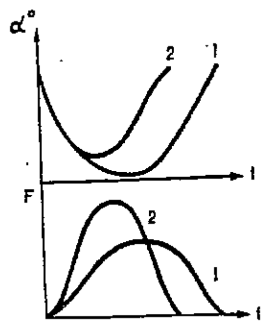

FIGURE 6 - Angular displacement ( ) and dynamic force (F) in a reactive-ballistic type of movement, 1) before training, 2) after training.

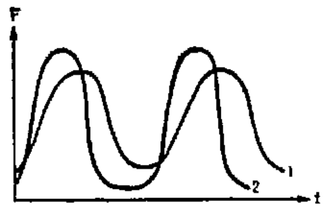

FIGURE 7 - DYNAMICS OF A CYCLICAL MOVEMENT, 1) before training, 2) after training.

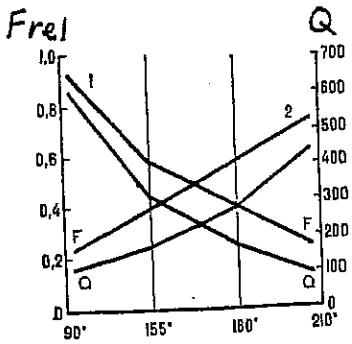

FIGURE 8 - Change in relative-strength (F rel), and gradient-strength (Q) along with changes in hip angles for qualified women-sprinters, 1) extension, 2) flexion.

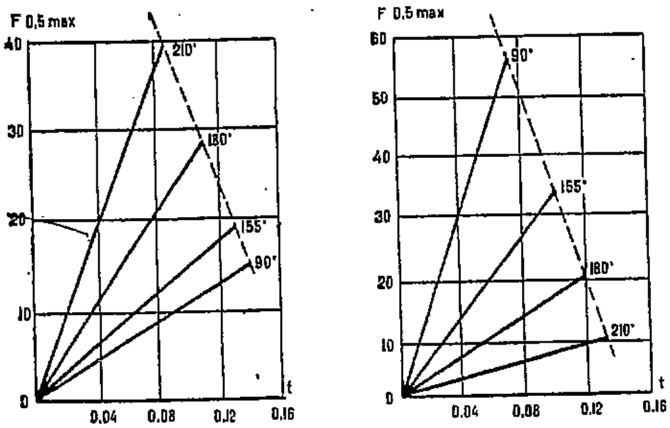

FIGURE 9 - Change in speed of a gradual isometric force with changes in joint angle.

lengthening or shortening the system's levers) or angular (relative to the proximal joint) movement of the working points found at the distal end of the system's links. The working-effect of the movements executed by the kinematic chain varies to a great extent, depending on attending conditions (relative disposition of the links, the motor potential of certain muscle groups and others); and to a larger degree undergo qualitative and quantitative changes during the course of exercises than the working-effect in kinematic pairs. Qualitative perfectioning of movement (as realized by the kinematic chain) is secured by three basic factors: an increase in the working amplitude, the concentration of dynamic force at a certain part of it and a rational form to the interaction of the working muscles.

An increase in the working amplitude is realized, as is known, by a large range of motion in the joint and by an increase in the elasticity and strength potential of the corresponding muscle groups (G. G. Topolyan, 1951; M. F. Ivanitsky, 1956; D. D. Donskoi, 1960). The amplitude of movement increases in two directions at the opening of the kinematic chain -- the beginning and end of its parts. This is realized in the first case by an increase in muscular strength and the ability (of the muscles) to develop a powerful force during the course of the movement, as well as an increase in the elasticity of the functional antagonists.

There are two clear regularities in the nature of the expressed force over the course of a movement: first, a decrease in the force of pull from the muscles at the end of the movement, especially with the ballistic regime of muscular work (it is more pronounced the faster the movement and the lesser the external resistance); second, there is an increase and a concentration of working force at a certain part in the amplitude of the movement. The first regularity is an obvious reflex regulator as expressed by the inhibitory action of muscle antagonists (R. S. Pierson, 1965), which is a manifestation of the self-preservation function of the motor apparatus. This mechanism does not undergo change with the growth in sport mastery, which concerns the second regularity, about which certain tendencies can be noted and are directly correlated to the process of the formation of a biomechanically appropriate movement, which we have already discussed.

The working force of an executable kinematic chain is produced by the coordinated work of the muscle groups serving each of its articulations. The coordination of force and the function of certain muscle groups have their own peculiarities in this context. There is merit in noting the following two facts have as yet not received sufficient interpretation in the sport literature.

It has been established that the resulting force is less than the sum of the forces of the muscles each kinematic pair are capable of producing (Y. V. Verkhoshansky, 1961, 1965, 1970; V. S. Yegorov, 1966). For example, in isolated forearm flexion, strength increases as the angle in the elbow joint decreases and reaches maximum at 90 . However, with isolated flexion at the shoulder, there is no significant difference in strength in the 40 to 160 range (H. Campney, R. Wehr, 1965). However, if the entire arm executed stretching work (simultaneous extension at the shoulder and forearm flexion with the working point at the hand) then maximum force is produced at 160 in the elbow joint. If "repulsion" work is executed, maximal force is developed with the arm bent, i.e., at the beginning of the "push-off". With isolated extension at the knee joint, maximal force is produced (with insignificant changes) from 80 to 130 and then quickly drops (H. Campney, R. Wehr, 1965; M. Williams, L. Stutzman, 1959). However, with "repulsion" work when the system's links are lengthened (extension at the iliofemoral and knee joints), maximal force occurs when the joint angle is near maximum and when the angle in the knee joint is close to 160 (V. F. Dorofeyev, 1965; V. S. Yegrov, 1966). The examples cited are a manifestation of the adaptive mechanisms of man's working apparatus acquired in the long term process of evolution. Thus, in the latter instance there is the obvious influence of man's erect gait, and with the shoulder girdle it is functionally advantageous to develop maximum stretching force for pulling the arm and vice-versa, force for bending the arm.

Studies (V. G. Semyenov in collaboration with V. V. Tatyanov) have established that for the maximum strength each joint combination of the lower extremities, there is a smaller correlation with athletic improvements in running-jumping exercises than the sum of the forces expressed by the entire extremity. This correlation rises noticeably with the growth in mastery, which indicates that the working-effect of the movement is determined by the sportsman's ability to rationally utilize his muscular potential; which in combination with functional in-sufficiencies, some are compensated for by the advantages of the others.

An attentive analysis of muscle group combinations under various work conditions of the kinematic chain, enables one to observe a certain biomechanical expediency. Depending upon the conditions of the activities, man involuntarily selects a relative disposition of the links in the kinematic chain that ensures the required working-force by simultaneously or sequentially utilizing zone angles of maximal strength in each joint. The first case is appropriately associated with the overcoming of significant external resistance, such as isometric tension (for instance, the attempt i.e., to move a heavy object). The second case is typical of movements which require the addition of as large a velocity as possible to an external object or bodyweight under conditions of limited working amplitude (the "take off" in jumping for instance). This functional relationship between the muscle groups attending the kinematic chain is such that the movement is begun by the most powerful muscles of the proximal joints (the key muscles in the kinematic chain) and is realized with the support on the distal links and the joints rigidly fixed. The distal links are then included in the work, while at the proximal links, fixation begins in the joints which ensures a rigid base for completing the movement of the distal links.

Thus, man always strives to begin the working-force by utilizing the joint-angle-zones of maximum strength. It can be assumed that sport technique evolving over many decades is fundamentally constructed on just such working poses which ensure the most favorable conditions for expressing maximal force at the time needed. However, in certain instances, it is not difficult to see the conflict between these mechanisms and the requirements of the movement's dynamics emerging from the conditions of the sport activity. It reveals in particular the necessity to increase the working amplitude of a movement especially in those cases if it is necessary to express maximum strength in those parts of the amplitude where this strength cannot be secured anatomically.

Nevertheless, the organism's extremely high adaptive capacity to external conditions finds the optimal resolution to such conflicting situations. This is possible, for instance, when the corresponding muscle groups (prior to beginning the working-force) possess some additional potential tension accummulated in the preparatory movement phase. Thus, during the amortization phase of the vertical jump, additional potential elastic energy accummulated at the end of the amortization phase is a source of strength, facilitating the extension of the legs. Therefore, it is possible to proceed from certain joint-angle-zones of maximal strength and achieve the greatest gain in the amplitude of the movement in comparison with jumping from a half-squat position (i.e., without the amortization phase). There is a tendency for the amplitude of amortization in knee flexion to decrease after a depth-jump. There is an obvious effort towards the zone angles of maximum strength in certain joints due to the large dynamic load here. Some of the loss in the amplitude of the movement is compensated for by the additional elastic potential energy of the muscles.

Thus, there is an expressed sequence in the process of functional perfectioning of movement at the kinematic chain level. First, the choice of the optimal working amplitude of a movement is based on the rational correlation between the zone angles of maximum strength in each joint, the real motor potential of the muscles and the conditions attending the resolution of the motor task: a) for small external loads there is a characteristic striving to increase the amplitude of movement independent of the zone angles of maximum strength in each joint; b) for large external loads and lacking additional sources of strength, the movement is characteristically facilitated by the shortening of its working amplitude in connection with the effort to execute the working poses near the zone angles of maximum strength; c) for large external loads and additional sources of movement (force of inertia, elastic potential energy of the muscles) there is a possibility of some increase in the working amplitude outside the joint-angle-zones of maximum strength; d) in all cases a forcible decrease in the working amplitude of movement is compensated by potential elastic-muscular tension accumulated in the prepatory phases of the movement, which ensures a powerful initial muscular force.

Second, increase the maximal motor-force and its concentration primarily at the beginning part of the working amplitude.

Third, the muscles in the kinematic chain are included in the work in an appropriate sequence which enables them to sequentially express their functional qualities (ability for powerful force and speed of contraction) during the course of the movement.

Fourth, strive to execute the movement within the range of the zone angles of maximum strength in each joint and to simultaneously raise the dynamics of its execution through additional potential elastic-energy of the muscles in the prepatory phase.

The kinematic system possesses significant degrees of freedom. Therefore, the process of functional perfectioning of movement, as far as studying it from kinematic pairs to a kinematic system, is all the more associated with the problem of the rational organization and control of the motor composition of the action. Nevertheless, biomechanical factors continue, in the given case, to play an important role.

The pecularities of the qualitative perfectioning of movement considered earlier are associated with the rational sequence of muscular tension in the kinematic chain and are to the fullest extent related to the kinematic system. The only difference is in the number of functionally interacting muscle groups. This interaction consists chiefly of the work of the strongest muscle groups of the legs and torso then the muscles of the shoulder girdle.

Thus, the qualitative perfectioning of movement at the kinematic level is associated with the determination of the most rational method of uniting individual kinematic chains and the working mechanisms inherent to them into a single working mechanism. The logical organization of such mechanisms is the biodynamic structure of a complex motor act which is discussed separately because of its special significance.

1.1.3 The Biodynamic Structure of an Athletic Movement

The motor system constituting a sport exercise is formed and functionally evolves on the basis of certain cause-effect relationships between its individual elements; and their line of force depends on the neuro-muscular apparatus. In the course of attaining sport mastery these relationships change continuously as a result of the search for a more rational interdependence between the elements of the motor complex as well as a result of quantitative additions to its dynamic mechanism. The latter represent the "rigid framework" of the movement system; determining its spatial-time characteristics and the functioning of the working-effect. Therefore, the dynamic mechanism concept, or biodynamic structure of a concrete sport exercise, is an extremely important condition for successfully solving the problem of special-strength training. With respect to the biodynamic structure of a sport action *(Y. V. Verkhoshansky, 1958, 1963, 1966, 1968) the strength field, appearing as a result of the sportsman's interaction with external objects, is divided into phases of active concentration and dynamic reaction. *The author originally utilized the expression "dynamic structure" for this concept. However, recently in the methodological literature this phrase was used rather frequently and without particular pretense as to its meaning. It is therefore appropriate and correct to subsequently speak of the "biodynamic structure" emphasizing that one is speaking not only and not simply about the interaction of force as a physical manifestation, but about the appropriate mode of concordance in accentuating the active motor phases, the logic of which is based upon a complex of psychological and biological factors. Initially these dynamic elements are expressed weakly, irregularly distributed in the strength field and are chaotic (figure 10, A). With repetitive reproduction of movements their quantitative significance and spatial-time coordination vary within a wide range. The motor act as a whole is still dynamically unstable and its final effect is low and unstable. Then, as adaptation to the interaction with the external surroundings takes place, the athlete finds the means for more effectively resolving the motor tasks. This is associated with differentiations and increases in the dynamic accentuations, clearly localizing them within the limits of the motor complex and the unification into a specific distinctly traceable system (figure 10, B). Now, with repetitive reproduction of a motor act, the range of variation (in its quantitative significance and time relationship) of its elements decrease, while there is a simultaneous compression, a concentration of this system in time and its elements do not simply sum in time and space but interact according to a pattern of correlation and subordination.

The correlation between the dynamic elements is such that any change in the quantitative and time characteristics in one of them is expressed in the others, even far removed in space and time. The inter-relationship of elements perform a form of subordination which is manifested by the clearly expressed dominant roles of some and the subordinating roles of the others. Thus, one can separate a key element (elements), crucial for the resolution of the motor objectives as well as organize the element (elements) acting as a systematic general beginning of the biodynamic structure; and in accordance with this secure the increased functional effect of the key element.

Thus, the biodynamic structure of a motor act is a stable principal connection of the accentuated phases of the active and reactive dynamics in the movement system; securing the effective utilization of man's real motor potential under conditions of resolving concrete motor tasks. The basis for the formation of the dynamic structure of the motor act is the dialectical entity and the inter-conditionality of the processes of differentiation and integration of the elements' dynamics. As a result of the motor system becoming an organic whole, it reacts and functionally evolves as a whole. With the formation of a biodynamic structure, a motor act is transfered to a new higher-qualitative level; signifying an increase in its working effect during the rational utilization of the individual's real motor potential.

As has already been discussed, the dynamic structure is constantly perfected by refining the connections between the elements of the motor complex as well as by quantitatively augmenting it. However, the motor complex possesses a certain flexibility in concrete situations and the ability to dispel sharp influences from without, without losing its logical integrity. This becomes possible owing to the biodynamic structure's ability to vary the adaptive changes to the external influences.

It should be pointed out that the principle of dynamic organization is inherent to any complex motor act. However, acyclic exercises require the expression of significant force in a minimal amount of time. Consequently, the whole notion of training consists of forming and perfecting the biodynamic structure. Cyclic exercises require the prolonged maintenance of work-capacity; the biodynamic structure forms significantly faster, its composition is simpler and the notion of training consists primarily in perfecting the vegetative functions of the organism.

The biodynamic structure is part of the general strength field, i.e., the sum total of all the external and internal forces relative to the organism; arising in the course of resolving its motor tasks. In a purposeful action the composition of the strength field is determined by the emphasis and the dosage, i.e., control.

Beginning with N. A. Bernstein, the forces, producing movement are represented by a type of geometric sum of three, comprised of: external, internal and reactive strengths. The results of the aforementioned studies permit refinement and addition to this classification. If it is based upon the character, origin and direction of force, the strength field can be classified in the following manner:

1. The active motive-force, whose origin, is the contractile function and the mechanical pull of muscle.
2. The reactive force is connected with or is the expressed force arising as a result of the interaction of the forces of active muscles with the immediate external surroundings.
3. The accummulated-force is stored in the muscles as elastic energy in the prepatory phases of the movement.
4. The force of inertia of the body (or its links).
5. The force of the body's weight (or its links).

This classification of the strength field's composition is somewhat conditional, because the origin of their (besides the last) obligation is the one and only source of man's muscular strength. But, each appears in the process of solving motor tasks, has a certain influence on the results; and therefore should be considered when analyzing the dynamic mechanism of the movement system and for selection of the special strength-training means.

These forces, depending upon the place and point of application, can be external or internal relative to the interaction of the body; and depending upon the body's (organ's) direction of movement -- resist or inhibit movement.

It is necessary to add the following characteristics to the strength field. The strength field consists of two systems: external and internal (relative to the organism) interaction with the working apparatus. These systems appear simultaneously and in a number of details, independently of each other although in their appearance they experience and obviously have an inter-influence on each other, the degree of which increases as sport mastery rises. The composition of the systems of external interaction render a decisive influence on the form and structural composition of the internal strength systems, whereas the latter are dependent on the magnitude and direction of the resulting dynamic movement and its change over time. Hence, the biodynamic structure of a sport act can be the correct notion only in the case if it represents part of the general strength field. At the same time, control of the external interaction of the motor apparatus is possible only through the internal biodynamic structure.

Consequently, when speaking about controlling the sportsman's movements it is necessary to bear in mind not so much his movement, i.e., the relative shifting of the body's links, as the appearance of this dynamic mechanism and speak about controlling the work-effect of the movement. This is the essence of the pedagogical aspects of the problem of controlling man's movement.

1.2 Morpho-Functional Specialization of the Organism in the Process of Attaining Sport Mastery

One of the conditions of development in the process of attaining sport mastery is the appearance of the steady morpho-functional perfectioning of the sportsman's organism, which occurs with a certain regularity. In the beginning, the organism reacts to a new motor regime with its entire system and this is sufficient for the initial successes on the athletic field. However, subsequent accommodative displacement acquires a clearly expressed selective trend, conditioned by the motor specifics and the peculiarities of the external influences. Under such conditions, one of the organism's systems receives considerable development, another less, depending upon their roles in securing the requirements of the motor activity.

Accommodative reconstruction is examined in sufficient detail and from many aspects; extensive material on this question can be found in appropriate texts on anatomy, physiology, medical-control, biomechanics and biochemistry of sport. However, the character and tempo of the reconstructions and their interrelationship in the PASM has as yet not been studied effectively. This is an important problem in the knowledge system and constitutes tne natural-scientific foundation for the theories of sport training.

Some tendencies are observed, in the dynamics of accommodative reconstruction of the sportsman's motor apparatus in long-term preparation, connected with the ability to display strength.

1.2.1 Specific Forms of Displaying Muscular Strength

Depending upon the primary coordination structure of the work of the motor apparatus, muscular strength acquires a specific coloring which becomes all the more expressive in relation to the athlete's growth in sport mastery. The fundamental, qualitatively specific forms in which strength is displayed that are most typical of athletic activities are: absolute-strength, explosive-strength, and strength-endurance.

Absolute-strength characterizes the sportsman's strength potential and is a measure of the maximal volitional muscular force in the isometric regime without a time limit or limit to the amount of weight lifted.* *In physiology, measurement of maximal muscular strength refers to the limit magnitude of working muscular tension revealed by means of electrical stimulation at the point of neural ennervation to the given muscle group (Y. M. Kots, 1975).

The so-called relative-strength of an athlete, (i.e., amount of force per kilo of bodyweight or the sport apparatus), is distinguished in sports. This index is convenient for comparing the strength of sportsmen of different bodyweights.

Speed-strength characterizes the ability to quickly execute an unloaded movement or a movement against a relatively small external resistance. Speed-strength is assessed by the speed of the movement.

Explosive-strength characterizes the ability to express significant tension in a minimal period of time. The maximum force, over the time of its achievement relationship is usually utilized for the quantitative evaluation of explosive-strength (figure 11) $[I = \frac{F\ max}{t\ max}]$ **

** This will subsequently be called the I-gradient.

Special studies (Y. V. Verkhoshansky, 1966, 1970, 1972) indicate that the F (t) curve of explosive-force has three components. The F(t) curve determines the absolute-strength of muscles, their capacity to accummulate external force at the beginning of working tension and the ability to quickly achieve maximal external force in the course of developing working tension (isometric regime) or at the beginning of a muscular contraction (dynamic regime). The first ability is conditionally called "starting", the second "acceleration" strength. This formula is utilized for the quantitative evaluation of starting-strength as expressed in the dynamic regime: $Q = \frac{Fp}{tp}$

or the tangent (t g alpha) to the F(t) curve at its beginning part (see figure 11); the means of assessing acceleration strength is the formula: $G = \frac{F\ max\text{-}p}{t\ max\text{-}tp}$

or the tangent of the angle of inclination of tangent (t g alpha) to the F(t) curve at point Fp. With the isometric regime as the base points of the F(t) curve, to assess parameters F and t of starting and acceleration-strength, use the ordinate $\frac{1}{2}$ F max. *

* Subsequently the Q and G indices are called Q-gradient and G-gradient respectively.

Explosive-strength is most commonly displayed in athletic movements when the contraction of the working muscles in the fundamental phases of the exercise is preceded by a mechanical stretching. In this instance, the working-effect of the switch from stretching to active contraction utilizes the elastic potential of the stretch for increasing the power of the subsequent contraction. This specific quality of muscle will subsequently be called the reactive-capacity of muscle (R).

Strength-endurance characterizes the ability to effectively maintain muscular functioning under work conditions of long duration. There are different types of muscular functioning associated with this: holding a necessary pose, repetitively executing explosive effort, cyclic work of various intensities and others.

1.2.2 Peculiarities of the Functional Topography of a Sportsman's Muscle System

Observations of some of the functional qualities of certain muscle groups, adopted from work-physiology, (Y. M. Uflyand, 1965), have been widely disseminated in sport and enabled us to determine the functional topography of the muscle system. Usually the basic, objective observations are of the absolute-strength of certain muscle groups. Visual representation of the topography of muscular strength produces the so-called dynamometric profile (Y. M. Uflyand, 1965), constructed according to the poly-dynamic record of the strength of various muscle groups (figure 12). The dynamometric profile enables one to compare the strength preparedness of individual sportsmen. Of particular interest is the study of the so-called general dynamometric profile; characterizing the strength topography of the representative muscle groups of athletes of various specialization; as well as the changes in the configurations of the general profile with the sportsman's growth of sport mastery. Such a general profile vividly reflects the peculiarities of the strength preparation of sportsmen of specific specialization and can serve to some extent as a standard for controlling the quality of the training process.

A study conducted by V. G. Semyenov (1971) and co-workers showed that the general configuration of the dyamometric profile of sportsmen of one specialization is preserved as sport mastery increases (figure 13). However, you can always discover some irregularity in the rate of strength development of certain muscle groups at the beginning as well as at the higher training stages of sport mastery. This is peculiar to sport ontogenesis and is associated with the changing conditions of the athlete's interaction with external objects; due to which some muscle groups receive a large potential for development, and others -- less.

Thus, the dynamometric profile vividly expresses the local-specialized character of the functional perfectioning of a person's motor apparatus; engaged in this or that type of sport. However, muscular strength is only one of the qualitative characteristics of the functional specialization of the motor apparatus. People with absolutely identical dynamometric profiles demonstrate essentially different sport achievements. The cause of this is the different levels of development of such indicators as the ability to quickly produce external force from the onset of working muscular tension. Two women sprinters (figure 14) are roughly equal in muscular strength. However, one of them runs the 100 M in 12.1 seconds and the other in 12.4 seconds. The reason for this is the differences in the speed qualities of the muscles as characterized by their ability to quickly develop maximum working-force (the ratio of maximal strength to the time of its display for explosive-isometric muscular tension).

From this it is obvious, that the characteristics reflecting the topography of the sportsman's muscle system should include its diversity; and also those qualities of muscle essential to the given type of sport. This enables one to obtain a comprehensive idea of the so-called poly-functional profile of the sportsman's muscle system (Y. V. Verkhoshansky, 1970); and has important significance for determining the objectives of his special preparation.

Depicted in figure 13 is a fragment of such a poly-functional profile of women sprinters, of different qualification, which consists chiefly of speed-strength characteristics (F-rel - relative-strength). It is easy to see that the basic differences in the women's speed-strength, with the increase in mastery, are revealed in the two latter (particularly the latter) characteristics.

The poly-functional profiles expressively indicate that the specific functional reconstruction of the motor apparatus embraces chiefly those of its segments with which the sport activities are primarily realized. The character of such reconstruction is a reflection of the specific peculiarities of the work regime of the motor apparatus and with the growth of mastery this is displayed all the more clearly.

Thus, the poly-functional profile of the muscle system appears as an objective prerequisite for concretizing the objectives of special-strength training; since it enables one to determine which muscle groups are underdeveloped and need additional work.

1.2.3 Basic Tendencies in the Dynamics of the Functional Specialization of the Motor Apparatus in the Process of Attaining Sport Mastery

The special-strength preparaedness of sportsmen of different qualification gives one an idea of the most general tendencies in the dynamics of the functional specialization of the motor apparatus; in the long-term process of training. For example there is a relationship between an increase in the reactive capacity of the neuro-muscular apparatus (R) and improvements in the long jump, the triple jump (figure 15). At the same time, the abilities assessed by the standing triple jump and the back squat have a more complex form of correlation with the triple jump. An analogous structure in the dynamics of the control indices can be seen in the weightlifting example (data applies to the period when competition consisted of the triathlon).

One should bear in mind however, that in the given case the dynamic indices being examined (pedagogical tests) are realized by this or that aggregate of specific motor abilities. The rate of perfectioning of each of them can reflect different relationships; the idea of which is an extraordinarily important condition for solving the problems of the organization of special-strength training in sport.

A detailed study of this question revealed five variants between the relationship of the indicators of the accommodative reconstruction of the organism and athletic achievements (figure 16). This relationship can be expressed by the following functions: linear (1), model with slowed (2) and accelerated (3) growth, logistical (4) and parabolic of the third order (5).

The first variant (1) is characteristic of the key motor abilities, i.e., abilities determining, for the most part, success in the sport. The second variant (2) is characteristic of those non-essential motor abilities which are indicators of general-physical preparation. They play an important role in the initial stages of the PASM; then only secure conditions for the

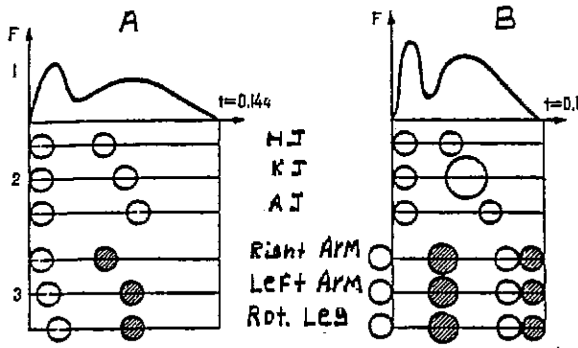

FIGURE 10 - Disposition of accentuated active and reactive dynamics in the motor complex (2nd take-off in a triple jump): 1) resulting dynamogram; 2) accentuation in muscular tension attending the hip (H), knee (K) and ankle (A) joints of the support leg; 3) accentuation of active and reactive (shaded) dynamics of a rotary movement. A- beginners, B- qualified athletes.

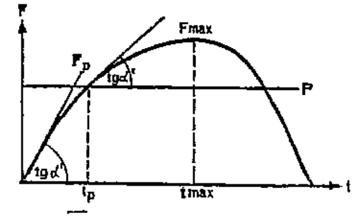

FIGURE 11 - F(t) graph illustrating a method of assessing explosive, starting and acceleration-strength (explained in the text).

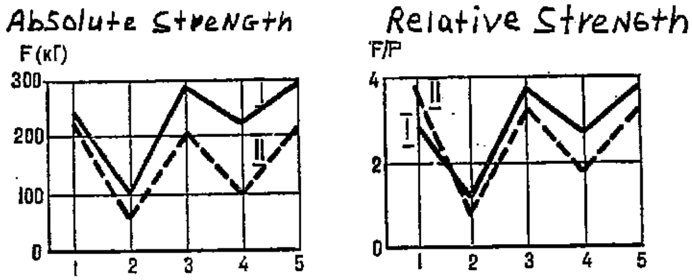

FIGURE 12 - Dynamometric profile: I-high jump; and II-distance running; 1) torso extension, 2) torso flesion, 3) thigh extension, 4) ankle extension, 5) foot flexion.

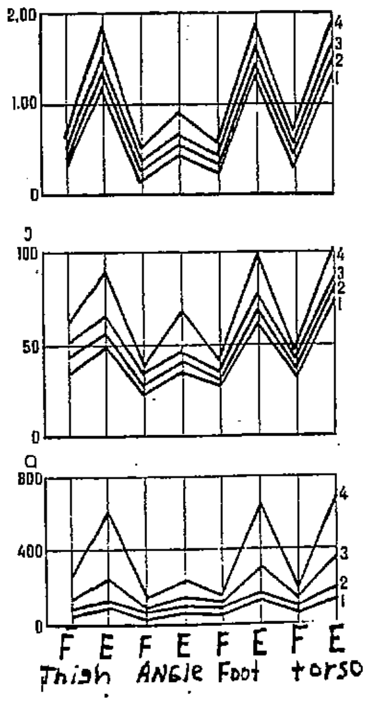

FIGURE 13 - General functional profile of women-sprinters' muscle-systems (bottom sport results); C-flexion, P-extension, 1,2,3,4 are III, II, I class and master of sport respectively.

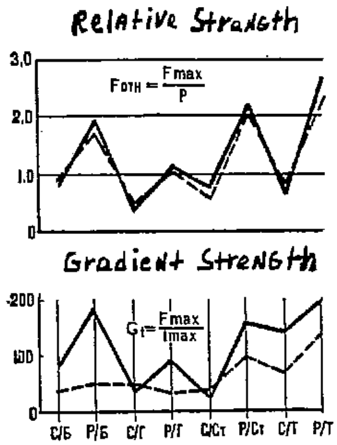

FIGURE 14- Strength-preparedness of two 100 M sprinters with times of 12.1 sec (continuous line) and 12.4 sec (broken line); T-thigh, A-ankle, F-foot, T-torso, F-flexion, E-extension.

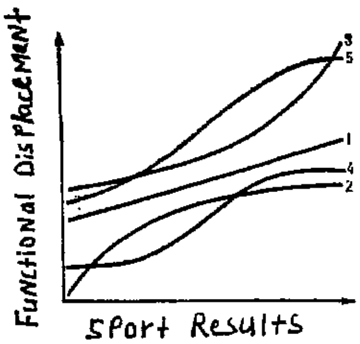

FIGURE 16 - Tendencies in the accommodative reconstruction of the organism during many years of training.

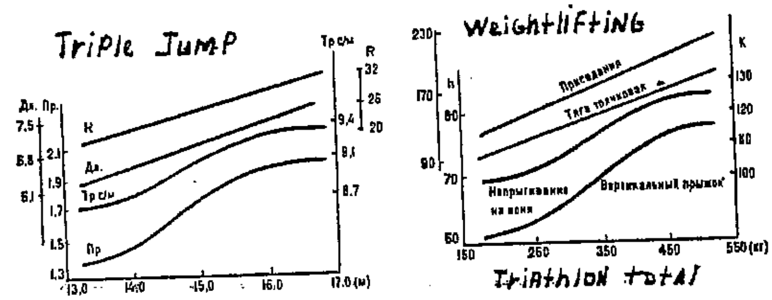

FIGURE 15 - Dynamics of control exercises relative to the sport results of triple jumpers and weightlifters.

harmonious development of the organism and are the foundation for perfecting specific motor abilities.

The third variant (3) is characteristic of the specific functional reconstruction chiefly determining the developmental level of the key motor abilities; and consequently the success of the athletic achievements as a whole. The form of this relationship indicates that the growth of sport achievements requires the accelerated development of the key motor abilities. The correlation of the latter with athletic results (equivalent with respect to the key motor abilities) increases significantly with the growth of sport mastery.

The fourth (4) and fifth (5) variants are characteristic of the variety of dynamic non-essential and essential motor abilities in the PASM.

It has been established that as sport mastery increases a key role in the realizetion of a movement can be transfered from one group of muscles to another. Specific regularities in the process of functional specialization of key muscle groups are discovered; in particular, the hetero-chronologicalness of the rate of developing specific motor abilities.

Thus, in collaboration with I. I. Nikonov we found that there is an irregular strength development of certain muscle groups of pole vaulters. If the strength curves are compared (figure 17, A) as well as the derivatives characterizing the rate of strength increase relative to athletic achievements (figure 17, B), then it is not difficult to notice that the arm flexors (1) prolong the functional perfectioning, begun by the abdominal muscles; from that moment when the strength of the latter stablize.

Such a continuity is easily explained. The fact is that young athletes raise their bodies up the pole with their abdominal muscles. With the increase in mastery, this element is executed quickly by the arms and shoulders. The strength of these muscles progresses noticeably at the same time as the strength of the arm extensors (2), increases uniformly.

In a study conducted in collaboration with E. Purvin we discovered that with the growth of mastery in the shot put the key role gradually switches from the muscles of the shoulder girdle to the leg muscles. For beginners, the correlation between athletic achievements and the strength of the arm muscles is 0.83; and with leg strength 0.37; the corresponding figures for qualified sportsmen are 0.73 and 0.87 respectively.

A more detailed analysis of the process of functional specialization of the key muscle groups (in the jumpers and sprinters example) also reveals the hetero-chronological phenomenon. It appears in the given case in two forms: one, the non-coincidental moments associated with the initial intensification of the increase of certain specific motor abilities (figure 18, A); two, in the obvious succession of functional specialization in the key muscle groups (figure 18, B).

Thus, absolute-strength (Po) increases immediately at the beginning of training, then the rise in explosive-strength (I) begins to accelerate and only after some time, starting-strength (Q). It should, however, be noted that the linear character of the increase in absolute-strength is only typical of those types of sports where the athletes overcome relatively small resistance; and where the speed of displaying working-force and not the magnitude of the external force is most important; there is typically some slowing in the rate of strength increase in the high mastery stage.

The second form of hetero-chronologicalness is expressed in the non-coincidental moments associated with the initial acceleration of growth in the key muscle groups of such specific abilities as starting-strength (figure 18, B). They are first revealed at foot flexion, then thigh extension and finally, thigh flexion.

It is not difficult to trace the connection between the examined forms of hetero-chronologicalness in the process of functional perfectioning of certain muscle groups, from the changes in the work regime of the motor apparatus in the long-term preparation of athletes. The onset of training renders an immediate increase in absolute-strength. Explosive-strength then begins to increase with the introduction of speed-strength training. Finally, the increase in the portion of special-strength training within the general volume of means (including the execution of the fundamental sport exercises with an intensity close to the competition intensity) leads to a quick increase in starting-strength.

The hetero-chronologicalness phenomenon, in the process of functional specialization of the support apparatus, originates from the rate of development of starting-strength in certain muscle groups. Then it has other causes. The flexors of the soles of the feet are subjected to the most intense loads, at the onset of training. Therefore, specific functional displacement is discovered in them first, as expressed by the increase in the Q-gradient (figure 18, B). Then as the power of the extensor force (for pushing-off) increases, accommodative reconstruction in the iliofemoral and knee joint extensors begins to intensify. It should be pointed out that the work of these muscles opposes the force of gravity and the inertial resistance of the body's mass naturally requires significant tension from them. On the other hand, the flexors of the thigh are confronted with the force gravity and the inertial resistance of the mass of only one leg, so they, consequently, possess a lesser prerequisite for functional perfectioning. Therefore, the thigh flexors are significantly weaker and display motive force slower than the thigh extensors. At the same time, their starting-strength increases later, but is distinguished by a less intense increase.

We should turn our attention to the fact that the Q and I gradients increase slowly in the high sport mastery stage (see figure 18). As was shown previously, this fact is associated with a decrease in the effectiveness of the special-strength training means; which appears to be one of the reasons for the decrease in the growth of sporting achievements. It can be assumed, in connection with this, that the fundamental means of special-strength training in such a case is the sport exercise itself, executed at the intensity close to the sportsman's individual limit.

Thus, the functional specialization of the motor apparatus in the PASM proceeds with a certain regularity which is expressed first, in the hetero-chronological moments beginning with significant functional reconstruction of certain muscle groups; second, in the different rates of functional reconstruction; and third, in a specific logico-conditioned sequentialness of the development of the required motor abilities.

The functional specialization of the organism in the PASM is manifested in two basic forms: first, in the specialization of the motor apparatus (certain segments of it acquire a clearly expressed accommodative displacement and are principally those which bear the heavy fundamental work during the sport activity); second, in the specialization of the organism as a whole and especially the isolation of the aforementioned parts of its working apparatus in the development of specific motor abilities; necessary for the success of the concrete sport activity. Thus, it is a matter of specialization of the organism by organ on the one hand and by motor ability on the other.

Specialization by organ is clearly local; restricted to specific muscle groups and their functional units. Specialization by ability is expressed in the development of such qualities of the organism as a whole and chiefly the key working systems which primarily determine the level of its specific work-capacity. As sport mastery grows the local character of the organism's functional specialization becomes all the more expressive and the specificity of the motor abilities all the more concrete.

It should be emphasized that the examined tendency of the long-term dynamic functional specialization of the ogranism reflects, in essence, the natural course of the accommodative process (i.e., not really controlled, because its regularities are simply unknown). It can be assumed, that the time and quantitative parameters of the stages and the tendencies in the functional specialization of the organism are not an objective necessity. In the interests of rationalizing and raising the effectiveness of long-term training, these parameters can be deliberately changed within reasonable limits. In other words, it is a matter of the purposeful and the controlled realization of the regularities that objectively determine the character and the dynamics of functional specialization of the organism in the course of long-term training; for which the means of special strength-training have an important role.

1.3 Structural Regularities of the Sportsman's Physical Preparedness

Sport activity is characterized by the introduction of an unaccustomed (for the organism) regimen. The organism accommodatively reacts to it with its entire complex of systems: the central-nervous, somatic, vegetative and the psychological spheres. A certain inter-correlation in the displacement to these spheres secures the effective activity of the organism as a whole. Thus, it is a matter of the structure of the sportsman's physical preparedness (i.e., the inter-relationship of the morpho-functional, accommodative-reconstruction to the organism that determines its work-capacity). The organism's work-capacity acquires a certain qualitative specificity depending on the type of sport. So, one can speak of the primary development of man's ability to display strength, speed, endurance, etc., and call this key qualitative characteristic his motor function.

Each key function has a typical accommodative reconstruction. It is roughly inherent to any sportsman of one specialization although it can have an individual expression in each concrete case. Especially distinct, individual differences can be displayed in the structure of strength preparedness. Different sportsmen obtain the same results with different degrees of work on the basic muscle groups; with their different ability to quickly contract; and finally, the compensation for the functional lag of one muscle, results in a more expressive development in another.

Hence, the notion of an athlete's structure of strength preparedness has great significance for the organization of the strength-training; and especially for the selection of effective means and methods of developing muscular strength.

1.3.1 The Structure of the Sportsman's Physical Preparedness

The concept of the structure of physical qualities in general, was formulated in a number of works (V. M. Zatsiorsky, 1961, 1965; Y. V. Verkhoshansky, 1963, 1970, 1972); but only the statement of the problems. Up until now a sufficiently in-depth elaboration has not been obtained. At the same time facts related to the structure of the sportsman's physical preparedness are rather extensive and concentrated in the literature around such questions as the intercorrelation of physical qualities (in the process of their development); and the "transfer" of these qualities from one type of activity to another (see N. V. Zimkin, 1956, 1965; N. N. Yakovlev and others, 1960; V. M. Zatsiorsky, 1965; D. Hebb, 1949; F. Lindeburg, 1949; D. Nelson, 1957; R. Woodworth, 1958; B. Cratty, 1962, 1964). It is appropriate here to note only the fundamental tenets of the attempts to elaborate, in-depth, the structure of the sportsman's physical preparedness.

It has been established, that the transferance of physical qualities decreases with the increase in trainability (N. V. Zimkin, 1965; V. M. Zatsiorsky, 1965); that the transferance mechanism is to a great extent specific (F. Cumbeca, et. al., 1957; D. Nelson, 1957; I. Bachman, 1961; B. Cratty, 1968; I. Lawther, 1968; A. Barrow, 1971); that the intercorrelation between physical qualities can be positive, negative or neutral (N. V. Zimkin, 1956); and positive transferance at the initial stages of training can then switch to negative (A. V. Korobkov, 1958).

It has been noted repeatedly in works dealing with the methodological questions of the intercorrelation of physical qualities that training consisting of exercises requiring speed, strength and endurance, develops each of these qualities collectively, better than training each of them individually even with an increase in the load (N. G. Ozolin, 1949, 1970). The development of each quality has a positive influence on the development of the others, and vice-versa, a lag in the development of one or several qualities limits the development of others (A. N. Krestovnikov, 1951; S. V. Kaledin, 1961). For example, the development of strength and speed conditions the development of the ability to display speed-strength (A. V. Korobkov, 1953; N. V. Zimkin, 1956; V. V. Kuznetsov, 1970).

Here the theoretical premise is based on the so-called "united" physical mechanism (the conditioned reflex), which underlies muscular activity. Training leads to the formation of a "vast background" of temporary connections, on the foundation of which (thanks to the "plasticity" of the nervous system) various combinations of the qualitative aspects of the motor activities can arise, depending upon the emphasis of training. It is assumed that in the beginning the means should develop the complex of motor qualities separately; and then they are integrated based on the sport exercises or movements structurally similar to them.

Recent developments have supplemented the 30's conception of the so-called qualitative specificity of man's motor abilities, based upon considerable factual material (I. Downey, 1923; G. Allport, 1933; C. McCloy, 1937; H. Iones, 1949; see Y. V. Verkhoshansky, 1970, 1972). This is indicative of the highly complex relationships between motor abilities; the development of a variety of means with the different regimes of muscular work, and due to this, the low degree of generality, a high degree of specificity and a poor transferance from one type of activity to another. General and specific abilities are in agreement with this conception. General abilities are the basis for the execution of more than one task, they are constant in comparison with the significant fluctuations of the conditions under which the task is executed. Man's general motor abilities provide the foundation for the realization of motor activities; determine the relative stability of the vital signs; and are regulated by heredity, the structure and physiology of the body.

Specific abilities condition the functional specifics of performance in complex motor situations; and are the chief results of motor experience, influenced by the environment and the interaction with it. If general abilities ensure the execution of several close (according to the qualitative indicators) task groups, then specific abilities will, to a large extent, be independent, securing only one concrete activity.

Attempts have been made to formulate theories, explaining the essence of the physiological mechanism of qualitative specificity and the functional independence of the motor abilities; in the presence of specific neuro-motor coordination of muscular activities (F. Pitts, 1954; F. Henky, 1952, 1960; F. Henkey, G. Whitlec, 1960,; K. Smith, 1962). However such attempts are represented by only speculative conclusions based upon rather "light weight" facts.

There is still much that is unclear and contradictory regarding the structure of strength abilities, despite numerous studies conducted in our country and abroad. An analysis of the literature (see observations of Y. V. Verkhoshansky, 1970, 1972) enables us to differentiate some of the positions on the basis of which there are more or less unanimity of opinion among specialists. Thus, a significant portion of experimental works indicate that muscular strength developed by one means does not have all-around usefulness; that there is no correlation between muscular strength and speed of movement; that strength exercises worsen speed of movement; that there is no connection between static and dynamic strength; that there is no carry-over from isometric training to the dynamic regime and that dynamic strength is to a greater extent connected with motor abilities than isometric strength.

However, it should be noted that the conclusions reached regarding the interdependence of motor abilities are made partially on the basis of experimental data obtained from a contingent of subjects of primarily low sport qualification and without taking into consideration the objective regularities determining the dynamics of sport mastery. It is therefore necessary to be very cautious in regards to these conclusions and restrict and sublimit their correctness to those categories of sportsmen (subjects) from which they were obtained and not hasten with generalities.

The notion of the structure of athletes' physical (and in particular strength) preparedness is based on the consideration of factual data and research (Y. V. Verkhoshansky, with collaborators). With respect to this, we propose that it is appropriate to distinguish between the notions of the composition and the structure of the sportsman's physical preparedness. By composition we mean the complex of qualitatively specific forms of the work-capacity, objectively inherent to a person which determine the success of his sport activities. By structure we mean the expedient, systemic-form principle of interdependence to the complex of motor abilities securing their functional unity and man's working potential.

1.3.2 General Characteristics of the Connections Between Motor Abilities

Research (Y. V. Verkhoshansky, 1970, 1972; V. G. Semyenov, 1971; V. V. Tatyan, 1974; A. V. Khodykin, 1976) enables us to speak of the following qualitative types of connections of motor abilities: general and partial, essential and non-essential, positive and negative, direct and indirect.

General and Partial Types of Connections. The general type of connection is characterized by the relationship between two abilities, taking into account the influence of the other abilities; while the partial has only an indirect relationship between two abilities. Calculation of the general and partial correlations is utilized for quantitatively assessing these types of connections.

Studies of the general and partial types of connections, with sportsmen of different specialization and qualification have established: 1) depending upon the abilities compared, the assessment of the partial type of connection can be lower (the most typical case) or higher than the assessment of the general type of connection; 2) the assessment of the partial connection between the same abilities, representative of different types of sports, is more stable and firm than the assessment of the general type of connection.

Essential and Non-essential Types of Connections. They are characterized to a greater or lesser extent, by the interinfluence of the motor abilities in concrete sport activities.

Research indicates that: 1) essential connections are more stable than non-essential connection (assessed by a general type of correlation), can bear a non-essential character, veiing the influence of the other abilities.

Positive and Negative Types of Connections. They are also characterized by the relationship between abilities where one of them favors, or vice-versa, hinders the other. Experimental data indicates that: 1) the positive type of connection is the most characteristic of the complex of motor abilities; 2) the negative type of connection appears primarily at the level of the partial connections; 3) the positive type of connection, at the general correlation level, can become negative at the partial correlation level.

It should be noted that the negative type of connection has been repeatedly discovered for such abilities as short and long distance running, absolute-strength, speed of movement as well as the ability to display explosive-force against a relatively small external resistance.

Direct and Indirect Types of Connections. The first type of connection is characterized by an indirect (direct) relation between two abilities and can express any of the afore-described types of connections. The second type is also a relation when there is an essential, direct connection between two abilities (for example there is no correlation between abilities A and B in figure 19.1 but they are nevertheless connected through the other -- third [C] ability). This type of connection is the most characteristic structure of physical preparedness. For example, there is no direct, significant connection between running speed and a sprinter's absolute leg strength (it has already been mentioned that this connection is negative at the partial level); however, there is a close connection with jumping exercises, which are also rather closely connected with running speed. This example is superfluous since it emphasizes how important it is to have a clear representation of the structure of an athlete's special strength preparedness and based upon this to determine tasks and to select and dose the means of special-strength training.

The indirect types of connections between motor abilities can be more complex. Thus, there is no direct, significant connection (see figure 19.2) between the height achieved in a vertical jump (h) and the absolute-strength of the legs (Po). However, the latter determines the magnitude of the maximal force of the "take-off" (F max), which in its turn, influences the magnitude of the impulse force of the push-off (Ft); and in the final analysis, the height of the jump.

The interdependence of the motor abilities changes both qualitatively and quantitatively with the growth of mastery.

The most typical dynamics of the connections at the qualitative level are the changes of the specific proportion of the aforementioned types of connections between the separate abilities and in some cases a clear switch from one type of connection to another. Thus, while preserving the partial type of connection, the general connection between individual abilities can increase or decrease because the non-essential connection can acquire vital importance and vice-versa. For example, triple jumpers lose some of their ability to execute the standing long jump (or triple jump) and conversely increase their sprinting speeds (at 30 and 100 M).

Positive and negative connections represent a special case. The changes in them are primarily one-sided with the growth of mastery -- from positive to negative (mainly at the partial correlation level); although a complete transition from one type to another type is apparently impossible because of the influence of the third (leveling) ability. In the initial stages of training, the principle -- "all means are good", is completely justified. However, as far as the structure of physical preparedness formation is concerned, the negative correlations between abilities show through more there, than where they should; but owing to the third ability, level out. Leveling proceeds according to the statistical mean principle; because of which, the optimal correspondance between a number of abilities is achieved, due to some quantitative decrease in both types of connections.

For example, the negative correlation between the 100 M and the 1500 M runs becomes all the more manifest in decathlon athletes with the growth of mastery. However, due to the improvement in the ability to run 400 M this correlation is leveled-out by some decrease in the closeness of the connection between running the 400 and 1500 M; and it is increased between the 100 and 400 M run.

Direct and indirect connections between abilities are subjected to the least qualitative changes. They are always present in the structure of physical preparedness, are its specific properties; and changes are primarily quantitative.

From the standpoint of quantitative changes, the connections between the individual abilities can be divided into two principal tendencies: a decrease or increase in the closeness of the connection and a linear or non-linear change of its indicators. These tendencies can be illustrated most completely by a model of the correlational structure of the specific physical preparedness of triple jumpers (figure 20). Presented in the model is an appraisal of the connection between tests; determining, in their aggregate, the level of the jumper's sprinting, strength and jumping preparedness. The coefficient of correlation relative to the groups of sportsmen based on the results in the triple jump are in the range 13.50-14.49, 14.50-15.49 and 15.50-16.70 M. respectively (there were 40 men in each group).

1.3.3 Factoral Structure of Motor Abilities

Very interesting data for understanding the structure of physical preparedness was obtained in special studies utilizing factoral analysis on a complex of tests (15-32); assessing the motor abilities of sportsmen of different specialization and qualification. An aggregate of junior and senior classified sportsmen in each type of sport were selected. In specific cases, the experimental data of training for various lengths of time of one group of sportsmen was analyzed. The possibility arose to examine not only the factoral structure of sportsmen's physical preparedness in this or that type of specialization but (chiefly) the change in this structure which is connected with the growth of sport mastery.

The quantity (composition) of factors increase with the growth of mastery and are distinguished from the aggregate characteristics from which motor abilities are assessed. This is expressed in the spearation of one or two factors. For example, the change in the structure of physical preparedness (table 1) of triple jumpers with the growth of mastery is connected with the separation of the first factor (separation of running 30 M, and the standing long and triple jump). Thus, if the factor composition of a junior jumper's physical preparedness can be identified as: 1) special sprint-jump preparedness and, 2) strength preparedness, then a new factor is added for qualified jumpers; the basis of which is explosive-jumping-strength (the specific factor).

The division of one relatively general, beginning motor ability into two specific abilities is a typical phenomenon of the process of the formation of sportsmen's physical-preparedness structure. The separation of the snatch and the clean and jerk indices from squats and barbell pulls indicators (weightlifters); the division of the absolute and relative strength indices (volleyball players); the division of the abilities to run with a running and a regular start as well as running 30 and 100 M from a regular start (sprinters, jumpers) and others have been observed in practical investigations.

The factor analysis procedure enables one to quantitatively assess the contribution of each factor in the general dispersion of factors. This circumstance was utilized for observation of the changes in the specific factor proportion with the growth of mastery. It has been established that simultaneous with the change in the factor composition (and consequently determinate motor abilities determining the success of sporting activities), there occurs (along with the growth of mastery) a distinctive over-assessment of their significance (see table 1). One of them acquires a greater significance, another becomes less important. It should be noted that there is a general tendency in speed-strength type of sports for the role of muscular strength to

Chapter I

Matrix of Factor Weights Table 1

Characteristics	Lower Classifications		Higher Classifications		
	43.6	14.1	46.3	13.7	7.7
	I	II	I	II	III
Triple Jump	757	114	671	244	290
Long Jump	721	-171	840	-078	175
100 M Run	666	-252	672	-064	416
30 M Run	477	-302	180	-159	567
Standing Long Jump	642	-221	267	035	551
Standing Triple Jump	718	219	153	020	711
Snatch	233	843	186	815	214
Clean and Jerk	185	884	189	877	218
Squat	170	757	081	790	229

Matrix of Factor Weights Table 2

Characteristics	Lower Classifications		Higher Classifications	
	41.5	13.3	58.6	18.3
	I	II	I	II
Standing Long Jump	102	697	170	914
Standing Triple Jump	210	712	222	917
F rel	640	288	579	369
Q	670	141	899	280
I	728	094	729	214
T	-847	-164	-933	-191

decrease and the role of the ability to express explosive force to increase (with the exception of weightlifters because they experience a sharp increase in relative muscular strength with the growth of mastery).

It has been established that simultaneous with the growth of sport mastery, the factor share of the individual motor abilities change (table 2) i.e., the degree of correlation of the latter with the given factor. Two fundamental tendencies are observed here -- an increase or decrease in the degree of connection of the individual characteristics with the corresponding determinant ability. It should be emphasized that this case convincingly corroborates the aforementioned tendency of the decreasing role of absolute-strength types of sports.

Research also indicates that the formation of the most essential changes of the composition and structure of physical preparedness primarily occurs in the beginning stage of an athlete's training. At the high sport mastery stage significant changes in the structure of physical preparedness do not occur; which is indicative of the stability of the composition of the determinant motor abilities and the significance of the factor share of the individual characteristics.

1.3.4 General Notions about the Structure of Physical Preparedness

In the methodological literature and the practice of sport it is acceptable to divide motor abilities into general and special. However, it should be emphasized that sport work-capacity is secured by a complex of motor abilities which are concrete, according to their qualitative characteristics; are relatively independent in both their manifestation and development; and can be called determinants. They are the determinants for a whole series of motor manifestations, the underlying basis of which is the united physiological mechanism.

Taking into account the definite functional role of the determinant motor abilities, it is appropriate to divide them into specific, non-specific and leveling abilities. The latter secure the so-called key motor ability, which adequately expresses the motor requirements that originated from the conditions and the motor regime of the concrete sport activity.

The functional role of specific abiities consists of securing the working productivity of the key motor abilities. The non-specific ability (according to its qualitative characteristic) does not satisfy the regime requirements the organism is introduced to and therefore participates as an assistance factor. The non-specific ability's role is noticeable, there, where the specific ability is displayed because of some objective difficulty. For example, if speed of movement (the specific ability) is the primary requirement but displaying it to a high level is difficult because of external resistance then muscular strength (the non-specific ability) acts as an assistance factor. On the other hand, if the qualitative level of explosive-strength displayed, decreases due to progressive fatigue for example, the required motor effect can be maintained by special-endurance.

The non-specific ability can often have a negative influence on the key motor ability. For example, an extraordinary development of absolute-strength has a negative influence on speed.

Leveling abilities execute an important functional role in the perfectioning of the key motor ability and the formation of the structure of physical preparedness as a whole. They smooth out the contradiction of the specific abilities; but in return neutralize the influence of the non-specific, if the latter acquires a clearly negative form with respect to the first.

Considering the qualitative diversity of motor functions, where the formation of a whole series of non-specific motor abilities is possible, it should be recognized that the leveling role of certain functions acquired by the organism has exclusive significance for securing a high level of sport work-capacity, under the changing conditions of the activity.

Finally, it should be noted that determinant motor abilities present their own complex structures of the elementary forms of the motor abilities. Thus, within the structure of the physical preparedness, according to the hierarchy principle, the key determinant and elementary abilities should be distinguished.

Based on studies of the types of connections between abilities (1.3.2) we can represent the principal organizational structure of physical preparedness (figure 21) in the following way. The key motor ability (B) is the result of the development and integration of a complex of determinants, primarily the specific (C) and non-specific (HC) ability for each concrete case of abilities. The leveling motor abilities (H), in the process of integration, actively participate first, in smoothing out the negative correlation between certain specific and non-specific abilities; second, remedy the connection between them, and third, expand the functional range and the accommodative potential of the key abilities. Each of the determinant abilities is represented as a structural complex of elementary abilities (E).

Underlying the formation of the structures of physical preparedness is the dialectical unity of the differentiation and integration of the motor abilities. As a result, a qualitatively new ability arises which is able to realize a high working effect under a wide range of conditions. This, if it can be so expressed, emerging ability is a qualitative novelty; its functional potential is greater than the sum of the properties of all the abilities.

The development of the specific motor abilities is one of the conditions for the formation of the structures of physical preparedness. Before making asumptions about the functional mechanism of the specific motor abilities it is necessary to consider the following factors. First, the elementary forms of the motor abilities are functionally independent, are not transformed into the key abilities (specific) and preserve their own qualitative individuality with the growth of trainability. Second, the specific motor ability (for example, explosive-strength) is in general, inherent to man and an innate property of his motor apparatus. Third, the specific ability is developed only by a certain motor regime.

Two premises for a theoretical hypothesis arise here: either the basis of the specific motor ability is functionally and qualitatively isolated from the close motor ability mechanisms or it is determined by the specific neuromotor structure, integrating part of the functional mechanisms of separate elementary forms of the motor abilities into a unified functional whole.

To simply accept this or a different hypothesis is difficult. It can only be stated (with good reason) that the formation and development of specific abilities is not based upon the synthesis of the elementary forms of the motor abilities; developed individually; and not by means of the gradual transformation from some abilities to others.

The latter circumstance relates to the second hypothesis, although it can only be accepted on the basis of logic. This hypothesis can be expressed by the principal scheme (figure 22) of the structure of explosive-force. The scheme emphasizes that the development of this ability (I), occurs under the conditions of a specific motor regime (CDP), has an influence on the components of explosive muscular strength (starting-Q, absolute-F, acceleration-G, the ability to quickly realize unloaded movement-V) and forms its specific neuro-motor structure (CHC). The latter is the fundamental condition for the development of explosive-strength, its specific neuro-motor structure acquires this or that functionally qualitative trait.

It should be noted that there is a principal distinction between the system-forming mechanism of the structure of physical preparedness as a whole, and the mechanism of the key and specific motor abilities. In the first of the two cases, the advantageous process of integration forms the foundation; in the latter case -- the process of accommodative perfectioning already has a functional structure. Therefore, the structure of physical preparedness and the structure of the key motor ability are more flexible, mobile and are formed on the basis of the wide diversity of the motor regimen. The specific motor abilities are more conservative and their neuro-motor structure is only perfected by a narrow range of means.

It is necessary to control the formation of the structure of physical preparedness, the solution to this problem, in theory of sport, is of exceptional complexity. This complexity is due to the fact that the physiological mechanism of integration of the structure of the motor abilities is as yet not sufficiently clear. Besides this, the structure of physical preparedness is revealed only in statistical expression. Therefore, it is extremely important to determine the general statistical regularities of the organization of this structure, acting as the premise in the search for means of objective assessment and control of the influences on it.

So, the material examined in this chapter indicates that the organism's adaptive behavior under the conditions of sport activity is a dialectical contradiction in nature. This is displayed by such tendencies as the integral and elective character of the accommodative reaction, the generality and specificity of acquiring functional reconstruction and the unity of divergent and convergent directions in the development of accommodative changes in the organism. The tendencies mentioned find concrete expression in the local specialization of the motor apparatus and the intensive development of specific motor abilities against the background of the rise in the organism's general work-capacity. Functional reconstruction begins with the organism as a whole then proceeds according to two interdependent (because of the organism's unity) and at the same time develops along independent (because of the differentiation and elective character of the organism's reaction) lines. The first unites general-functional reconstruction chiefly through the quantitative criteria of the training work; the second, goes a long way in determining the first by the rate of its development, -- specific reconstruction, having a clearly expressed qualitative tint; acquired chiefly through the specific criteria of the training load. Specifically, this line primarily determines the success of the sport activities. In the first place, for the partial training effect, achieved at the fundamental components level of the PASM (special and technical preparedness), there is a clear tendency for its specific characteristics to move close together in securing the resolution of a single aim -- raise the organism's special work-capacity (figure 23).

Observations of the accommodative displacement to the organism and its external relationships in the course of long term training showed that there is a tendency towards a correlation curve with sport results (see for example 1.2.3). This circumstance contributes to exposing the most general dynamic and structural regularities of the PASM (Y. V. Verkhoshansky, 1966, 1970).

It is appropriate to examine the dynamic and structural components of the PASM in general; which stand out, in light of the aforementioned factors. The dynamics of the four fundamental components of sport mastery (A - the sportsman's special work-capacity, B - the sportsman's ability to fully utilize his real motor potential in sport activities, levels of C - general and D - special preparedness) relative to sport results, can be expressed by the scheme presented in figure 24. The athlete's special work-capacity chiefly determines his sporting success; it improves steadily and has a linear correlation with sport results. Perfectioning of the ability to effectively utilize motor potentials can be described as a monotonously growing curve, asymetrically converging on the line expressing the increase in the key motor ability. Perfectioning of the organism's general work-capacity can be expressed as a monotonously growing and special preparedness as an intensely growing parabola.

The close correlation between the components differentiate, and to a significant degree, determine the motor specificity of the sport exercise. However, a certain regularity is observed in the dynamics of these connections according to the growth of mastery; its principal direction generally, can be expressed in the form of a vector correlational matrix (figure 25), where the arrows indicate the tendency in the changes of the close connections (up - increase, down - decrease).

Of course this scheme does not pretend to quantitatively, strictly express the dependencies and probably excessively simplifies reality. However, it is sufficient for the practical

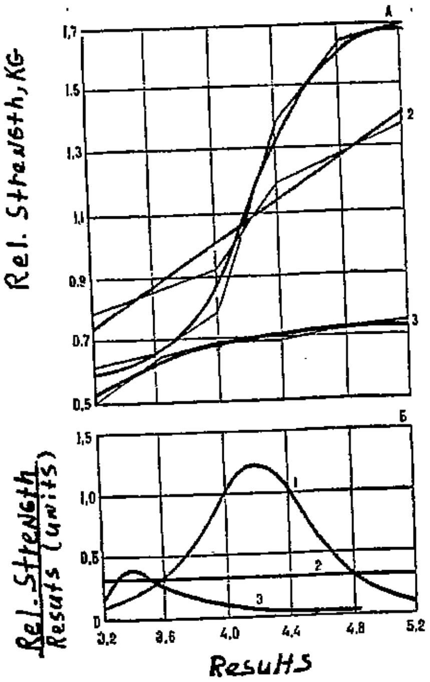

FIGURE 17, - Increase in relative-strength of the shoulder flexors (1), arm extensors (2), and the abdominal muscles (3) of pole-vaulters with the growth of sport mastery (A), and the increase in muscular strength, in units of sport results (B).

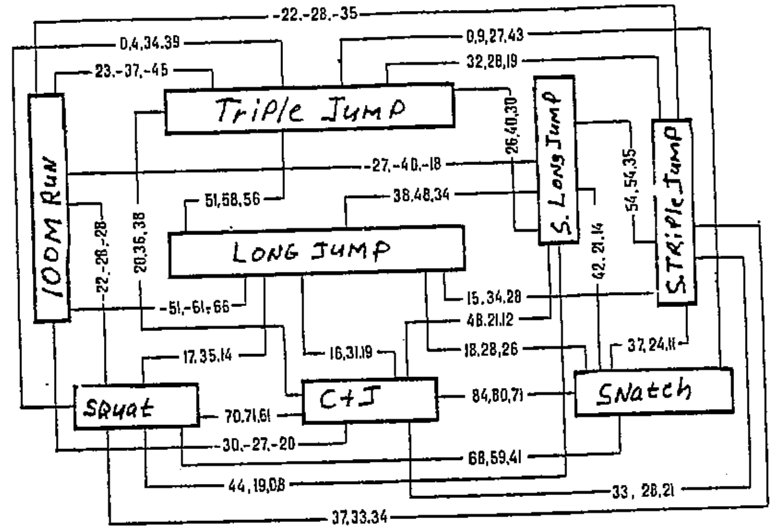

FIGURE 20 - Corrleation of special physical preparedness of triple jumpers.

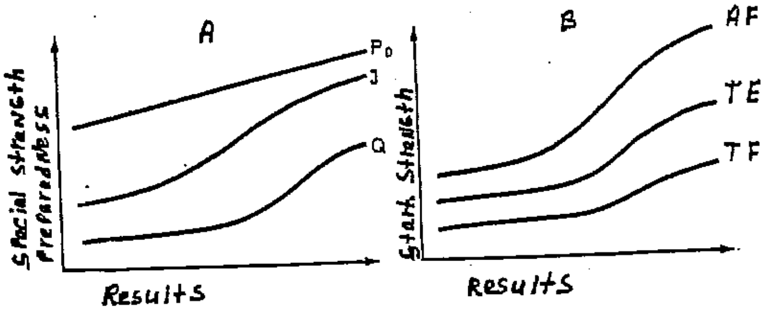

FIGURE 18 - Dynamics of speed-strength (A), and starting strength (B), relative to sport results (AF-ankle flexion, TE-thigh extension and TF-thigh flexion).

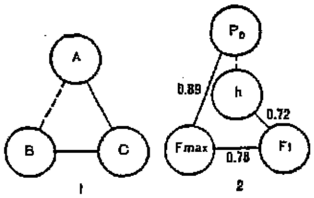

FIGURE 19 - Types of connections between motor abilities: 1) theoretical model, 2) concrete example.

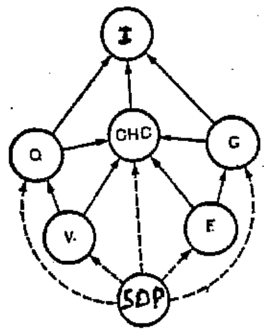

FIGURE 22 - Model of special-motor abilities.

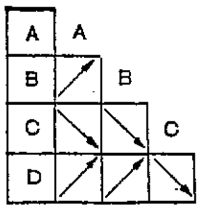

FIGURE 25 - Vector correlational matrix of changes in the close connections making up the PASM.

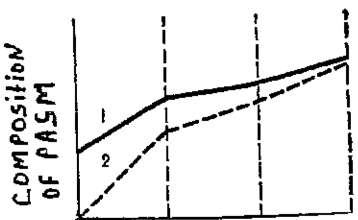

FIGURE 23 - Dynamics of special (1), and technical (2), preparedness of the PASM.

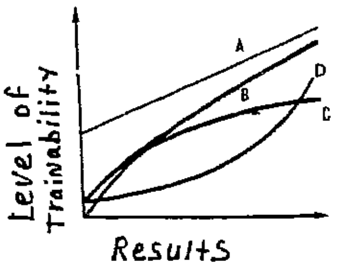

FIGURE 24 - Tendencies in the fundamental composition of sport mastery.

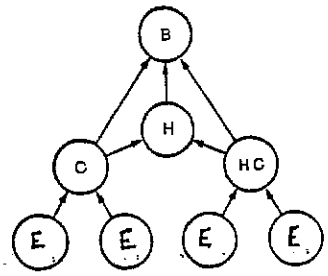

FIGURE 21 - Model of an athlete's physical preparedness.

aims of clearly characterizing the tendencies in the dynamics of the fundamental components of the PASM; and can serve as a point of orientation for long-term planning of training, at least until there is a more subtle and "richer" mathematical attempt to resolve the problem of not yielding more precise and reliable results.

A few words in conclusion about sport technique (the precision and essence of this notion) which secures from the aforementioned regularities in the dynamics of the PASM.

The working-effect of an athletic movement is none other than the product of the specific form of the organization and control of man's interaction with the environment. However, the scheme presented in figure 23 indicates that the fundamental notion of "sport technique" appears not only and not so much as the organization of the motor composition of the exercise as the determination of this organization of the sportsman's ability to purposefully utilize the external conditions and their possibilities. This ability is the result of many years of perfectioning the motor functions and its securing of the organism's systems. And if this is so, then sport technique is the result of a certain form of the process unfolding over time, and consequently, as a concrete scientific notion, includes time coordinates. This determines an important methodological principle, that sport technique is not a constant which can be achieved once but is the result of an uninterrupted and interminable process of movement from lesser perfection to greater perfection.

The aforementioned consideration persuasively indicates that sport technique is widely understood in practice and the methodological literature as a means of solving motor problems and not exhausting the essence of a certain notion. Strictly speaking, sport technique is an expressed concrete system of movement, representing not so much a means of solving motor problems as the very motor problem itself which the athlete must solve each time he executes a sport exercise. Consequently, sport technique, consists of the search and assimulation of rational motor methods that provide the best way to utilize the sportsman's motor potentials.

Therefore, the sportsman's ability to utilize his real potential in purposeful, adequate motor tasks by maintaining a concrete system of movement is the essence of sport-technical mastery. Continual perfectioning of this abiity is a key invariant of the training process and the degree of completeness of the utilization of motor potential -- is the criterion of its effectiveness.

Chapter II

Peculiarities of the Displaying of Man's Strength in Athletics

It was not very long ago when an athlete did not trouble himself to discuss the point which is so important in today's training. The question of strength was decided rather simply: whomever could lift the most weight or record the highest reading on a dynamometer was the strongest. However, experience and scientific experimentation has uncovered facts which indicate how primitive those evaluations of strength were. This resulted in the necessity to consider the question of strength preparation in sport more carefully; and to precisely define the concept of strength. Thus, what is understood by the term strength?

The notion of strength is first of all physical. In mechanics it expresses the extent of the interaction of bodies, causing their movement. Therefore, in the physical sense, as a vector quantity -- strength is understood with respect to the quantitative aspects of man's interactions -- with say the support, an apparatus or other external objects. In other words when assessing the force which results in movement -- its working-effect.

If one speaks of the source of movement, then one is talking about strength -- a man's ability to perform work. This ability is the reason for the movement of the body or of its links. In this instance, we are referring to the type of force associated with the pull of man's muscles -- a physiological phenomenan.

And, finally the notion of "strength" is utilized as one of the qualitative characteristics of volitional movement by man to solve concrete motor tasks. Here, in conjunction with such criteria as speed, endurance, dexterity and others, strength is a pedagogical notion; evaluating the qualitative side of the execution of movement.

The infinite diversity of man's movements makes it necessary to quantitatively evaluate the strength components of movement (moderate, maximal strength, impulse-strength, work and power); man's ability to display strength (absolute and relative-strength, the moment force of muscular contraction relative to the joint); as well as a differential comparative evaluation of the strength components of movement (fast and explosive-strength, speed-strength movements, strength-endurance and others), reflecting the qualitative specificity of movements and the selection of the corresponding means and methods of strength preparation.

Thus, muscular strength is a concrete notion and it is displayed purposefully under concrete conditions. However, the conditions under which muscular strength is displayed in athletics are extraordinarily diverse. Therefore, prior to talking about the means and methods of special-strength preparation, the fundamental peculiarities of displaying muscular strength in sport movements should be examined.

2.1 The Regimes of Muscular Work

Many experimental studies have been devoted to the different regimes of muscular work. Based on the purpose of the works (prior to their undertaking), they can be divided into two groups. One group is devoted to determining the conditions and regimes which secure the working-effect of muscular strength; the other to the search for the regime which most effectively develops muscular strength. Unfortunately many of these investigations lead to nothing less than an abundance of contradictions and confusion.

For example, one author maintains the largest strength gains are made with the dynamic (overcoming) regime, another -- with isometric tension (see Y. V. Verkhoshansky, 1970, 1972). Besides this, a careful analysis of the experimental design creates the impression that similar contradictions are associated with incorrect generalized conclusions of the participating factors obtained in different laboratories and natural surroundings; on different muscle groups of subjects of different preparedness; different loads and movement speeds. Thus, it was established that with maximal isometric tension of the biceps muscle (the elbow bent at a 90° angle) the subject was able to develop a force 6.5-10.0 kg greater than the maximal weight he could lift.

However, this changes with the decreasing load and the increasing speed of movement. The electrical activity in the biceps muscle as it is lifting a weight 50-80% of maximum is significantly greater (as far as the force produced) than it is during the period it is subsequently 'held' (A. S. Stepanov, M. A. Burlakov, 1963; V. D. Monogarov, N. P. Laputin, 1966; I. Scheraev A.O. 1954, 1957; Ph. Rasch, W. Pierson, 1960), in both its magnitude and display of strength (I. N. Knipst, 1952; A. A. Yanchevsky, R. P. Steklove, 1966). Thus, there is an important difference in the characteristics of the muscular force displayed depending upon the magnitude of the load and the speed of movement associated with it. It should be pointed out, that the force arm of the muscles increases four-fold up to an angle of 90° during elbow flexion. Therefore, if for example, you compare the force of a maximal isometric contraction developed at an angle of 90° and the maximum weight raised beginning at an angle of 180°, then the advantage will naturally be the first instance.

Consequently, if one is talking about developing muscular strength, then to discuss excelling at dynamic or isometric regimes is scarcely appropriate, because the biomechanical conditions for the display of strength are not comparable. If the necessity arises to compare the training-effect of a certain regime then you must first answer the question: what kind of strength are you measuring?

A similar approach is necessary when you are considering the advantages of yielding and overcoming regimes of muscular work. It has been shown (A. Bethe, 1929) that the force a muscle develops with a maximal contraction (active strength) is significantly less than the resistance strength the contracting muscle displays when it is stretched (passive strength) [on the whole 1.2 - 1.6 times more]. The superiority of passive strength over active for some muscle groups are the following: for the arms -- 22%, forearms -- 46.8% and 50% for leg extensors. According to Semyonov's data (1968), the maximal force developed by the leg extensors at an angle of 120° in the knee is 465 kg in the isometric regime and 401 kg in the overcoming regime. For combined regimes, the largest strength was recorded in the slow yielding regime (under conditions of equivalent forced leg flexion with the aid of an electric motor) after preliminary maximal isometric tension -- 504 kg; and 453 kg in the yielding regime after overcoming work.

The stretch reflex (myotatic reflex) has great significance for increasing the working-effect yielding work. Experiments on animals and humans have established that the larger the speed of muscle stretch, the stronger the myotatic reflex (A. Samoyloff, M. Kisseleff, 1928; O. Foerster, H. Altenlurgey, 1933; O. Lippold A.O., 1957). It has been noted, that the better trained the athlete, the more precisely and fully the utilization of reflex muscle tension; which comes about in the course of executing yielding work (Y. Z. Zakharyents, 1962).

The energy expenditure of yielding (passive) work is significantly less for the organism than overcoming (active) work. It has been demonstrated (Chauveau, 1904), by the substitution of active contraction with resistance work -- that the expenditure of energy is almost 1/2, when movement velocity does not exceed 0.12 meters/second. These conclusions have been coroborated experimentally. It has been revealed that more energy is expended by contraction of a muscle which shortens and executes work than for an isometric contraction. The energy expenditure for muscle lengthening is less than an isometric contraction (W. Fenn, 1924, W. Hartree, A. Hill, 1928; A. Hill, 1930; M. Cattel, 1983; B. Abbott A.O., 1952; D. Wilkie, 1954). However, it should be emphasized that the aforementioned advantage of yielding work is displayed only with slow movement and large loads. Therefore, there is no reason to associate these advantages with the potential to acquire the ability for quick and powerful movements in overcoming work.

This was a very short survey of the important mechanical and physiological differences in the forms of muscular activity. Therefore, the search for an absolute, universal regime of muscular work to develop strength is as useless as it is to discuss the advantages of a specific regime without taking into consider-on the type of sport activity and the specific character of the muscular tension.

Before going on to the next section, one should designate more precise terminology for all of the diverse manifestations of muscular work. This is associated with the types of mechanical work and their corresponding regimes of muscular tension. We do not pretend to have classified all the forms in which the working activity of muscles are expressed in figure 26. It is obviously only for convenience; and within the limited scope of this book, a systematization of the concept. Although it should be pointed out that the principle can be utilized to devise a stricter and more representative classification.

Thus, to evaluate the external manifestation of muscular activity one proceeds by differentiating the four basic types of muscular work (based upon mechanical criteria): overcoming, yielding, holding and combined. In specific cases, when talking about moving the body (its links, external objects); or maintain- a posture with muscular force equal to bodyweight (its links, external objects); or external influences, then one can speak of the correspondence of dynamic and static muscular work. True, in the latter case, there is no work in the physical sense, since there is no movement. Therefore, in order to quantitatively evaluate static work the production of force over a distance is not used; but assessment is based on the physiological meaning of work; and the production of force and the time of its action are utilized.

Muscular tension should be considered a physiological criterion and is distinguished by three basic regimes: isotonic -- a change in length, but the tension developed remains constant; isometric -- tension is developed without a change in the length of the muscle; aucsotonic -- there is a change in tension along with the change in muscle length. However, these regimes do not exhaust all the tensions of the working activity of muscle and do r reflect such essential peculiarities of a sportsman's move- t as the speed and magnitude of the tension; dependence of the tension upon the external interaction of the motor apparatus, and tic

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ACTIVITY OF WORKING MUSCLE

TYPES OF MUSCULAR WORK

OVERCOMING YIELDING HOLDING COMBINED

REGIMES OF MUSCULAR TENSION

ISOTONIC ISOMETRIC AUCSOTONIC

CHARACTER OF THE DISPLAY OF MUSCULAR TENSION

CYCLIC SPEED ACYCLIC SPEED EXPLISIVE REACTIVE-BALLICTIC EXPLOSIVE BALLISTIC EXPLOSIVE ISOMETRIC PHASO-TONIC PHASIC TONIC

FIGURE 26

others. Therefore, taking into consideration the diversity of sport activities it is necessary to distinguish the specific character of the display of muscular tension, in particular, the different speeds with which tension is developed; its magnitude; duration and repetition, as well as the state of the muscle preceding the working tension. With all the diversity in sport movement, the display of muscular tension can be conditionally divided into eight types (see figure 26). These criteria will be decisive in the subsequent discussion of special-strength preparation in sport.

The tonic type of muscular tension is characterized by significant and relatively prolonged tension; the speed with which it is developed however, does not have decisive significance. This type of tension can be observed in wrestling when one athlete pins another to the mat; in weightlifting when the sportsman holds the barbell on the chest or presses it overhead; and in many gynmastic elements. In all these instances, the muscles are working at their absolute limit force capabilities; and in individual elements of single-combat competition, it is advantageous to manifest absolute force against an opponent. However, tonic tension can accompany a significantly lesser force in instances where it is necessary to hold a pose (shooting, gymnastics). Depending upon the type of sport, the qualitative characteristic of the strength displayed by tonic tension, is determined by strength-endurance or the absolute magnitude of muscular strength.

The Phasic type of tension corrresponds to dynamic muscular work in exercises requiring the display of a motive force of a certain magnitude. Such exercises are typically cyclic movements. Each cycle has its own changing rhythm of muscular contraction and relaxation and repetition frequency. Here, the speed with which maximal motor force is developed is not so important; but strength or speed-strength endurance play an important role. The type of exercise, the magnitude of tension (rowing); or the cycling tempo (swimming, speed-skating) or both (bicycling) can have decisive significance in the working of the muscles. It is also possible to develop the ability for phasic work of long duration at a moderate tension (running and swimming distances).

The Phaso-tonic type occurs when work can change to holding and vice-versa, due to different musical rhythms and tempos of movement (gymnastics, wrestling). The qualitative aspects of a sportsman's strength preparation in these cases, is very complex and multi-sided. One type of sport or even one sport exercise may require both tonic and phasic tension; and it is very important to note, that there may be a rapid switch from one type of tension to another at a high level of effort, in each of them. This occurs in gymnastics during the switch from the dynamic elements to the static (holding); or when a boxer attacks quickly against the opponent's resistance.

Explosive-force is inherent to the following types of muscular tension: explosive-isometric, explosive-ballistic and explosive-reactive-ballistic.

The Explosive-Isometric type of muscular tension is inherent to movements in which significant resistance is overcome (for example, snatching or jerking a barbell, some elements in gymnastics and wrestling, throwing a heavy projectile). A basic peculiarity of these movements is the necessity to develop a significant working-force; the maximum of which is achieved, advantageously, at the end of the movement.

The Explosive-Ballistic type of muscular tension is characteristic of movements in which maximal force is applied to a relatively small resistance (for example, the shot put, javelin, some elements of figure skating, the serve in tennis and others). Here the motive force reaches maximum quickly at the beginning and middle ranges of the movement, then begins to diminish. Due to inertia and muscular force (which at the end of the working amplitude does not exceed the weight of the load) the load has no acceleration but is only maintaining its velocity. The typical kinematic characteristics of ballistic movements are presented in figure 27. As the resistance increases, this type of muscular tension switches to explosive-isometric.

A ballistic movement, in its correct working phase, can be preceded by some muscular stretching.

The Explosive-Reactive-Ballistic type of muscular tension has the same peculiarities as the explosive-ballistic type except for the regime of muscular work. Here the preliminary stretch phase is sharp and clear-cut, after which there is an immediate switch to overcoming work. This can be observed in some throwing, in the individual elements of wrestling, gymnastics, figure skating, kicking in football, volleyball or tennis.

In speed movements where the rapid switch of the working links or the body as a whole, plays an important role; the type of tension is a quick momentary muscular contraction (punching in boxing, the prick in fencing), or is repeated at a specific tempo (for example, sprinters). The first instance is an example of the speed of an acyclic type of tension; and the second, of the speed of a cyclic type.

The speed type of tension is basically inherent to movements where the force developed resists the inertial force of the system's working links and can be executed with an insignificant additional load (rapier, racket). Therefore, they do not require that tension be developed quickly. Speed-cyclic types of tension require that the level of the working-effect be maintained in each cycle of tension (with respect to its repetition) during the muscles' highly-developed ability to relax after a working movement.

Many movements in sport are superficially similar in their spatial structure and are executed with basically the same muscles. For example, punching in boxing, putting the shot, the bench press, the spike in volleyball, the serve in tennis, javelin throwing and others. Even the experienced eye can not see the essential differences in the kinematic characteristics of some of them. The reverse is true for other movements. The differences in the speed, amplitude, direction, beginning conditions of execution and the magnitude of the strength displayed are strikingly obvious to the naked eye. A more detailed analysis (with instruments) reveals such nuances as the variations in the activity and the muscles working, the sequence and speed of their inclusion in the work, energy expenditure, means of utilizing energy resources and others.

All of the diversity in athletic exercises can be divided into a number of groups in which they are unified according to the primary peculiarities of the muscles' activity. Such an approach is clearly practical when the selection of training methods is considered; in so far as helping to reveal the most common exercise traits in muscular work for the group; as well as the specific character of this work, expressed in the speed with which tension is developed, its magnitude, duration and repetition, state of the muscles, and the preceding working tension.

2.2 Qualitative Characteristics of Man's Strength

The diversity of the conditions under which muscles work in athletics, conditions the differences in the functioning of the motor apparatus and consequently, the primary development of a specific strength capability. Dividing the strength capabilities into four parts is rather conditional (absolute, speed, explosive -strength and strength-endurance) because all of them (in spite of their inherent-qualitative specificity) are interrelated in both their display and development. They are not displayed separately (or more precisely are displayed rarely) but are part of the components of any movement. The strength ability most characteristic of athletic activities is explosive-strength, as displayed in acyclic and cyclic movements. The former is distinguished by powerful muscular work, while the latter by the necessity to maintain an optimal power level for a relatively long time. If attention is turned to the fact that the explosive character with which strength is displayed to any degree (depending upon external conditions) is secured by the presence of absolute or speed-strength, then two general abilities -- explosive-strength and strength-endurance are the basis for the realization of all the diverse athletic movements of man.

2.2.1 Explosive-Strength

Explosive-muscular-force is determined by the external resistance overcome. Therefore, it makes sense in considering the peculiarities of explosive-force (in the dynamic regime of muscular work) to look at loads of various weight; for example, the graph of F (t), depicted in figure 28. Also shown in figure 28 are absolute-strength (Po), in the isometric regime (for specific joint angles); the corresponding maximum strength in the dynamic regime; and the graphic F (t) of explosive-isometric tension.

The graph has a number of peculiarities. In all instances the maximum force F (t) is less than Po. The closest value to (P) is the maximum force of explosive-isometric tension. In the dynamic regime, the difference between Po and F max (i.e., the strength deficit) increases as the resistance decreases (table 3). In other words, with decreasing external resistance, the realization of the muscles' strength potential for explosive-force is diminished; which the correlation between Po and F max indicates.

Despite the differences in height of F (t) over the abscissa on the graph for different loads and isometric tension, they are precisely superimposed upon each other at their beginning points. This is seen when the resistance of the weight of dynamic work and the resting inertia of a shifting load are compared. For example, presented in figure 29 is a graph of F (t), explosive-force at 40 (1) and 70% (2) of Po (continuous line) and the resistance of resting inertia of turning, equivalent masses (broken line).

Thus, if explosive-force is entirely dependent upon external conditions; and its maximum on the level of absolute-strength; then the beginning part of the graph F (t) is determined by the special ability of the neuro-muscular apparatus; conditionally characterized earlier (Y. V. Verkhoshansky, 1968, 1970) as starting-strength. It can be assumed the the degree to which this ability is displayed, is secured by the intensity of the hemo-physical conversion of substances in the muscles, which are responsible for the quick development of initial tension. The intensity of these conversions during limit volitional effort is characteristically constant (for given functional state and a sportsman's level of trainability); and is independent of the

TABLE 3

Resistance Movement	Fmax in % of Po	Strength Deficit	Fmax Po Corrleation
80% of Po	94.0	6.0	0.822
60% of Po	82.7	17.3	0.798
40% of Po	64.4	35.6	0.657
20% of Po	47.7	52.3	0.316

Matrix of Factor Weights TABLE 4

Character-istic	Women, Foot				Men, Thigh			
	51.8	29.3	12.8	8.3	48.0	28.5	10.6	8.9
	I	II	III	IV	I	II	III	IV
Po	318	889	-105	089	187	958	095	085
Fmax	448	857	-125	135	214	961	008	067
tmax	-876	152	315	367	-887	416	-016	133
I	804	222	-337	006	932	065	219	167
Q	179	188	-925	144	300	-114	856	209
G	150	335	-362	628	198	218	318	591

external resistance, its character (the load or its resting inertia) and the regime of muscular work (dynamic, isometric).

During explosive-isometric tension and dynamic effort with loads 60 and 80% of Po, the external force quickly attains a certain level (due to the starting-strength) and continues to grow more slowly to maximum (see figure 28). In dynamic regimes of muscular work, graphic changes in F (t) correspond to the instant the force reaches that of the weight of the load. One can assume that in so far as this is the instant when the movement begins, that it is carried-out by the inclusion of some new physiological mechanism, mobilized by additional resources for the purpose of increasing muscular strength; and it determines the ability of the muscles to display power of movement.

The ability to determine that segment of the working-effort which secures the acceleration of a moving object was conditionally described as the acceleration force of muscle (Y. V. Verkhoshansky, 1970, 1972).

Thus, one can conclude that explosive-strength (this general qualitative characteristic) distinguishes movements which require the display of significant neuro-muscular tension in the shortest time, from several other movements of the speed-strength type; and assesses the ability to quickly build up the working force to maximum. Starting-strength is the ability to quickly develop force at the initial moments of tension. Acceleration-strength is the ability to quickly build up working force at the beginning of contraction.

It is not difficult to conclude that during dynamic-explosive-force with 20-40% of Po, the F (t) curve is characteristically determined entirely by the starting-strength of the muscles. With a resistance of 60-80% of Po their functional characteristics are essentially changed. As it was in the previous instance, the beginning of the F (t) curve is determined by starting-strength, however, further on it is increasingly connected with the muscles' ability to quickly display the maximum possible strength, i.e., the acceleration-strength of muscle.

A number of specially designed studies indicate that there is a small connection between starting-strength and acceleration-strength; and that they are qualitatively specific motor abilities. Thus, based on a factor analysis, the F (t) curve of explosive-force in the isometric and dynamic regimes indicates these abilities are distinguished by different factors. As an example, we listed fragments, typical for these investigations, of matrix factor weights for the parameters of the F (t) curve of explosive-isometric-tension of highly-qualified women sprinters in foot flexion; and thigh extension of jumpers of middle-qualification (table 4). The distinguishing factors are easily identified in the following way: 1) general ability to display explosive-strength, 2) the sportsman's strength potential, 3) the muscles' ability to rapidly display a working-force at the onset of tension, i.e., starting-strength, 4) the muscles' ability to quickly accumulate the kinetic effect of the initial working tension, i.e., acceleration-strength. We should add that in certain experiments where the absolute speed of movement was recorded (the average velocity of an unloaded movement Vo); it was singled-out as an independent factor.

Thus, the working-effect of an athletic movement, executed with maximal volitional tension, is determined to a greater or a lesser degree by the four qualitative special-strength abilities: absolute-strength (Po), starting-strength (Q), acceleration-strength (G) and the absolute speed of muscular contraction (Vo). To a greater or lesser degree these abilities are intrinsic to children and adult sportsmen of various levels of preparedness and specialization, executing isometric and dynamic regimes of muscular work (investigated by I. M. Dabrovolsky, A. Mamadzhanyan, D. M. Iliev, E. Purvin, V. G. Semenov, V. N. Deniskin and others). It has been established that training did not change the aforementioned factoral structure of the speed-strength abilities. Depending on character and primarily the emphasis of training, the factor weight of certain characteristics, the assessment of this or that strength ability, as well as the contribution of each factor in the general dispersion are altered (Y. V. Verkhoshansky 1972, 1973).

In the interests of solving the problem of special-strength preparation it is expedient to dwell on the principal relationships between the strength abilities and their role in the realization of athletic movements (depending on external conditions).

The larger the resistance the greater the connection between strength potential Po, and maximal explosive-force F max. As external resistance increases the percent generality of the individual differences between Po and F max increases (figure 30, curve #1), and vice-versa; as it decreases the percent specificity of the differences between them increases.*

*[The quantitative assessment of the generality (generality - r^2) and specificity (specificity - k^2) factors is based on the motor task (determined by the correlation coefficient between the signs). Raising the correlation coefficient to the second power, and multiplying the 100 (r^2 x 100) gives the percent generality of the individual differences, determined as the sign of similarity for the two shifting magnitudes. The quantity characterizing the specificity for both of the shifts (k^2), is determined by the equation (r^2 x 100) + k^2 = 100. It is acceptible to consider that the specificity of the sign is significant, if k is larger than r^2. (W. Lotter, 1961; F. Henry, L. Smith, 1961; I. Bachman, 1961).]

In all instances, the strength potential Po and the maximum force F max, with any ordinate values of the F (t) curve, are less, the closer the latter during the onset of force. The mean generality of the individual differences between Po and the value of the beginning portion of the F (t) curve is 20-25%; at the same instant, the specificity is 75-80%. It should be pointed out that the connection between potential and the values of the F (t) curve at its initial point, for poorly trained people, is substantial but with the rise in trainability, this becomes unreliable. The degree of generality between Po and the initial part of the F (t) curve diminishes noticeably, as a result of even short-term training (30-36 workouts).

Not only is there no relationship between the strength potential Po and absolute speed Vo; it is negative (the correlation does not permit the rejection of the null hypothesis). The connection between strength potential and the speed of a working movement, executed against external resistance, has a significant generality (up to 40% of Po) which then increases with an approximately linear dependence on the external resistance (figure 31).

Thus, absolute-strength determines neither the working-effect, at the initial instant of muscular tension; or the maximum force in movements against small external resistance. It is connected with maximum explosive-force only if the external resistance is significant. Not only does absolute-strength not ensure the development of absolute speed of movement, but it is associated with just the opposite -- it is a negative factor. However, if the movement is executed against an external resistance, then the larger the resistance, the more speed is dependent on absolute-strength. There is an exceptionally low degree of generality between the absolute speed of movement Vo, and its speed, if it is carried-out against an external resistance. In this instance, even with a resistance 20% of Po; the specificity of the individual differences reaches 70% (figure 30, curve 2). Consequently, the absolute speed of movement has a very moderate influence on the speed of explosive force, if the external resistance is in the range of 10-20% of Po. The correlation between the gradient characteristics of the F (t) curve are different. The mean degree of power between the I and G gradients is 84%; the degree of specificity -- 16%; between the I and Q gradients 52 and 48% respectively; and between the Q and G gradients 27 and 73%. The significance of the gradient forces are moderately connected with absolute-strength (I and G to a larger and Q and G to a lesser degree) and to the absolute speed of movement (Q to a larger and I and G to a lesser degree). Here the power segment of the individual differences depends on the external resistance and averages 20%, whereas the specificity portion is 80%. The gradient forces and their corresponding time parameters of the F (t) curve, have a typically higher power; reaching an average of 64%. Due to training, the power of the gradient forces from Po decrease significantly (particularly Q) and in accordance with the time parameters, the F (t) curve, increases; but the absolute speed changes insignificantly.

Starting-strength (Q) and acceleration-strength (G) are weakly dependent upon each other. The general abilities to display explosive-strength (I) and acceleration-strength (G) are to a significant degree determined by an aggregate of causes. Starting-strength (Q) and the general ability to display explosive force (I) have little in common.

It should be emphasized, that the componential abilities examined are intrinsic to the neuro-muscular apparatus of man, but are, nonetheless, utilized for the realization of speed-strength movements to an unequal degree. Depending upon external conditions one of them acquires a preeminent role. The general tendency here can be expressed by the following: the lesser the external resistance of the movement (consequently, the faster and briefer its execution) the larger the role of such abilities as absolute speed; and especially, starting-strength. And, vice-versa, the larger the external resistance the greater the importance of acceleration and absolute-strength. In accordance with these criteria of componential abilities (which secure the working-effect of explosive force), one can arrange the following series: Vo - Q - G - Po; which can correlate concretely with the external resistance of the movement, as depicted on the abscissa in figure 30.

This series has some peculiarities. First, the development of componential abilities proceeds independent of each other, the progression of one of them is reflected in a very insignificant development in the others. The further the abilities are removed from each other in this series; the lesser their interaction. Second, the development of each ability requires an adequate motor regime. A training influence directed primarily at one ability has no afffect (or affects very little) the other abilities. Third, the relative independence of the componential abilities in their display as well as in their development becomes even more obvious with the increase in the sportsman's trainability. Fourth, the componential abilities are subjected to unequal training. The abilities on the right side of the series are easier to perfect than those on the left.

In a practical sense, since sport movement is always associated with overcoming an external resistance, two componential abilities primarily determine the working-effect of explosive force -- starting and acceleration-strength. In order to examine their role in the execution of speed-strength movements we have to look at the graph in figure 28. It is obvious that when overcoming insignificant external resistance (20 and even 40% of Po) man is simply unable to display his strength potential. In this instance, the impulse force producing the movement is developed chiefly by starting-strength. With a large resistance (more than 60% of Po) the impulse force securing the working movement is developed primarily by acceleration and absolute-strength. Starting-strength plays an assistive role here. Thus, in order for the working tension to reach a certain level as quickly as possible, starting-strength is the underlying mechanism crucial for the display of acceleration-strength. First, it follows that with an external resistance, starting-strength is displayed under isometric conditions of muscular tension (the greater the external resistance the larger it is expressed); and acceleration-strength is displayed in the dynamic regime; second, the higher the level to which starting-strength is developed, the faster the acceleration-strength can be realized. The latter circumstance should unconditionally be emphasized considering the limited time for the execution of a speed-strength movement in athletics.

Not all of the componential abilities are equal in securing the working-effect of explosive-strength. Depending upon the conditions one or the other acquires a key role and consequently receives the main potential for intensive perfectioning. Participating to a greater or lesser extent during the realization of powerful motor acts, the componential abilities, due to relative independence of the securing of their neuro-motor mechanisms, unite not in organic, but functional units. In other words, they integrate into some new general ability but they regulate the interaction, solve general tasks and at the same time maintain their qualitative individuality and preparedness to enter into any functional union which the changing conditions of the activity may require. Depending upon the character of the movement, a motor program is formed through which the componential abilities are realized instantaneously and in succession. For example, initially the mechanisms crucial to the display of starting-strength are realized, then speed of movement (if only the force of inertia of a working organ or the body as a whole is overcome); or mechanisms crucial to the display of starting then acceleration and absolute-strength (if there is additional burden or resistance). It is not difficult to see the potential for extensive accommodative maneuvering in the interests of securing the most effective motive diversity (according to motor regimes) of movement, while utilizing comparatively limited neuro-motor mechanisms.

We should dwell here on the particular form of the muscles' ability to realize explosive force (characterized earlier as the reactive ability of the neuro-muscular apparatus). This is understood as the specific ability to display a powerful motive force immediately after an intense, mechanical, muscular-stretch i.e., there is a rapid switch from yielding to overcoming work at the instant a maximal dynamic load developed. The preliminary stretch causes an elastic excitatory deformation in the muscles, creating an accummulation of potential energy which is transformed into kinetic energy as the muscles begin to contract. This is added to the muscles' force and increases their working-effect.

Reactive ability, as a specific quality of man's working apparatus comes from some of the principles of neuro-muscular physiology. It is known, for example, that the preliminary stretching of a muscle increases the working-effect of its subsequent contraction. It has been established that the overcoming work of a muscle which begins contracting quickly after a preliminary stretch (in a state of tension), is larger than the overcoming work of the same muscle executing an isometric contraction

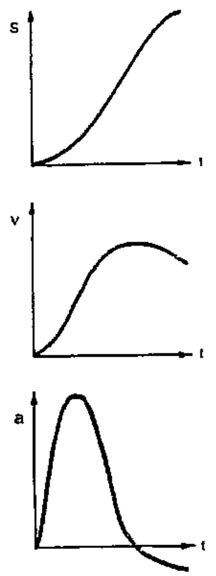


FIGURE 27 - Graph of a ballistic movement.

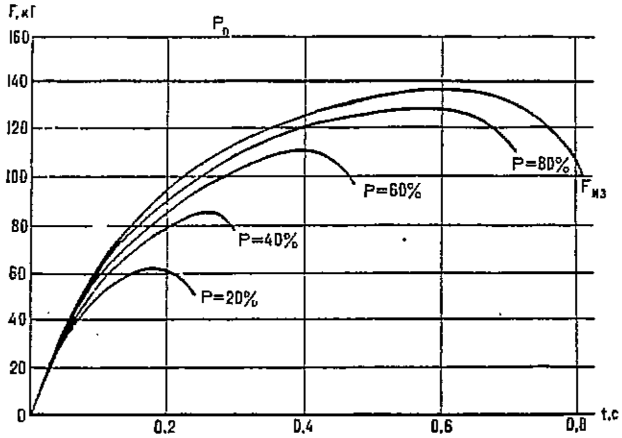


FIGURE 28 - F(t) graph of explosive isometric tension F(iso) and dynamic work with 20, 40, 60 and 80% of maximum strength (P) for a leg-press movement.

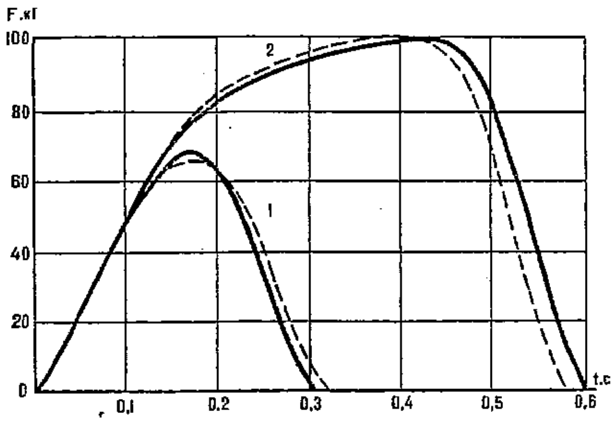


Figure 29. F(t) graph of dynamic work of limit volitional effort (explained in text)

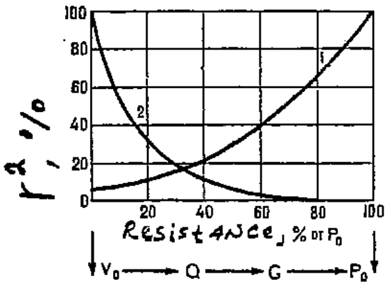


FIGURE 30 - Alteration in the power of individual differences (r2) between the maximum explosive effort (1); and between absolute speed of movement and the speed of a resistance movement (2) depending on the external resistance (% of Po).

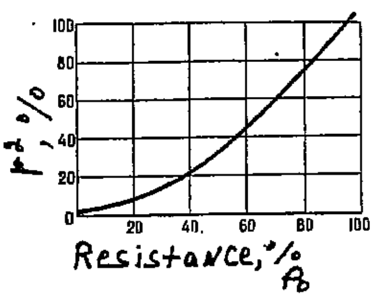


FIGURE 31 - Alteration in power of individual differences (r2) between strength potential and the speed of a resistance movement depending on external resistance (% of Po).

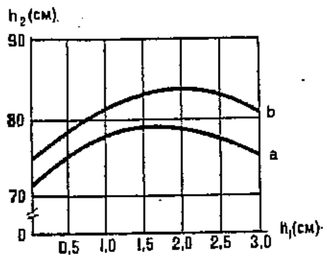


FIGURE 32 - Dependence of height (h2) attained by a 6 Kg weight thrown upward after falling from different heights (h1): a- before training, b- after training.

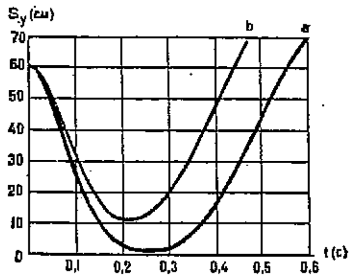


FIGURE 33 - Time-distance graph of a 6 Kg weight thrown upward after falling from a height of 2 M: a- before training, b- after training.

(B. Abbott, X. Aubert, 1952; G. Covagna A.O., 1965, 1968). The additional strength achieved as a result of stretching grows, depending on its speed and muscle length (A. Hill, 1938; B. Katz, 1939; S. Wolker, 1953); the faster the stretch the greater the additional strength (G. Covagna A.I., 1965). Practical application of this effect was done with work (I. M. Sechenov, 1901) and athletic (W. Fenn, 1930; G. Covagna A.I., 1964) movements. The material obtained from the athletic exercises showed, in particular, that the utilization of a preliminary stretch as a working mechanism ensures that the execution of the motor task will be more effective (N. G. Ozolin, L. V. Chkhaidze, 1951; Y. V. Verkhoshansky, 1961, 1963). The regime, in which an external resistance is actively overcome after being preceded by a sharp preliminary muscular stretch, is the most effective for training explosive-strength (Y. V. Verkhoshansky, 1963).

The basic characteristics of the neuro-muscular apparatus' reactive ability were demonstrated vividly in a laboratory experiment in which the muscular work involved in the take-off for the triple jump was modeled. The subject throws a load upward along guiding rails after it has been dropped from different heights. The height of the drop and the height of the throw were recorded. The path was graphed -- the time for the working points of the hand (figure 32). The curves depicted indicate that with the increasing strength of the irritant (characterized here as the falling load's kinetic energy) the working-effect (height of this load's subsequent flight) increases; stabilizes, as the strength of the irritant exceeds some optimal limit, then begins to decrease. With training, the height of the reactive curve over the axis of the abscissa increases, and its plateau and the descending part are displaced to the right. In other words, the neuromuscular apparatus has the ability to respond with a positive reaction to such a strong irritant; which at first, caused the working-effect of the movement to be diminished.

This experiment merits attention to still another detail -- the time of the working points of the hand is traced on the graph (figure 33). The movement has an amortization phase in which the speed of the load's preliminary fall is cancelled out and an active thrust phase in which a vertical velocity is imparted to the load (the motor purpose is to throw the load as high as possible). The slope in the graph between the descending and ascending parts indicates that the transition from yielding to overcoming work is preceded momentarily by holding work. Its duration varies, but on the whole it has a tendency to shorten in conjunction with the increasing strength of the irritant. As a result of specific training, the movement is executed as a whole quicker, more energetic, with a faster switch from yielding to overcoming work; and with a large velocity of muscular contraction in the thrust phase. The working-effect of the movement is higher, in that instance, where the preliminary muscle stretch bears a sharp, shock character.

In the course of studying reactive ability, the question arises as to how this can be quantitatively evaluated. We can utilize this formula $R = \frac{K2}{K1}$

where it is permissable for K to represent any characteristic of muscular work in the stretching or active thrust phases; for example, the power of the working-force. However, the complexity of determining the range between the phases restricts the possibility of utilizing Rn, to the laboratory. This formula is convenient for practical work:

$$R = \frac{Favg}{Pt}$$

where Favg is the mean working force, t - its duration and P - the weight of the moving object or the sportsman's bodyweight. The physical coefficient of reactivity - R - consists, primarily of assessment of the overloading of the working organ in units of movement time (Y. V. Verkhoshansky, 1963). The reactivity coefficient has found widespread utilization in research (V. I. Chudinov, 1966; V. N. Papysheva, 1966; V. V. Kuznetsov, 1966; S. G. Kharabuga, 1967; L. Y. Chereshneva, 1967; P. E. Polmachev, 1968; V. A. Kuznetsov, 1970; V. G. Semenov, 1971 and others).

In order to objectively evaluate reactive ability we devised the so-called reactive test; which consists of a series of vertical jumps (without use of the hands) after a depth-jump (h = 0.4 meters); without loads and with loads of 10, 20, 30, and 40 kilograms. The height of the jump was measured with a centimeter tape and the duration of the support period with a stop watch. We graphed the height of the jump (figure 34). The left part assesses speed; and the right part, the force component of reactive ability. The coefficient of reactivity is determined by the length of the support period and the analytical examination of the mean take-off force (based on the height of the drop and the height of the jump).

A number of investigations studied the interdependence of reactive ability (evaluated with the reactivity test) with muscular strength and functional speed. The connection between reactive ability and muscular strength increases with the increase in the additional load. A high corrleation (r = 0.95) was observed only with large dynamic loads (30 and 40 kg.). The largest correlation between reactive ability and speed (determined by the duration of the support period) was noticed only for R and t, registered for one specific movement. It should also be pointed out that the closeness of the connection between R and t is by far higher than that between R and F in all the tests. The correlation between the length of the support period and strength has a tendency to increase in proportion to the weight of the load; but it is essentially true only with large loads (30 and 40 kg.).

The correlation between the speed of muscular contraction and maximal strength is dependent upon the conditions of the take-off. With a relatively small dynamic load (depth jumps without weight) absolute-strength has a negative influence on the speed of muscular contraction; but it has a positve influence with relatively large dynamic loads (depth jumps with 40 kg.). On the other hand, relative-strength has a positive influence on the speed of muscular contraction with small dynamic loads; and a negative influence with large loads.

We have evidence that reactive ability is a specific characteristic of the motor apparatus acquired and perfected in the

Matrix of Factor Weights of
Biomechanical Characteristics of the
Second Jump of the Triple Jump

TABLE 5

Characteristics	Factors I	II	III
Speed of Preceding Phases	860	-315	-040
Initial Flight Speed	858	-501	-078
Loss of Speed at the Take-Off	-283	781	201
Angle of Flight	-209	531	632
Height of Flight	183	008	797
Length of the Jump	753	472	196
Duration of the Take-Off	741	239	157
F_{center} of Take-Off	903	358	-187
$F_{tangent}$ of Take-Off	-150	944	055
Coefficient of Reactivity	969	004	-070

process of training. The motor regimes in athletics condition the level to which reactive ability is developed (figure 35). The highest level of reactive ability was demonstrated by jumpers and the lowest by middle-distance runners; of the subjects studied. Reactive ability is to a significant degree inherent to triple jumping; which is obvious from its linear relationship with athletic results (figure 35) and the high correlation between them (on the order of 0.95). Reactive ability also has a high factor weight in the complex of biomechanical characteristics of the take-off in the triple jump (table 5).

2.2.2 Strength-Endurance

Strength-Endurance is the specific form of man's strength displayed in motor activities which require a relatively long duration of muscular tension without diminishment of working effectiveness. For example, a sportsman rowing 2,000 meters in 6-7 minutes must execute 230-250 strokes (at a rate of 36-45 per minute) with the force of each stroke equal to a weight of 40-60 kg. (E. B. Samsonov, 1969).

Strength-endurance, like explosive-strength is an intricate complex of motor abilities which finds its expression primarily in two forms: dynamic and static. Dynamic-strength endurance is typically associated with cyclic exercises in which considerable tension is repeated, uninterupted in each cycle of movement (running, swimming, rowing); and also with acyclic exercises which are executed repetitively with various rest intervals (jumping, throwing). One should also differentiate the particular types of dynamic-strength-endurance which secure the effectiveness of repeated intensive efforts during a sportsman's continuous movements (for example, the set up in volleyball, punching in boxing, the prick in fencing or the take-down in wrestling). Static-strength-endurance is associated with those activities where it is necessary to execute holding tension of various magnitude and duration (wrestling, sailing); as well as with holding a certain posture (shooting, skating). For example, skaters were discovered to have the highest indices of static-endurance in the postures which they are characteristically forced to maintain

(G. I. Chernyaev, 1965).

The type of athletic activity and the character with which muscular tension is displayed determine the particular qualitative distinctions between these two forms of strength-endurance. Thus, based upon the character of muscular tension, strength-endurance can be divided into tension of large or moderate power. Depending upon the type of athletic activity, one should distinguish between dynamic-strength-endurance, which is associated with repetitive exercises with various rest intervals (repetitive movement), as well as moderate or fast tempos of repeating separate movement cycles (cyclical exercises); and static-strength-endurance, which is associated with relatively long or short term muscular tension, distinguished by its magnitude.

Finally, depending on the number of muscles taking part in the work, it is necessary to classify strength-endurance into general and local. General-strength-endurance is associated with those activities where a large quantity of muscle groups are involved in the work. Local-strength-endurance is associated with those activities which are carried out by individual muscle groups. This is very significant in so far as the means of strength training should primarily influence those muscle groups which chiefly carry-out the movement. In several cyclic sports such muscle groups can be observed directly (on an electromyograph), for example - rowing (A. M. Lazarov, 1967); and indirectly (on the basis of correlating muscular strength with athletic results), in swimming for instance (G. A. Shchavelyev, 1969). The muscles tested in rowing were the quadriceps, gastrocnemius, biceps, triceps, deltoid and latissimus dorsi muscles. In swimming, the relative participation of the various muscle groups depends upon the stroke executed. For example, the relative strength of the arm flexors, leg extensors and gastrocnemius muscles do not have a significant connection with swimming speed of the crawl, back and butterfly strokes; but there is a significant connection with the breast stroke. On the other hand, the relative strength of the arm extensors is closely connected with the swimming speed of the first three strokes, but not with the breast stroke.

Thus, the forms in which strength-endurance are displayed are extraordinarily diverse and there is an intricate interdependence between them; as there is with the other strength abilities. For example, a close connection has been established between strength and static-endurance, strength-endurance and the special-endurance of distance runners, swimmers and skiers (Y. A. Popov, 1968; N. N. Trushkin, 1968; A. A. Guzhalovski and B. M. Fomichenko, 1971). In certain instances these connections have an intricate character. Thus, figure 36 is a correlational model of the special-strength preparation of crawl stroke sprinters. The highest correlations with swimming results are the maximal force of the pull developed in a period of 10 seconds (r=0.810); and the sum of the pulling force developed over a period of 40 seconds (r=0.721); which is closely connected with endurance on dry land and in the water (direct connection); as well as with static-strength of the stroke and general muscular strength (indirect connection).

This is one of only a few studies dealing with the problem of the structure of strength-endurance. Unfortunately, recent studies are still extraordinarily weak and are "full of holes" on the theory of athletic training. There exist a number of works in the area of general-endurance (M. Y. Nabatnikova, 1972; N. I. Volkov, 1975; V. V. Mikhailov, G. M. Panov, 1975) which do not touch at all on the structure of strength-endurance. Furthermore, as has been noted repeatedly (V. M. Zatsiorsky, N. I. Volkov, N. G. Kulik, 1965; Y. V. Verkhoshansky, 1970) the comparatively small number of experimental works in this area are distinguished by their large diversity and contradictory conclusions. For example, one author found a general, positive correlation between strength and endurance; another discovered no such relationship; while a third observed a negative correlation between these abilities. The reason for these discrepancies is that they are measuring different endurance abilities. With respect to this it has been suggested (V. M. Zatsiorsky, et. al., 1965) that endurance be classified into two types: absolute (the achieved result without determining the developmental level of the other motor abilities) and partial (the calculated development of the other abilities when their influence is in some kind of way excluded). Thus, for determining partial endurance in strength exercises, a weight (in a static exercise - holding) should be raised which is some portion of the subject's maximal strength. A partial index is obtained by either no correlation with maximal strength or a negative correlation. In those instances, when the subjects raise the same weight, the assessment of absolute-strength-endurance has a high positive correlation with strength. Thus, as has been noted, the contradictory evaluations of strength-endurance and its connection with strength is explained by the fact that some works utilized partial endurance and others - absolute.

Strength-endurance is as specific as are the other qualitative characteristics of muscular activity. However, the specificity of strength-endurance is expressed to a lesser degree than say the specificity of speed; but its carry-over from one type of activity to another is greater.

One should bear in mind that strength-endurance secures a high level of special work-capacity; inherent chiefly to cyclic types of sports and primarily with those requiring the repetition of large powerful efforts. In acyclic sports and chiefly those where technique and skill are important, the role of strength-endurance (depending upon the growth of sport mastery) is all the more significant. For example, archers experience a steady increase in maximal muscular strength (F max) and strength-endurance (t max) (figure 37); while at the same time, the relationship between these indices and sporting results gradually decreases. It follows then, that the rise in the results of highly-qualified sportsmen (archers) is determined not so much by strength-endurance as it is the ability to control the muscular tension necessary for stretching the bow-string (V. S. Farfel and collab., 1975).

The opinion that special (including strength) endurance is developed from a preliminary base of general endurance is rather universally accepted (see M. Y. Nabatnikov's review, 1972). The best way to develop strength-endurance is to execute the competition exercises under difficult conditions or in a large volume. However, this does not exclude the utilization of special-strength exercises.

In conclusion, it should be pointed out that up until now an objective reliable means of evaluating strength-endurance has not been devised. Specialists utilize various and frequently inadequate tests which diminish the applied and theoretical value of the studies and create contradictions. Therefore, the first condition to be met for eliminating "gaps" in the theory of sport training is to devise objective, unified ways of evaluating strength-endurance.

2.3 The Dependence of the Working-Effect of Strength on the Conditions of Displaying It

Muscular force and consequently, the working-effect of movement are significantly influenced by external conditions which accompany the activities of man; as well as physiological and psychological factors.

2.3.1 The Influence of the Pre-Working State of Muscles on the Working-Effect of the Movement

The working-effect of an athletic movement is for the most part determined by the state of the muscle prior to the display of force: it is important whether at the beginning it is relaxed, tense or in a stretched state.

Under laboratory conditions, with model movements (throwing a load upward on a special device), evaluation of the working-effect (height the load attains) is dependent on the pre-working state of the neuro-muscular apparatus: 1) a relaxed muscle, 2) an isometric tension with loads of various weight, 3) the muscles are stretched during the "wave" phase in swimming, 4) a "shock" muscular stretch as a result of quickly braking a load which has fallen from some height. The results of an experiment, graphically depicted by (Sy) distance, velocity (Vy) and acceleration (Ay) of a load, illustrates the growth of the working-efffect by switching from one "thrust" variant to another in the sequence shown (figure 38).

In other experiments, the same type of pre-working state of muscle (besides the first) is reproduced in the take-off for the vertical jump. The subjects executed the vertical jump without arm movement, from a static half-squat position, after a preliminary half-squat and after a depth-jump, from a height 0.5 M. The heights attained were, respectively: 39.0 ± 6; 44.2 ± 5 and 48.6 ± 7 cm. (Y. V. Verkhoshansky, 1963, 1970).

Thus, the muscle's preliminary state renders an appreciable influence on the working-effect of the movement. When the muscles are relaxed or in a state of isometric tension, the speed and power of their subsequent working contraction is primarily determined by the effector impulses to the muscles. If the muscles undergo a preliminary stretch by an external force, then the work they perform is aided by the utilization of the elastic energy they have accumulated. Of considerable significance are the muscles' (tendon and myotatic) reflex properties, which increase the power of their contractility, the faster and the more intense the afferent impulses.

It is important here to examine the first type of pre-working state of muscle. It is frequently asserted in the methodological literature that it is necessary for the muscles to be relaxed in the pre-working state. This is considered an important indicator of a sportsman's mastery. However, this recommendation should not be generalized as applicable to every sport activity, without considering the character and conditions of the movements.

It is known, that the working force is preceded by some transmutation in the muscles, displayed particularly in its preliminary tension (the anticipation tuner of the musculature, N. A. Bernstein). A great speed of movement was noted from the sudden release of muscles in a state of full tentanus (Jewell, Wilkie, 1958). Under conditions of preliminary muscular tension, the subjects executed the movement 4% faster, the reaction time was 7% faster, than in the relaxed state. The best reaction time and speed of movement indices correspond to the following

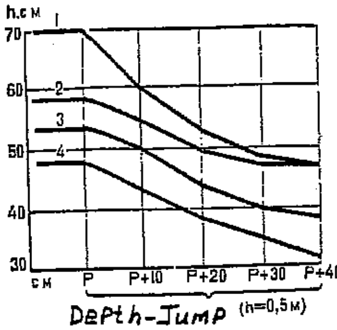


FIGURE 34 - Graph of reactiveness test for jumpers (1), throwers (2), short (3) and middle (4) distance runners (explained in text).

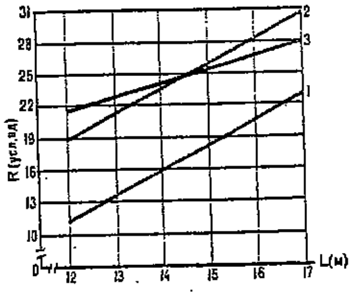


FIGURE 35 - Dependence between reactive ability and achievements in the triple jump (1- first, 2- second, 3- third take-off).

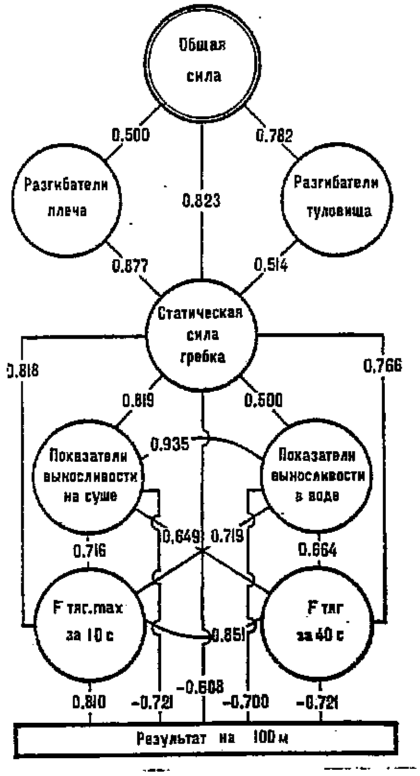


FIGURE 36 - Correlation model of special-strength preparedness of crawl stroke sprinters.

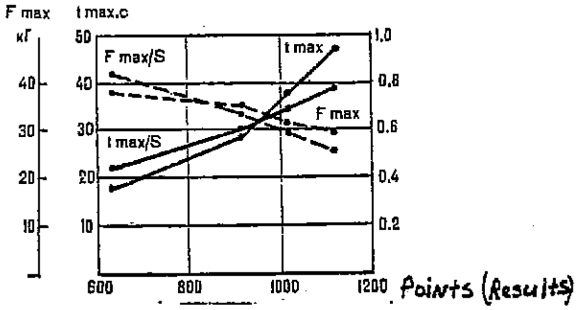


FIGURE 37 - Dynamics of strength indices (Fmax) and strength endurance (tmax) relative to results of archers. The broken line shows the correlation of Fmax and tmax to sport results (S).

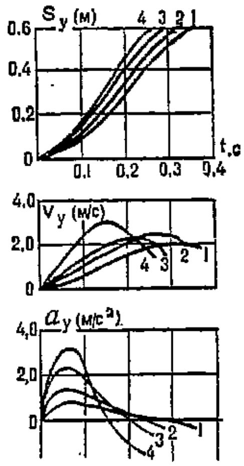


FIGURE 38 - Graph of path (Sy), speed (Vy) and acceleration (Ay) of a moving weight for different pre-working states of muscles (explained in text).

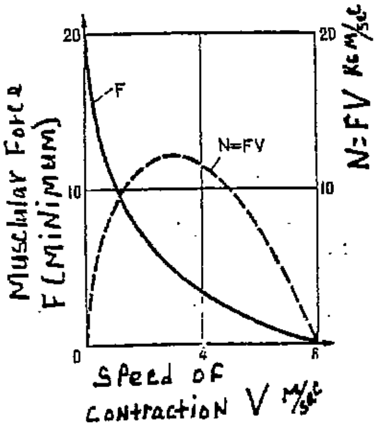


FIGURE 40 -Change in muscular power as a function of speed of contraction (D. Wilkie, 1950).

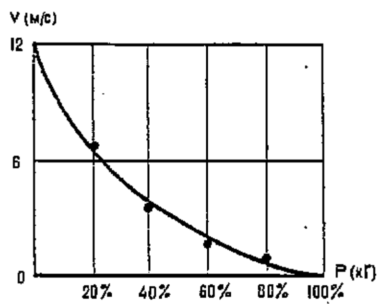


FIGURE 39 - Dependence between the load and speed of contraction in the leg extension example.

preliminary conditions: stretched, tensed and relaxed muscles (L. Smith, 1964). It was also demonstrated that the latent period of a motor reflex reaction is shorter when the muscle is lightly tensed for ten milliseconds (R. S. Person, 1965), than under other conditions.

The experimental data presented, indicates that when a movement is begun with the muscles relaxed, they are not ready to work; consequently, there is a lesser kinetic effect than they are capable. The larger the disparity in the kinetic effect, the greater the resistance they overcome.

Clearly, preliminary muscular tension is not a bad factor, as it is frequently made out to be in the methodological literature: it is just the reverse, because an optimal magnitude increases the working-effect of the movement. Therefore, preliminary relaxation should be understood to be relative, i.e., depending upon the specific movement. Relaxation -- meaning the elimination of excessive muscular tension, does not have a direct relationship to the movement or the working of the muscles engaged in the passive phase of cyclic locomotion (for example, movement with momentum); but it is without a doubt an important index of mastery in many sports. However, for brief movements, especially explosive movements, optimal preliminary tension is appropriate and necessary; although its duration should be limited, because exceeding it can significantly diminish the dynamic force.

2.3.2 The Dependence of the Load--on the Speed of Muscular Contraction

Athletic activities require chiefly quick and forceful movements, and consequently, special attention to the development of quick-strength. And, in so far as strength is developed primarily with resistance exercises, it is necessary to clearly demonstrate the dependence between the amount of weight and the speed of muscular contraction.

In order to determine the relationship between the speed of an isotonic muscular contraction and the resistance overcome, several mathematical formulas have been devised which effectively coincide with experimental data (W. Fenn, B. March, 1935; A. Hill, 1938; M. Polissar, 1952; Aubert, 1956). Hill's equation is the most widely used for muscle dynamics:

$$(P + a)(V + b) = (Po + a)b = const.$$

Graphically it describes a parabola (figure 39), with the asymetries parallel to the main axis of the coordinates, at a distance from the latter of a and b respectively. The parameters a and b are constants, representing strength and speed respectively. They can be determined from dynamics experiments or from measuring the heat produced by the muscles (A. Hill, 1950; B. Katy, 1939).

Thus, the equation establishes the functional connection between the amount of weight being raised (P) and the maximal speed of muscular contraction (V). It is evident the speed of muscular contraction diminishes hyperbolically as the load increases; and since any hyperbolic equation can be adduced by the formula xy = const, then obviously the speed of muscular contraction is inversely proportional to the load. It is important to point out that it is possible strength and speed (P and V) with different loads, depend on the maximal strength potential (Po), as measured in the isometric regime.

The load determines such important mechanical characteristics as the power of muscular work. If muscular contraction is examined, where the changes realized in connection with the loads are the strength (F) and the speed of contraction (V), then the dependence between them, as in the example of forearm flexion, will look like that depicted in figure 40. Consequently, muscular power is determined by the product of these changes (N = FV) and reaches maximum at approximately 1/3 the maximal speed of muscular contraction and at 1/4 its maximal strength (D. Wilkie, 1950). In other words, maximal muscular power is displayed when the external resistance requires 25% of the maximal force the muscles are capable of producing.

Thus, the picture which emerges from the equation of muscle dynamics is that of a dialectical contradiction between the weight of the load and speed of movement. If this contradiction is not important for the development of absolute-strength, then it is for the problem of speed-strength. As to what extent this problem is solved today will be obvious in this text.

2.3.3 The Dependence of Strength on the Speed of Muscular Contraction

Analysis of Hill's equation of muscle dynamics indicates that speed of movement is dependent upon absolute muscular strength, as measured in the isometric regime. It is not difficult to corroborate this. Physics postulates indicate that in general, speed (V), is directly proportional to force (F) and the time of its action (t); and inversely proportional to the mass of the body (m), i.e., $V = \frac{Ft}{m}$.

The physics of this expression is obvious: in order to increase speed it is necessary to increase the significance and duration of the force applied or decrease the mass of the body. However, for practical purposes not all of the enumerated possibilities are realized in man's movements. Sportsmen are unable to decrease the mass of their body or a standard athletic apparatus, and increase movement time. The first is obvious, the second is explained as the limited working amplitude of the movements. Strictly speaking, it is only possible to increase the time of a movement, with a limited amplitude, by decreasing its speed, which is foolish. Consequently, only one recourse remains -- increase strength.

This is well known in practice and has been corroborated experimentally. In reality, speed of movement increases with the increase in muscular strength (I. Kusinitz, C. Kecney, 1958; D. Clarke, F. Henry, 1961; A. Hunold, 1961). The question is sufficiently clear. However some facts exist which throw some doubt on the logic of this reasoning. It is not difficult to see a unidirectional displacement in muscular strength and speed of movement as a result of training; and laboratory experiments have discovered a rather moderate correlation between these displacements (D. Clarke, F. Henry, 1961). It has been established that there is essentially no correlation between the absolute speed of unloaded movement and relative strength (P. Rach, 1956; F. Henry, 1960; F. Henry, I. Whitely, 1960). However, the role of strength grows as the amount of weight increases. For example, if the speed for raising a weight of 13% of maximum requires 39% of the maximum strength, then a load equal to 51% requires 71% of maximal strength (N. A. Masalgin, 1966). Thus, the correlation between strength and speed of movement increases with the increase in the amount of weight lifted (figure 41). However, in this instance, the strength is applied to the load. This same correlation can be seen under other conditions; such as when a movement is executed after a moving load is stopped and is thrust in the opposite direction. In this case, as the correlation between muscular strength and speed of movement can remain relatively constant or even decrease (figure 42).

Apart from the amount of weight and the regime of muscular work, the connection between strength and speed of movement is also determined by the qualitative differences in man's ability to display strength. An important characteristic of the relationship between strength and speed is the ratio (Po) (A. Hill, 1938, H. Ralston, et.al., 1949; D. Wilkie, 1950). If the speed of the load is expressed as a portion of the maximal isometric strength Po, and maximal contraction speed without a load Vo, then the relationship a/Po completely determines the character of the load curve -- the speed. N. A. Masalgin's research has shown that the a/Po ratio is to a significant degree conditioned by the peculiarities of the sport.

Systematic training in this or that type of muscular activity provokes the formation of a specific relationship between strength and the speed of muscular contraction. Hill (1950), discussed the broad significance of the velocity constant (b); explained this by the differences in the speed of movement of various animals, and noted the different form of the load curve -- the speed of sprinters and distance runners.

So, it is rather obvious that absolute strength is the main factor determining speed of movement; but the decisive role of strength is not equivalent under different conditions or when lifting different weights. The question remains however, as to why there is no correlation between absolute-strength and speed of movement; but under natural training conditions with the increase in strength, there is a corresponding increase in speed. What is the reason for such a paradox that throws some doubt on the objectivity of the research mentioned? The latter are already rather numerous and sufficiently authentic. Well then, it remains to be seen which means in training, including those for developing strength, have a positive influence on the development of speed. In other words, this means that something affects some specific neuro-motor mechanism that is essential for training speed of movement. It should be stated, with respect to this, that the relationship between speed and strength is the basis of an earlier conclusion which is: in the selection of a means of strength-training the sportsman should be totally aware of the conditions under which the specific strength is displayed in a movement or athletic exercise, for the sake of which the strength is developed.

2.3.4 The Relationship between Strength and Posture

Of the conditions influencing the displaying of strength, the relative disposition of the body's working links has important significance, i.e., man's posture. The joint angles in the working links change with movement. Consequently, so does the operating length of the muscles for a given articulation and the angle of attachment to the bones. Increasing or decreasing the leverage and the moment force of the muscles changes the mechanical conditions of work; which can be advantageous when the muscles' force potentials are utilized fully and a hinderance when only part of the muscles' maximal tension is utilized.

The changes in strength, depending on posture can be associated with changes in the muscles' functioning. For example, the pectineus muscle, during extension of the iliofemoral joint, externally rotates the thigh; and during flexion of the same joint, rotates the thigh internally (H. Baeyer, 1922). Depending upon the position of the thigh, the sartorius muscle can either bend or straighten the thigh (M. F. Ivanntsky, 1956; D. D.

Donskoi, 1960). Research on the contribution of the sartorius muscle in flexion and extension of the thigh has established that the close correlation between the strength of the sartorius muscle (measured in a position with the thigh at 30° relative to the vertical axis of the body) and the strength of the thigh flexors and extensors is greatest at the extreme positions of the latter. The correlation is 0.92 for flexion (at an angle of 210°), then decreases to 0.41 (at 90°), while the reverse is true for extension -- 0.86 at 90° and 0.32 at 210°.

In certain cases an insignificant change in the position of the links can lead to significant alterations in strength. Thus, pronation of the forearm decreases the strength of the arm in flexion by 1/3 (P. Rasch, 1956; K. Wells, 1960, B. Tricker, 1967). An insignificant bend in the arms while lifting a barbell decreases the lifting force by 40%; a rounded torso by 13.3% and tilting of the head an average of 9% (L. P. Sokolov, 1967).

The maximal force displayed at the working points of the system's links during the simultaneous working of muscle groups operating different joints, is for the most part, dependent upon the position of the system's links relative to the proximal joints. For example, the force developed in extension or flexion of the knee joint is determined by the body's position relative to the iliofemoral joints (H. Clarke, et. al., 1950; S. Houtz, et. al., 1957; G. Lehman, 1962). Thus, maximal force in thigh extension in the seated position was found to be at an angle of 160° in the knee joint. However, in the leg press (lying down) no difference in force was discovered within the range 100-140° (F. Lindeburg, 1964). Strength increases 10-12% if the torso is moved 20-25° backwards from the vertical (V. F. Dorofeyev, 1965), with the subject seated in the "rowers" position.

Thus, if a sportsman wishes to produce maximal force in a movement it is necessary for him to consider the anatomical stability of the motor apparatus and take care that at the crucial moment his posture is in such a position to enable his muscles to develop maximal external force.

2.3.5 The Dependence of Strength on Muscle Mass

Strength is associated with the physiological diameter of the muscles and, consequently, indirectly to body weight. Therefore, the heavier the athlete the larger the load he can lift. The sportsman's bodyweight is proportional to the cube of its linear dimensions, at the same time a muscle's physiological diameter is only proportional to its square. The mathematical relationship between maximum strength (F) and bodyweight (w) can be expressed as $F = a \cdot w\ 2/3$, where a is a constant, which characterizes the athlete's level of trainability (T. Lietzke, 1956). Expressed as a logarithm this equation appears: $\log F = \log a + 0.66 \log w$. This equation satisfactorily expresses the relationship between a weightlifter's bodyweight and his results in the weightlifting exercises. The connection between a wrestler's absolute-strength and his bodyweight is expressed by this equation: $\log F = \log 1.005 + 0.724 \log w$ (E. G. Martirosov and others, 1967). A rectilinear dependence between the strength of certain muscles and bodyweight has been observed in wrestlers.

Quantitative analysis has corroborated the rather close connection between a weightlifter's bodyweight and his achievements (P. Rasch, 1960; M. V. Starodubtsev, 1966; I. A. Pismyensky, 1974). However, this dependence is associated only with maximum strength and not with the speed with which it is displayed. If the latter factor is considered, then the relationship between an athlete's bodyweight and the strength displayed will be totally different. It has been demonstrated, that the correlation between bodyweight and the weight of the barbell decreases as the speed of the lift increases. Thus, it is 0.719 for the press, 0.706 for the clean and jerk and 0.685 for the snatch (M. V. Starodubtsev, 1966). A decrease in bodyweight has a far lesser affect on the snatch than the press (A. N. Vorobyev, 1964; A. S. Medvedev, G. S. Tumanyan, 1967).

Thus, the highest correlation between muscle mass and strength is observed in those cases when strength is maximal and the speed at which it is displayed is of secondary significance. The connection between strength and bodyweight decreases as the speed at which strength is displayed increases; or to be more precise, it does not have the vital importance for explosive types of exercises; especially jumping exercises (L. Smith, 1961; H. Peters, 1961; Z. Kuras, 1962; H. Schunke, H. Peters, 1962).

In athletics, especially when comparing athletes of different bodyweight and physical preparation, it is acceptable to utilize relative-strength. It has been observed that as a sportsman's bodyweight increases so does his absolute-strength; while relative-strength decreases (A. N. Krestovnikov, 1939; I. N. Knipst, 1952; V. I. Chudinov, 1961; V. M. Zatsiorsky, 1966; E. G. Martirosov and others, 1967); although you can come across just the opposite (I. N. Abramovsky, 1966).

Thus, an increase in muscle mass is accompanied by an increase in muscular strength, only in certain cases where the required movement is connected with overcoming a large resistance or moving it with a low velocity. Examination of the facts from all sides, indicates that morphological changes in muscles, especially hypertrophy, condition the character of the strength displayed as well as the method of its development. These facts lead to the fundamental problem of the methods of strength preparation -- associated with the specificity of muscular strength.

2.4 Factors Raising of the Working-Effect of Muscular Strength

The external strength man is able to display is not constant and is to a significant degree dependent upon the conditions preceding and accompanying the motor activities. Therefore, in opposition with distance, time, rivals and gravity, the greater an athlete's chances for victory, the better he knows how to fully and skillfully utilize the reserves of the nervous and muscular systems.

2.4.1 The Warmup

The warmup serves to bring the sportsman's organism to the necessary work-capacity. The warmup has two parts -- general and special. The purpose of the general part is to raise the functional potential of the organism as a whole; the purpose of the special part is to establish the most optimal interrelationship between the structure of the forthcoming movement and the activities of the C.N.S.; carried-out by the motor apparatus executing the given movement (N. G. Ozolin, 1949; A. N. Krestovnikov, 1951; R. Miller, 1951; L. Blank, 1955). The raising of the work-capacity of the organism by means of the warmup, is determined by the intra-central changes of the mobilization as well as the changes at the working peripheries, i.e., in the muscles.

Naturally, the special part of the warmup preceding strength work in all of its manifestations (see the review of H. Thompson, 1958; D. Swegan, G. Jankosky, 1958; I. Grose, 1958; A. Sedgwick, H. Whalen, 1964) is of special interest.

It is known, that a muscle contracts faster and more intensely the higher its temperature (I. S. Beritov, 1947). The electrical activity of a muscle increases with increasing body temperature (K. Golenhofen, H. Goptert, 1958; K. Book, K. Golenhofen, 1959) and after stimulation, the active-state period decreases (A. Hill, 1951; L. MacPherson, D. Wilkie, 1954). Increasing the temperature locally, increases strength; as measured on a dynamometer (A. Robbins, 1942); and the amount of time a muscle is able to hold a standard tension or execute standard work (A. Nukada, 1955). A hot shower increases isometric endurance (A. Nukada, 1955); as well as the speed of muscular contraction and endurance, in work of a cyclic character, up to 7.5-9% (E. Assmusen, O. Boje, 1945; L. Miudo, 1946; F. Carlisle, 1956; H. DeVries, 1959). On the other hand, cooling renders a decrease in strength and lengthens contraction time. Muscles cooled to 18°C, have a work-cpacity period that is 2-3 times shorter (N. A. Tikhomirova, 1961; I. Fray, G. Smith, 1941). It is known, that massage has no influence on endurance in cyclic exercises (P. Karpovich, C. Hale, 1956; H. DeVries, 1959); but increases the power of explosive work (V. Skubic, I. Hodgkins, 1957; L. Merlino, 1959). However, maximal work-capacity can be achieved only after a series of contractions; the number and character of which are determined by the functional state of the organism and the intensity of the forthcoming work. Repetitive work as a form of warmup increases speed of movement (D. Swegan, G. Janosky, 1958). At the same time, if this work is of a moderate intensity, then it is not advantageous for strength. An active warmup, which includes intense exercises, is an effective means for successfully executing speed-strength exercises and particularly exercises of an explosive character (I. Hipple, 1956; E. Michael, et. al., 1957; B. Pacheco, 1957).

Thus, women basketball players increased their jumps from 1-4.5 CM (P. Panaiotov, 1962); and track and field jumpers up to 10 CM (V. M. Dyachkov, 1961). The strength of boxers increased an average of 40-70 KG; and the striking time decreased 0.02 to 0.04 seconds. It is interesting that at rest between strong and quick punches, there is no significant relationship (r = 0.40, not significant); after a warmup, it is distinguished from the null hypothesis [r = 0.624 at P < 0.99] (A. A. Karabanov, 1966). It has been observed repeatedly that a 100 M sprint or a 4 x 100 M relay sprint aids the subsequent long jump results (V. Y. Verkhoshansky, 1961).

Thus, preliminary work, similar in character to the subsequent, diminishes significantly the working period in comparison to work of any coordination structure. But it chiefly enables the muscles to withstand (without injury) a large load and execute significant (in strength and speed) contractions. The movements included in the warmup should be appropriate for the special exercise, not only in their coordination structure but the intensity of the neuro-muscular tension as well. The latter circumstance is particularly important for speed-strength exercises.

2.4.2 The After-Effect

It is known, that if a muscle is stimulated with several impulses its activity falls slower after the last one, than when it is stimulated by one impulse. Any irritation, whether it is momentary or not, leaves traces in the nervous system. The traces phenomenan lasts for some time after irritation ceases; which is indicative of the relative inertness of the nervous system and has an enormous significance for the organism's activities (P. P. Pimenov, 1907, I. P. Pavlov, 1929, L. A. Orbeli, 1947). These phenomena and the processes of structural and functional accommodative reconstruction associated with them, are the foundation for the development of the sportsman's trainability. They determine the uninterrupted rise in trainability despite an interruption in the training process (L. P. Matveev, 1964; D. Mateev, 1964; N. V. Zimkin, 1965).

In the literature (particularly foreign), there are rather contradictory interpretations concerning the after-effects of muscular activity. There is a statistically significant increase in the speed of an unloaded movement after the execution of this same movement, with a weight (I. Murray, 1959; W. Van Huss, et. al., 1962), and vice versa; such an effect was lacking, despite the subjects' assertions that (subjectively) their movements were quicker after using loads (M. Nofsinger, 1963; R. Nelson, W. Lamber, 1965). An increase in the vertical jump did not occur after executing resistive exercises (A. Stockholm, R. Nelson, 1965). Shot put results even deteriorated after doing preliminary "puts" with a heavier shot (R. Bischke, L. Morehouse, 1950).

The after-effect is examined in more detail in the domestic literature. It has been noted that preliminary static-tension renders a positive influence on the subsequent dynamic work. Despite fatigue following static-tension, the effectiveness of dynamic-work increases; usually up to 20% in comparison with work executed without preliminary static-tension. With the reverse sequence of work, results worsen (Y. A. Shiedin, V. G. Kunevich, 1935; M. I. Vinogradov, V. E. Delov, 1938; N. K. Vereshchagin, 1956; M. N. Farfel, 1964; Y. M. Uflyand, 1965 and others). The after-effect occurs immediately after preliminary static-tension. The first dynamic contraction still bears some evidence of inhibitory influence, but by the second, strength increases sharply in comparison with the initial level (M. V. Leinik, 1951; M. I. Vinogradov, 1966). The data presented indicates that static-tension, under certain conditions, can serve as a stimulant for dynamic work and play an important role in the development of muscular strength.

Dynamic-work executed with heavy weights (a high intensity of tension with a relatively small volume) also renders a positive after-effect in the C.N.S.; which is expressed in a general toning influence on the motor apparatus and improvement in speed and strength (V. P. Portnov, 1955; I. P. Ratov, 1957; V. M. Diachkov, 1961; I. V. Muravov and F. T. Tkachev, 1964; S. P. Letunov, 1965).

In practice, the after-effect phenomenan of strength work is utilized in planning its quick and delayed effects. Bear in mind there is a quantitative improvement in activities immediately following strength tensions, i.e., quick after-effects. Preliminary, intense strength tensions lead to improved results in jumping exercises (V. M. Diachkov, 1958; 1961; Y. V. Verkoshansky, 1961; V. V. Tatian, 1964; F. T. Tkachev, 1967); putting the shot (D. Fritsch, 1961; L. S. Ivanova, 1964; A. D. Markov, 1966); and rowing (N. R. Ermishkin, S. V. Vozniak, 1965; A. K. Chuprun, 1966). For the delayed effects, preliminary stimulation is utilized for improving the functional state of the neuro-muscular apparatus during the sportsman's preparation for competition or in training for speed-strength (V. M. Diachkov, 1961; V. V. Vrzhesnevsky, 1964; A. V. Khodykin, 1976). The positive effect is obtained only if this state is achieved at the optimal level. Over-excitation of the C.N.S. renders a negative influence on the precision and coordination of movements, i.e., on the quality of athletic technique (V. M. Diachkov, 1961; O. D. Yakimova, 1964).

The traces in the nervous system phenomena and their influence on the effect of the subsequent work are conditioned by many factors; in particular, the strength of the irritant, fatigue and the time interval separating the previous work from the subsequent. Thus, after tonic-work (barbell squats) the following changes in the parameters of the F (t) curve of explosive isometric force, in a controlled task (leg extension), are observed. There is a rather significant increase in maximum force (figure 43) over the first minute, at 25% of the initial level; then after 4-5 minutes it continues to grow to 65%. The beginning part of the F (t) curve undergoes less significant changes because the magnitude and duration exceed the initial levels less, the closer the beginning force comes to the F (t) ordinate. The time required to reach maximum force (figure 44) immediately after tonic-work was reduced by 2.6%; by 4.6% after 3-4 minutes; and it later began to increase till it exceeded the initial level (V. V. Tatian, 1964). The largest increase in dynamic strength after a static effort corresponds to a load of 50% of maximum (at 90%), and the least to 25% of maximum (at 6.7%) and 100% (at 5.8%). With the growth of trainability, the post-working displacement can occur with large loads -- up to 100% of maximum (E. P. Ilin, 1961). Consequently, with the rise in trainability and the strength of the irritant, the ability to render a subsequent positive effect also rises. However, in principle the optimal and not the maximal load is necessary for obtaining the greatest after-working-displacement.

The strength of the irritant also determines the time to achieve the maximum lifting force and the length of the after-effect. Therefore, from a practical standpoint, when the subsequent work begins, is of some importance. For example, vertical jump height varied in the after-working period; depending on the character of the tonic work (figure 45). Three to four minutes after barbell squats the height of the jump was 6.8% above initial levels and 8-10 minutes after depth jumps 8.0% above initial levels (V. V. Tatian, 1964). In experiments with preliminary static-tension (E. P. Ilin, 1961), the maximum was achieved quickest with loads of 25% (after 12 minutes); the slowest with 100% (after 15.4 minutes), and 50% (after 17.2 minutes). Research has determined that the optimal rest interval bewteen sets in weightlifting (during the presence of the traces phenomenan in the C.N.S.) is 2-5 minutes (S. E. Ermolayev, 1937; A. N. Krestovnikov, 1952; Sh. D. Budze, 1959; M. B. Kazakov, 1961). It has been established, that weightlifters who time their rest intervals make 20% fewer failures than those who do not (E. A. Klimonov, 1965).

The delayed-effect of strength work depends on the volume and intensity of the preceding loads. For example, a moderate habitual volume of barbell exercises renders a positive tonic influence on the motor apparatus of sportsmen, the next day or the day after (V. M. Diachkov, 1961). The use of depth jumps as a means of stimulation delayed this moment for 5-6 days (Y. V. Verkhoshansky, 1963; A. V. Khodykin, 1976).

The utilization of the traces phenomenon opens some interesting perspectives for raising the effectiveness of strength preparation with a limited volume of training work. Sportsmen and coaches have great potential for creativity, which can significantly enrich the theory and methodology of sport training.

2.4.3 Additional Movement

Some experienced coaches judge the mastery of a sprinter by his jaws. If the teeth are clenched and the face has a strained expression -- the level of mastery is low. If the jaw is loose and the face calm, then their movements are free and unconstrained and they possess the skill for running fast. Although curious, it is a rather accurate evaluation of mastery in cyclic movements during which the muscles work in a rapid sequence of tension and relaxation. However, in acyclic movements requiring the display of powerful force, no one is able to evaluate mastery in this manner. In this instance, muscular force is concentrated in a single instantaneous tension and even the anatomical antagonists function as synergists. Under these conditions, the so-called additional movement contributes to raising the working-effect.

Muscular activity (electrical excitation indicator) is dependent not only on the processes taking place within but the state of the other muscle groups. Both unloaded and movements with large resistance provoke an electrical potential on the unexercised side of the body (M. N. Farfel, 1961; A. S. Levin, 1964; F. Sills, A. Olson, 1958). Furthermore, the strength and endurance of the arm muscles executing dynamic work increase significantly by including other skeletal muscles in the work (A. F. Gorbunova, M. I. Khabarova, 1955; E. A. Mukhamedova, 1958). Exercising the muscles on one side of the body causes an increase in strength on the other unexercised side (C. Wissler, W. Richardson, 1900; R. Davis, 1942; F. Hellebrant, et. al., 1947; A. Slater-Hammel, 1950; D. Laun, 1954).

Thus, an additional movement which can not be associated with raising the economicalness of the motor complex, has a specific physiological expediency; and its rational organization has great significance.

The combination ot two or several motor systems included simultaneously or sequentially, has some advantages. Thus, the amount of force developed by the right arm is significantly influenced by the muscles taking part in the additional movement: a momentary contraction of the flexors of the left arm increases the strength and speed of the muscles flexing the right arm to a larger degree than a contraction of the arm extensors (E. A. Mukhammedova, 1958). If, during the rhythmic flexing of the right arm, the extensors of the left are momentarily tensed, then the work-capacity of the right arm will increase by 39-42%; if the flexors of the left arm are tensed -- it will decrease 8-22%. Tensing the extensors of the left arm after first fatiguing the flexors of the right, increases the capacity of the latter to do significantly more work. Tensing the flexors of the left arm has no effect, in this instance (G. V. Popov, 1938).

Thus, the change in the work-capacity of one muscle group by including others in the work, is dependent on many factors and is different under different circumstances. The sportsman's trainability, the type of muscular activity during the additional work (dynamic or static), as well as the decrease or increase in the load and work rhythm influence the working-effect (M. I. Vinogradov, 1966). Thus, in the aforementioned experiments by E. A. Mukhammedov, a large stimulatory effect is obtained when the additional effort of the left arm comprises 1/3 - 1/4 that of the right arm.

Finally, results are determined by the phase of work of the muscle groups or, in other words, the functional state of the motor apparatus. Research indicates that in order to obtain a distinct stimulatory effect, the appropriate motor analyzer should be in a state of stable excitation and reactiveness. The excitation of one "neuro-center" strengthens this process in the other centers, if the latter acquire a significant dominance. Thus, tension in the additional muscle groups causes (because of the afferent impulses coming from them) an increase in the excitability of the dominent center and leads to a strengthening of the effector process in the fundamental muscle groups. The basis for this dominance principle is obvious: in the beginning stages of work when dominance is still only forming, the inclusion of the other muscle groups will be ineffective. The effect appears only after some time has passed, when dominance has alrady been established (D. I. Shatenstein, E. I. Yordanskaya, 1955).

In athletics you can find examples where the motor-effect is secured (while utilizing additional movement) by the dominance center and by clearly mechanical factors. This is observed in exercises featuring a take-off from a support, utilizing a rotary movement. In this instance the concentration of muscular excitation, crucial for the acceleration of the rotary movement of the body's links, strengthens the excitation in the domminant center; securing the key element of the take-off -- the work of the extensor muscles. At the same time reactive forces, resulting from the accelerated shifting of the amortization, increase the power of the muscles executing the take-off (for example, an average of 25% in the vertical jump). Thus, additional movement is an example of the organism's accommodative mobilization, when necessary, to display maximal tension; and it can have a place in training for developing strength.

2.4.4 Prepatory Movement

If you were to execute a vertical jump from a half-squat position, then it will become immediately obvious that this is not possible without a preliminary movement. Considerable tension will be needed to restrain the natural prepatory movement which man willfully or unwillfully resorts to each time he is preparing to execute an action requiring the display of significant force.

The prepatory movement is different in each concrete case depending upon the situation and the resolution of the motor tasks. However, the idea is still the same -- to increase the length of the working range and prepare the muscles for a more powerful working-effort. The latter is accomplished by stretching the muscles, which causes a strong motor impulse (due to the myotatic mechanism) and creates an additional, potential elastic tension. At this juncture it is appropriate to recall the observations of A. A. Utomsky (1927); who emphasized that the primary nature of the contractile effect of muscles is the process of muscular tension and it is through this tension that contraction and mechanical work are produced.

The fact that preliminary muscular tension, preceded a working-effort requiring a concentrated display of strength (based on EMG data) was noted in several investigations (I. N. Salchenko, 1960; E. G. Kotelnikov, 1966; V. B. Popov, 1968; E. Asmussen, F. Bonde-Peterson, 1974). True, this fact should not make one draw conclusions about the necessity of special tension for the execution of exercises. Preliminary muscular tension can be appropriate if it is well timed and immediately precedes the working-effort; or is accomplished during the course of the prepatory movement and its magnitude is determined by the organism. Thus, there is always the notion to think of prepatory movements when it is necessary to achieve great strength and speed of movement; and not underestimate them as something incompatible with the notion of economization of a motor act.

2.4.5 Rational Coordination in Muscular Work

Even with relatively simple movements, the same effect can be secured through multiple combinations of the muscles participating in the work. A stereotypical working-effect, in non-standard muscular work, was observed (K. Fidelius, 1959; E. K. Zhukov, Is. Z. Zakhariants, 1960; N. V. Zimkin, 1962; I. P. Ratov, 1962). The external display of this stereotypical working-effect varies, according to the amplitude, speed and strength of the movement. Thus, the impulse-force of the vertical jump take-off varies according to the force and the time of its action. The higher the sportsman's trainability, the more stable the impulse-force; the more rational and stable the distribution of force over time (Y. Verkhoshansky, 1963; S. M. Arutyunyan, 1964). Thus, during exercise the ineffective and weakly-effective variants of integration, comprising the elements of movement, are differentiated from the more effective (N. V. Zimkin, 1962; A. A. Korobova, 1964). Well prepared sportsmen use only those effective combinations which enable them to utilize their real motor potential to the maximum.

Changes in the character of muscular activity, during the execution of movement, can occur in several forms: 1) change in the sequence of including different muscle groups in the activity, 2) change in the number of muscle groups participating in the movement, 3) increase or decrease in the relative participation of some muscles in the movement (V. S. Averianov, 1963; I. V. Moikin, 1964). In cyclic movements, the duration of the active and relative rest phases changes (L. G. Kuchin, 1960; G. G. Ratishvili, 1966); and the maximal output shifts from one group of muscles to another (A. M. Lazareva, 1966; T. M. Absalyamov, 1968). Movements associated with overcoming large resistance or executed with great speed, characteristically involve a switch in the activity to the muscles of the proximal links (M. F. Ivanitsky, 1956; V. M. Lebedev, 1962; I. V. Moikin, 1964); and a differentiation in the activity of different sections of the muscle (V. S. Averianov, A. I. Shibanov, 1964).

In complex multi-link movements, the resulting force does not equal the tension each of the muscle synergists are capable, thus, the largest summated force a rower develops is at the beginning of the movement (table 6); although at this instant the legs are working at an unadvantageous angle in the knee and ilio-femoral joints. However, the percent utilization of absolute-strength (the sum of the maximum force that the muscles of the arms, torso and legs develop individually) is the largest (V. S. Egorov, 1966). Thus, the unadvantageous conditions for the work of one muscle can be compensated for by the more advantageous conditions for another's work (in this instance the back muscles) due to the suitable coordination of effort.

The most important aspect of muscular coordination in speed-strength exercises, is the concentration of force at the crucial (from a biomechanics standpoint) phases of the movement. In the future, one of the most typical regularities of motor skills will

A Mean Strength of Rowers
in Three Positions and Percent Utilization
of Absolute Strength

TABLE 6

Stroke Phase	Classification			
	III	II	I	MS
Beginning	128	131	134	143
	34%	31%	32%	33%
Middle	119	124	130	128
	27%	26%	27%	29%
End	112	116	118	126
	26%	24%	25%	26%

be the concentration of muscular force where the dynamic accentuations are necessary for the formation of the biodynamic structure of a complex motor act; and raises the total working-effect of the latter.

2.4.6 Tuning, Instructing, Emotions

The organism's muscular activity, including the display of strength, is not isolated but is part of the formation of the so-called individual's purpose. This purpose is basic reaction of a subject to the influence of the situation in which he sets and resolves tasks. It is characteristically, a preparedness for a certain activity and is a major factor in any motor activity (D. N. Uznadze, 1961; I. T. Bzhalava, 1966).

Physiological preparedness for action is associated with the tuner receptors, which secure an adequate preception of irritation; and with the functional mobilization of the motor units, which facilitate motor activity. The physiological nature of this phenomenan has been similarly examined by E. N. Sokolov (1959); N. A. Berstein (1961); P. K. Anokhin (1965). The motor objective in sport, as a tuner to the forthcoming action (N. G. Ozolin, 1949; K. E. Shoikhet, 1964, 1966; Y. S. Eremin, 1968), is formed by the influence of the situation and informational-instructional influences of the teacher and assumes a clear-cut representation of the motor task. The formation of such tuners creates the objective prerequisite for great success.

Thus, a preliminary verbal signal concerning the heaviness of the load renders a change in the tonus of the working muscles of the arms. The words "heavy load" increase the tonic tension of the working muscles of the arm; the words "light load" decrease the tonus of these same muscles (M. N. Farfel, 1961, 1964). Hypnosis increases muscular strength. It can increase strength by 22.5% and lower it 31.7% (M. Ikai, A. Steinhaus, 1961). The correct instructions can have a significant affect on strength if the sportsman is oriented to executing the movement by accentuating one or more of its qualitative characteristics; or further improve the coordination of effort. Thus, the optimal combination of force, speed and amplitude of a speed-strength

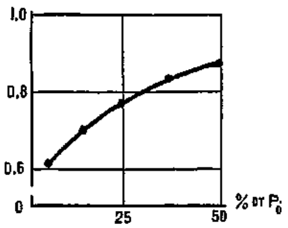


FIGURE 41 - Alteration in correlation (r) between speed of movement and resistance. The weight is expressed as a percentage of maximum (N. A. Masalgin, 1966).

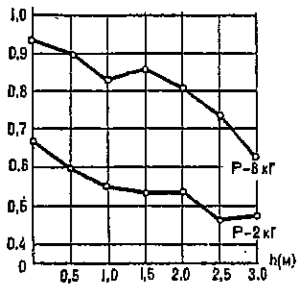


FIGURE 42 - Alteration in correlation (r) between speed of movement for throwing 2 and 8 Kg weights and maximum isometric strength depending on the height of the preliminary fall.

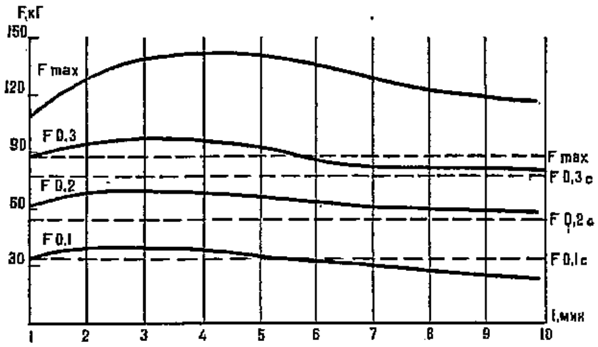


FIGURE 43 - F(t) curve of explosive isometric effort after barbell squating. Broken lines indicate initial levels.

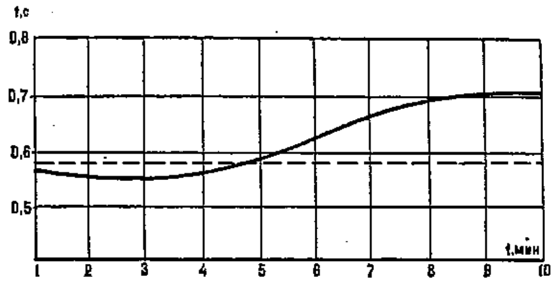


FIGURE 44 - Alterations in time of achieving maximum explosive isometric force after tonic work.

FIGURE 45 - Change in height of a vertical jump after tonic work of different character (1- barbell squat, 2- take-off after a depth jump).

movement secures the maximum (for a given functional state of the organism) effect (determined empirically in training). However, active guidance of the action helps in finding the effective combination faster. It has been shown that sportsmen with little experience, execute the take-off after a depth jump, faster or slower than usual (table 7); which leads to an increase in the height attained (Y. V. Verkhoshansky, 1963).

Qualified instruction can ensure the maximal utilization of force through a rational redistribution of muscular effort. Thus, rowers informed of the amount of force recorded, developed by the sum of the action of all the muscles, imitate the beginning, middle and end of the row. Then they are told to repeat the effort in these positions, utilizing the force advantages of the muscle groups indicated. All of the subjects increased their strength scores (table 8) in the rowing phases (V. S. Egorov, 1966), as a result of the short experiment with this sort of information.

The samples presented are indicative of the effectiveness of instruction if it is based on the correct dynamic structure of the movement. These examples also point to the necessity of taking into consideration the qualification of the sportsman: the effect of instruction decreases with the increase in qualification (for what we spoke of), since a master of sport to a large degree, learns to mobilize his potential to a greater extent. Instructions should always be within the framework of a clear-cut motor aim, in accordance with the meaning of the structural action. Instructional directions should be divided into two types: heuristic (what needs to be done) and concrete (how it is done). In other words, heuristic instruction is the precise meaning of the movement's structure. The sportsman is assigned the task of finding the most favorable (for him) details of the act in order to execute if effectively.

The second type of instruction concentrates on the advisable (from the teacher's point of view) method of executing the concrete details of the action. The combination of these types of instruction by the experienced coach, invariably raises the

Influence of Different Motor Aims
on Height of Jump (h) and Take-off Time

TABLE 7

Take-off Characteristic	Motor Aim								
	Usual Take-off			Take-off Slowly			Take-off Fast		
h(cm)	68	69	69	73	70	73	57	67	68
t(sec)	0.240	0.260	0.245	0.310	0.315	0.310	0.160	0.220	0.230

Mean Stroking Force after
Instructing to Redistribute Effort

TABLE 8

Stroke Phase	Classification			
	III	II	I	MS
Beginning	6.3	10.2	8.8	3.8
Middle	19.4	10.7	12.5	17.5
End	19.3	13.8	21.3	15.0

effectiveness of the execution of the strength exercises.

The force displayed by man is to a significant degree determined by his emotional state. Strong positive emotions can instantaneously increase the energy of muscular contraction 4 times (M. I. Vinogradov, 1966). In athletics, observations have shown that group activities produce greater results than individual activities (H. Gurnee, 1937; Th. Abel, 1938; N. Weyner, D. Zeaman, 1956; I. Beasley, 1958; B. Cratty, 1965). The presence of spectators increases the effectiveness of the motor operation (G. Gates, 1924; R. Lazaruc, et. al., 1952; B. Cratty, R. Hutten, 1964); the reason being that non-sportsmen demonstrate a significantly higher level of achievement than sportsmen (R. Singer, 1965). Thus, carefully directed training creates a specific emotional background; making strength work more productive.

Chapter III
The Means of Special Strength Training for Athletes

The evolution of opinion concerning the means and methods of strength training is a periodic repetitive cycle, entirely determined by the movement of creative ideas. The beginning of such a cycle provided the usual success in the cognition of the motor mechanisms of athletic technique. This helped determine the means of strength-training more precisely. However, with the growth in athletic achievements, the effect of these means, became less noticeable. The volume of these exercises was increased, but it was discovered that this has its limitations. Once again, they turned to analysis of the sportsman's movements; armed with better measuring techniques. Thus, the beginning of a new cycle of searches leads to new progress in training methodology. This was the cause for example, when information concerning the significance of strength in athletic exercises emerged from the laboratory and trainers looked hopefully to barbells. Something similar is observed now, when studies indicate that the strength necessary for the successful realization of one movement, has little affect on another. Such a specificity of strength turned attention, in the new fashion, to the principle of selectivity in the means of special preparation.

Thus, the progress of strength preparation methods foregoes penetration to the motor mechanisms of the athletic exercises. This leads to open (formed in place of already universally accepted) assertions, which in solving the problems of strength preparation should originate, first of all, from the sportsman's real movements and the concrete level of his physical preparedness. Thus, one can understand why it is necessary to devise new means that are not always easily rejected in favor of those achievements resulting from the painstaking labor of many generations of enthusiasts to please some new fashion; but are sometimes of no substance besides sensation.

Thus, the necessity of selecting the training means (particularly for the development of strength) based on the motor specifics of a concrete athletic exercises, is one of the most valuable methodological ideas in sport. This was a turning point, and was justified, but it quickly experienced a progressive phase, the course to general physical preparation. The change lead to assertions about the pre-eminence of specialized training, based on the fundation of general preparation; for which it is proper to consider the specific character of the athletic activity. As a result of the practice of selecting the means of strength preparation, based upon the specifics of the athlete's movements, one leaves the realm of intuition to find a specific objective foundation. This foundation finds its general theoretical expression further, in the statement of the principle of dynamic correspondence; which formulates the extent and the criteria of correspondence of the means of special-strength-preparation; and the character and regime of work of the neuromuscular apparatus in the specialized exercises.

3.1 The Problem of the Means

The physiological basis for adaptive reconstruction in living tissue is the irritation coming from the external or internal environment; and as a result of this irritation, certain traces are left within the organism. With repetitive irritation the traces accumulate, leading to adequate qualitative alterations of an organ, such that the ranges of its functional potential are broadened in accordance with morphological reconstruction. A specific peculiarity of a living substrata is the relative speed with which it adapts to repetitive irritation. The irritation soon becomes habitual and does not render any additional accommodative displacements; but only maintains them. Excluding a given irritant from the complex of external influences causes an organ to return the initial functional level, because previous accommodative reconstruction has lost its life-preserving role.

This, in general terms and greatly simplified, is the physiological essence of training. It is in reality a very complex picture, in so far as systematic exercise, as a means of structural-functional perfectioning, is made-up of a complex of different irritational influences, affecting all the organs and systems of the organism. For example, to successfully train for strength, the amount of weight, the number of repetitions, the tempo of execution and the place in the workout all affect the effectiveness of the training. These conditions could be listed ad-infinitum since the development of strength is not the only goal of training. However, besides this, it is quite clear, inspite of the difficulty of organizing training; the coach in all probability will select, from the limitless number of variants, the combination of means which will lead to success.

3.1.1 Peculiarities of the Growth of Strength

Strength as an external expression of the accommodative reconstruction of the organism is associated with the intensity and repetitiveness of the irritant; which the organism sustains during the working of the motor apparatus. Only the optimal strength of muscular contraction, which can be achieved in different ways (isometric tension, heavy loads and small velocities and vice-versa), acts as a training irritant. Research on the threshold of the training irritant necessary for increasing muscular strength showed that it should be no less than 1/3 the maximal strength (T. Hettinger, E. Muller, 1953). The threshold of the irritant capable of rendering a training effect should be increased; and comprise 80-95% of the sportsman's maximum, as strength increases. It was considered appropriate that the strength of the training irritant equal that of the competition irritant of the specialized exercise, or exceed it (R. P. Moroz, 1962; I. P. Ratov, 1962; Y. V. Verkhoshansky, 1963).

Thus, the development of strength requires that the strength of the irritant be gradually increased. Any irritant has a specific "limit of strength" (E. Muller, 1962) the achievement of which, causes the cesation of growth in muscular strength.

The less trained the muscles, the further the "limit strength" from the initial. The speed with which strength increases from the initial level to the "limit strength", expressed as a percentage of the limit magnitude, is independent of sex, age, muscle group and the level of the "limit strength" (E. Muller, 1962). Strength can be increased after attaining the "limit strength" only by intensifying training (substituting stronger means, determining their combinations, increasing the volume of work).

These were early attempts at general principles, although they needed to be more precise relative to the means and methods of strength development. According to A. V. Korobkov (1953), V. S. Gerasimov (1953), I. G. Vasiliev (1954), strength increases relatively uniformly in the initial stages of training, independent of how the load is applied in training -- large or small. Approximately equivalent increases in strength were obtained with loads 20, 40, 60 and 80% of maximum. An increase in the physiological tension of training in the initial stages (large load, fast tempo of movement, short intervals between sessions) does not always lead to a rise in the effectiveness of strength development; this is only effective later on as trainability increases. This principle can be illustrated by the training results of weightlifters. Exercises with 45-60% in the first 8 sessions were slightly more effective than exercises with 60-75% and 75-90% loads. After 16 sessions, the most effective load was 75-90%; the least effective was 45-60% (N. V. Zimkin, 1961). A noticeable training effect occurred in the beginning stages of training 30-46% of maximum, while at the same time strength increased, for more experienced athletes, with 60% weights (E. Muller, T. Hettinger, 1957).

In order to interpret these factors one must bear in mind the phasic character of the influence of intense strength loads; expressed by the temporary decrease in strength and speed of movement, and after the intensity of the strength loads has decreased -- the subsequent, significant increase in strength and speed. Therefore, the effectiveness of heavy weights does not occur immediately, but some time later. Thus, strength increased after sessions of isometric tension ceased (H. Clarke, A.O., 1954); an intense increase in strength and speed of movement from the use of significant resistance, occurred only after 20 training sessions (D. A. Chernyavsky, 1966). An increase in speed-strength (for a controlled movement), averaging 18-25% (V. N. Nyeniskin, 1974), was noted after a 10-day rest from intense specialized-strength-training. It can be assumed that this phenomenon is connected with the known inertness of the organism and a super-compensatory restoration after strength work.

As strength and the level of physical preparedness of the athlete increase, the dependence of the increase in strength and its specific affect on the character of training (in connection with the specific influence of the applied means and methods on the development of the qualitative characteristics of movements) becomes all the more lucid. In those cases where training is conducted with small loads there is a simultaneous increase in endurance and speed of movement along with the increase in strength -- executed with and without loads. If large loads are used in training, strength grows to a significant degree as does the speed of execution of an instantaneous movement; however, endurance without loads begins to diminish and can even drop below initial levels.

The magnitude of a strength increase as well as its specific character is also determined by the combination of the training means used. Thus, the increase in strength and speed of movement after 20 training sessions in which weights of 10 and 40% of maximum were utilized (in different volumes) were as follows: in the group executing 20% of the special loads with the first weight and 80% with the second, there was an increase in strength of 44.8% and an increase of 35.2% in the speed of movement from the initial levels; the corresponding figures for the second group doing just the reverse were 31.6% and 18.3% respectively (D. A. Chernyavsky, 1966).

The increase in strength is also dependent upon the sportsman's level of preparedness. In principle, the lower the trainee's level of preparedness the greater the increase in strength. All the means are good in this case. However, with the rise in mastery the tempo of strength increases diminish and can be provoked only through appropriate special means.

Developing rational methods of strength training is associated with the preservation of the strength acquired. In so far as the main goal in the preparation period is the development of strength, then naturally, it is important that as much strength as possible survives into the competition period. In other words, some of the training intensity should be directed to preserving the level of strength attained. This is better than having to restore the strength, after it has faded away. Unfortunately, there are very few special studies in this area. After $1\frac{1}{2}$-2 months without systematic strength work the strength of the extensor muscles decreased 5-6% and the flexors by 15-20% in skiers. This is especially true of sportsmen who possess a high level of strength development (A. A. Chistyakov, 1965). Muscles can lose up to 30% of their strength after a period of total rest for one week (E. Muller, 1966). The loss of strength occurs at approximately the same rate as it increased (T. Hettinger, E. Muller, 1955; G. Ravick, G. Larsen, 1959).

The total loss of strength acquired as a result of 20 sessions of speed-strength exercises was noted 5 months after the special training had ceased (8.8% after the first, 33.8% after the second, 60.2% after the third, 81.5% after the fourth and 88.8% after the fifth month). The greatest loss was between the second and fourth months (D. A. Chenyavsky, 1966). However, according to other data, strength acquired in a period of 40 sessions does not decrease to initial levels even a year after training has ceased (I. G. Vasiliev, 1954; R. McMorris, E. Eklins, 1954). The increase in strength achieved as a result of 10 electro-stimulation sessions was maintained for a period of 5 months (V. A. Khvilon, 1974). It has been noted that increased strength is maintained for a longer period of time when it is accompanied by an increase in muscle mass (DeLorme, A.O., 1950; V. A. Khrolon, 1974).

Thus, although this material gives one an idea of the most general tendencies for the growth and preservation of muscular strength there are obvious contradictions. Devising methods of special strength-preparation requires the resolution of the following problem on a strictly scientific basis: first, study the training effect of the means used for this or that type of sport and from the determined level of the athlete's preparedness; second, determine a rational sequence, interdependence and continuity of training means for the yearly and multi-year training periods. In other words, the combination of teaching efforts and special-practice should be directed to introducing the quantitative contents under the following principle scheme of the organization of special strength training (figure 46): the contribution of different training means (conditionally designated a, b, c, in the figure) to the development of the key motor abilities diminishes according to the calculated growth of athletic results; at the same time these means are different in terms of their training effect and the use of each of them is justified only when the athlete's level of preparedness is taken into consideration. In other words, with the growth of athletic mastery, it is necessary to determine the sequence for the introduction of means in the training process by calculating the growth and continuity of their training effect -- this is the basis for the steady rise in the level of the organism's special work-capacity.

3.1.2 The Training Effect of the Strength-Training Means

In recent years scientific research and many years of practical experience have yielded a wealth of factual material on which contemporary methods of special strength-training are based. However, it is necessary to note that this material is generalized and the analysis and the interpretation of it is theoretical. And, although today's athletes attain a high level of sport mastery there is still no basis to say it is because of the detailed methodical systems of special strength-training. To a great extent they attain mastery through a large volume of strength work and a colossal expenditure of energy. The selection and utilization of means in the organization of special strength-training has a number of weaknesses.

In spite of the apparent diversity, the range of special strength-training means is rather limited. In effect, beginners and qualified sportsmen use the same means, the difference being only in the volume and intensity of their loads. This first of all leads to training monotony and second, the organism adapts to a habitual irritant and does not reciprocate with the accommodative reconstruction the sportsman expects. Qualified sportsmen therefore spend a lot of time utilizing ineffective means; none of which augment their level of strength preparedness. Beginners on the other hand utilize virulent means for which they are not yet prepared and have done nothing to justify the premise of over-loading the organism; and therefore disrupt the natural process of attaining sport mastery.

An essential shortcoming in the organization of strength-training is that sportsmen give little consideration to the phenomenon of the qualitative specificity of the training effect of strength exercises. Therefore, very often they utilize means whose specific training influence only slightly conforms to the demands placed upon the organism during the execution of the fundamental athletic exercises. Exercises that are selected for strength have a general-developmental character. We have to take note of the fact that on the other extreme there is the effort to select exercises which are structurally similar to the fundamental exercises. This is justified and correct in principle, but it is sometimes carried to absurdity and sportsmen devise such intricate exercises that they are even less effective than the traditional general-developmental movements. All of this indicates that a scientifically sound, methodical system of special training in which general-developmental as well as special-strength exercises are included, is lacking.

In order to devise such a system it is necessary to objectively evaluate the training effect of the strength means. The training effect -- is the measured influence of a means or a complex of means on the organism as reflected by the magnitude, quality and stability of its accommodative reconstruction. A number of specific indicators, characteristic of the training effect (which are necessary to take into consideration for selecting the means and for devising a methodical system of special strength preparation) would be chosen.

It is first of all necessary to distinguish between the immediate and the delayed training effect. An organism's immediate reaction to the application of a strength means is expressed in a short-term improvement or deterioration of the sportsman's current functional state. Deterioration or improvement is dependent upon the cost of the task, which determines the rest interval prior to the execution of the next exercise: it can be increased if the organism requires more rest or optimally shortened if the superimposed "one upon the other traces" phenomenon effect is utilized by the organism. The reaction of the organism is removed, as expressed by its relatively stable functional reconstruction, which can be substantial only in that instance if the volume of the training influence was sufficient.

The particular and commulative effects respectively are the result of the affect of one or several unidirectional or a complex of qualitatively different-directional means. In the first case, the accommodative reconstruction to the organism is a reflection of that qualitative specificity of the regime which is peculiar to the means applied. In the second case, the accommodative reconstruction bears an integral generalized character. However, this is not simply the sum of the organism's functional acquisitions, but are qualitatively new forms of its motor potential, containing those specific traits which are inherent to the use of the training means. Since training consists of a complex of different influences (according to the qualitative specifics of the means), the cummulative training effect is in essence the basic product of the sportsman's preparation determining the developmental level of his abilities. Therefore, to a significant degree the sportsman's success depends upon the skill to select a diverse (according to the training effect) spectrum of means which will secure the requirements of the cummulative training effect.

One should also take into consideration such indicators that are characteristic of the training effect as absolute and relative strength, qualitative and quantitative, stability and temporal characteristics.

It is necessary to evaluate the effectiveness of two or more means (with regards to the absolute strength of the training effect) in order to select the best one. The relative strength of the training effect is the same as the evaluation of the effectiveness of the means, but the athlete's real level of special preparation is taken into consideration. The qualitative and quantitative characteristics of the training effect are an appraisal of its specific expression and the magnitude of the growth in the level of the organism's functional indicators. And finally, the stability and temporal characteristics of the training effect are evaluated by the length of time it is maintained.

An examination of the specific indicators and some of the peculiarities of the training effect of the strength means is unequivocably indicative of the complexity the coach encounters in planning the content and emphasis of the sportsman's strength training. Although the basis for selecting a strength means by taking into account these indicators and their peculiarities is very convincing, it is unfortunate that this is still very little and the probability that the sportsman will attain the desired level of strength preparation is also very small. In order to eliminate this obvious problem, it is necessary first of all to pay serious attention to an objective evaluation of the training effect of the strength exercises currently practiced today and second, organize a scientific search oriented to devising theoretical tenets and methodological solutions connected with the realization of the cummulative effect of a complex of strength means. It is more to the point to say that in this regard, very little has been done. True, some generalizations are already possible:

1- The training effect of any means diminishes as the sportsman's special physical-preparedness increases.

2- The means used should secure the optimal training effect relative to the current functional state of the sportsman's organism.

3- The 'vestiges' of previous work alters the training effect of any means.

4- The training effect of a complex of means is determined not only and not so much as the sum of the irritants but their combination, order of succession and intervals of separation.

5- The content of special strength-training as a whole should include a complex of specific irritants and secure the formation of the structure of strength preparedness required for the given type of sport and be based upon the concrete level of the athlete's sport mastery.

One question is still very important for devising methods of strength-training.

A training effect comes about through frequent and systematic repetition of a complex of means. The training load is understood as the sum of all the specific influences on the sportsman's organism. The essential characteristics of the training load are: its resulting effect (the qualitative and quantitative assessment of the special work-capacity the sportsman achieves), composition or contents (the complex of means applied), structure (correlation of means), volume (the quantitative aspect of the training work) and intensity (the difficulty or tension of the training work). It is appropriate to examine the composition and structure, the volume and intensity further as parameters of the management of the training load; the resulting effect as the special purpose of the management; the emphasis of the load and the relationship of the volume of the load to the training effect achieved -- as the criteria of the effectiveness of the management of the training process. The purpose of managing the training load is to obtain a high training effect through the rational organization of the composition and structure of the load, with an optimal volume and intensity.

A load will lead to success if its means create an adequate training effect, i.e., provoke a specific accommodative reaction within the organism. This is especially important for highly qualified sportsmen in so far as the means they have utilized in previous stages of preparation do not have the ability to provoke a sufficient training effect for further improvement. Therefore, the search for highly-effective means and methods of special strength-training are always found to be at the center of attention in our country and abroad. Recently isometric and isokinetic exercises have been incorporated in practice as well as the "shock" method of developing explosive-strength, the electrostimulation method and others. And, although not all of them have been studied sufficiently and detailed methods of their use have not been worked-out, nonetheless they bring appreciable success, corroborating their fruitfullness and the viewpoint of the research in this area.

In recent years the volume of the load has grown noticeably. However, it is impossible to accept the tenet where increasing the volume of the training work is considered as the only or as the best possibility for raising the effectiveness of the sportsman's preparation.

Elementary logic and practical experience clearly indicates that it is impossible for the quantitative criterion of work to compensate for the low training effect of the means utilized. However, there is no assurance that highly-effective specialized means, rationally organized within the limits of a specific stage or training cycle, can achieve a high level of special work-capacity at a significantly lesser volume of work and within a shorter period of time. Nonetheless, it should be pointed out that the volume of the load is undoubtedly one of the conditions for raising the special work-capacity in many types of sport (chiefly cyclic) in specific stages of preparation. In order not to create the wrong impression about the volume of the load we must point out that it resolves two basic tasks in the training process. First, it is connected with the creation of a functional base for the further development of the sportsman's specific work-capacity. And, second, it is associated with raising the level of his special preparedness, primarily by developing endurance. If the first task has significance as a universal methodological principle, then the second is correct only for certain types of sports. We should add that the volume of the training work is an important condition for the success of the sportsman's technical preparation. Besides this, available data indicates there is a direct correlation between the volume of the load and the length of time a training effect is maintained.

In contrast to the volume of the training load, its rational structure is very important in any type of sport. From practical experience it is known that no one means or method of special preparation can be considered universal or absolutely effective. Each of them can (and should) have their own special place in a particular training stage depending upon the motor specificity of the sport, the sportsman's level of preparation, the character of the previous training loads, the concrete aims of the current training stage and others. With respect to this, research (Y. V. Verkhoshansky, 1966, 1970; V. V. Tatyan, 1974; A. V. Khodykin, 1975) has clearly shown that the absolute effect of special strength-training, making use of a specific system of different means and methods is significantly greater both qualitatively and quantitatively than the separate unorganized utilization of different means and methods; and is achieved at a lesser volume of the training load.

There is still one more circumstance to be noted. If the means applied do not provoke a sufficient training effect, then stimulation of further growth of the special-work-capacity becomes not so much a factor of the volume of the training load as it is a factor of a specialized exercise and only in that instance if it is executed in training at record levels (for the given athlete). It is necessary to point out that the execution of specialized exercises in training at near maximal intensity should be considered a progressive tendency in the methodological idea determined by the strategy of the sportsman's preparation and is impossible to acknowledge as correct. This would mean not only a rejection of the principles of the rational construction of training which were developed in the course of the evolution of training methods, but is a return to the original primitive notions from which it began.

Thus, the problem of means in the theory and methodology of sport training is far from being solved and the tendency to increase the volume of the training load (in vogue at the present time) should not detract from its significance and turn the attention of specialists away from its in-depth study.

If a logical sequence can be seen as a practical resolution to the problem of raising the effectiveness of the special strength-training methods, (with the selection of a strategy, a scientific search is necessary) then it is layed down in the following principle scheme:

regime -- means -- methods -- system -- volume.

From this scheme it follows that the means of special strength-training should be selected on the basis of objective quantitative notions about the motor specificity of the specific sport and be an adequate regimen of work for the organism. The basic criterion for this is a guarantee of the training effect for the given level of the organism's special work-capacity. The next step is to determine an adequate method, i.e., a way of utilizing the means based not only on the specific motor regimes inherent to the given sport but on the level of the sportsman's preparedness, the tasks of the current stage of training and others. Of great potential for the perfectioning the methods of special strength-training, is the realization of the principle of systematic application of the means based upon the task of obtaining the necessary cummulative training effect. And, finally, attaining the necessary level of special strength-training is the volume of the special work; the optimal magnitude of which should be determined by the stage and current tasks of the sportsman's preparation, the competition calendar and the intensity of the load.

The scheme emphasizes that to pin one's hopes on any one parameter of the load for the realization of potentials is appropriate only after the potential of the previous parameter has been "inhereted". For example, it is not wise to increase the volume of the load without having fully utilized the possibility of raising the training effect of the individual strength training means and their systematic use. True, the realization of this requires a certain amount of courage from the specialists, because it necessitates serious investigative effort. Since increasing the volume of the training work is easier and simpler than finding a really effective means of special preparation, then such a course is very easy to follow in practice.

3.2 Principles of Stimulating Neuro-Muscular Tension to Develop Strength

The external force muscles generate is a result of volitional effort. However, under normal everyday conditions, working tension from volitional effort has certain limitations. In order to increase the external muscular force it is necessary to stimulate them from without -- for example by means of mechanical irritation. Afferent impulses signal the central nervous system (because of mechanical irritation) concerning the degree of external influence (say the resistance of a moving load) provoking a corresponding muscular tension. The more optimum the strength and intensity of the external irritant the greater the muscle effector impulsation, the larger the external work. Thus, afferent signals to the neuro-motor mechanism play an important role in the qualitative and quantitative characteristics of the display of man's muscular strength. Therefore, the stimulation of muscular tension (for the purpose of developing strength) is of great significance.

So, in all cases the magnitude of working muscular tension is determined by volitional effort and external mechanical causes. The stimulation of working force can be divided into three basic types:

-- The stimulation of resistance when muscular tension is provoked by volitional effort, and the resistance of the moving load raises and regulates the effector impulsation of the muscles;

-- The stimulation due to the kinetic energy of a falling training apparatus (body), when the volitional effort is primarily a component of the motive aim;

-- The stimulation is primarily volitional effort (additional mechanical stimulation from without is lacking or limited).

The first two cases are associated with dynamic work and the third with isometric. An increase in the stimulatory influence is realized in the first case by increasing the velocity of the preliminary fall of the body or load, and by mobilizing the sportsman's volitional resources in the third. It should also be pointed out that volitional effort plays an important role in the magnitude of the muscles' effector impulsation in the first instance and its influence in the second is insignificant. The mechanism chiefly responsible for the braking-amortization work of the muscles causes a protective effector impulsation sooner than a purposeful sequence. Therefore, such a compulsary stimulent is able to provoke an extraordinary mobilization of latent functional reserves of the neuro-muscular apparatus which is impossible where there is a reliance on only volitional effort. As has already been stated, there is now an intense search for original highly-effective means of special strength-training. For example, domestic studies have established that electro-stimulation of muscular contraction is an adequate training irritant which provokes effective development of muscular strength (Y. M. Kots, 1971; Y. M. Kots, V. A. Khvilon, 1971; V. A. Khvilon, 1974). Practical utilization of electro-stimulation in the preparation of highly-qualified sportsmen (mainly those in speed-strength type of sports) is very effective and there are a number of advantages associated with this method of developing strength; although it cannot be considered absolute. It should have a specific place in the yearly training cycle; be used in combination with other methods of developing muscular strength and chiefly utilized in the preapration of highly-qualified sportsmen. However, it is not appropriate to consider it in detail here in so far as the methodological fundamentals for electro-stimulation have still not been worked-out. Use of electro-stimulation is applicable only under appropriate conditions and requires qualified personnel.

3.2.1 Resistance

In principle, the heavier the weight muscles lift the larger the tension they develop. The latter is achieved by the effective stimulation and inclusion into the work of a large quantity of the muscles' functional elements. Strength development through the use of resistance movements was demonstrated in 500 B.C. by the legendary Milo of Crotona. According to legend, he increased his strength enormously by daily lifting a young bull onto his shoulders. As the bull grew in size so did Milo's strength.

In our own era Milo's idea is personified by the DeLorme method of progressive resistance exercise (T. DeLorme, 1945; T. DeLorme, A. Watkins, 1948, 1951; T. DeLorme, et. al., 1952). Essentially, this method consists of developing strength through repetitively lifting a weight which is gradually increased in the workout, as well from workout to workout, as strength increases.

However, in that instance when the display of great force was required, resistance was a natural and without a doubt a means of training, but where speed of movement plays a decisive role, resistance was used initially, with great care. True, certain authors have noted that strength-training makes it possible to increase results in speed type exercises (G. A. Dupperon, 1926; A. D. Lubimov, 1927; A. Curie, 1937; D. P. Markov, 1938, N. G. Ozolin, 1939; E. Chui, 1950; W. Gullwer, 1955; D. Pennybaker, 1961). However, a long period of experimental and practical verification was required before this supposition gained acceptance. At the present time with regards to the use of resistance for developing speed, this supposition is correct only in connection to the amount of weight, the coordination structure of the movement, the tempo, the number of repetitions, etc.

When resistance is utilized for stimulating muscular tension it is necessary to consider the following basic premise. First of all, strength can be displayed in resistance exercises in the form of maximal tension or the largest speed of contraction by the working muscles. One can then talk about strictly strength exercises in which force is displayed primarily by increasing the amount of weight and speed-strength exercises in which the display of force is associated with increasing the speed of movement (U. S. Farfel, 1940). In the first case, one tries to work with the largest resistance possible and in the second with resistance, the optimal magnitude of which is determined by the required speed of movement.

It ought to be pointed out that the work regimes of strength (primarily slowly) and speed-strength exercises (inherently fast movements) are essentially different with respect to the physiological mechanisms and the manner in which energy resources are utilized. It is believed that the execution of quick explosive movements requires a sufficient level of liveliness from the basic neural processes, with a high concentration of them at one time; whereas for the execution of slow movements the basic role of the nervous system is to create a sufficient output of excitation and maintain it for a relatively long period of time (V. L. Fedorov, 1957).

In the interests of a more detailed account it is opportune to look more closely at the dynamic characteristics of movements (of limit effort) in connection with the magnitude of the resistance displaced and the regime of muscular work.

The amount of work increases, naturally, as the weight a weightlifter raises increases. However, the changes in the power output of the work are not unidirectional. Initially power output increases, but after the weight of the barbell exceeds 66% of maximum it begins to decrease (G. B. Chikvadze, 1961). A similar picture can be observed in the jump with a barbell on the shoulders (figure 47). Maximal dynamic force grows as the weight of the apparatus increases during the rapid increase in the length of the movement -- mainly through the active thrust phase. Maximum power output is achieved with weights 30-40% of maximum and the maximal coefficient of reactivity with 30-33% of maximum.

The fact that power and the reactivity coefficient increase as movement time increases is due to the additional potential tension accumulated in the muscles from the absorption of the kinetic energy of the body and the apparatus in the amortization phase.

Observations of the movement characteristics of lifting increasingly heavier weights (20, 40, 60, 80% of maximum) in leg extensions in the sitting position (from an initial angle of 110° in the knee joint and only in the overcoming regime) (figure 48) favor such conclusions. It is obvious from the graph that maximum dynamic force and movement time increase with the increase in resistance in an analagous fashion to the jumps with a barbell. However, the surplus potential tension is lacking in this instance, causing a progressive decrease in power output.

Other factors have an influence on the working-effect of a movement with resistance. Variations in the amount of weight, the regime of muscular work, the speed and tempo of the movement, the number of repetitions per set and the duration of the rest interval between sets significantly change the biomechanical characteristics of the movement and consequently the training effect as a whole. Therefore, in each concrete case the selection of this or that work condition with resistance is of necessity based upon the specific character of strength displayed in the specialized exercises.

It should be also added that the resistance, its speed of movement and the duration of the work with it determines the manner in which it influences which muscles participate in executing the movement, the coordination of their activities and the instant the work ceases. The most stable indicator of the coordination structure of muscular activity during the repetitive lifting of a barbell is the sequential inclusion of the fundamental muscles, essential to the given movement, into the work. With 60% of maximum the muscles taking part in the work remained constant during experimental observations -- 82% of the time in all sportsmen. With 80% weights the degree of stereotypicity was less (bearing an individual character) and was higher for qualified sportsmen. The coordination structure of muscular activity is disrupted by fatigue (V. G. Pakhomov, 1967).

The composition of the participating muscles can change during repetitive work (A. M. Lazareva, 1966, I. M. Kozlov, 1966). The number of muscle groups participating in a movement can either decrease (Y. V. Moikin, 1964) or increase (V. S. Averyanov, 1963). In movements executed with little effort or small velocity a large part of work is taken up by the muscles of the body's distal links (K. S. Tochilov, 1946; S. A. Kosilov, 1948; M. I. Vinogradov, 1951). For movements connected with overcoming significant resistance or executed with large velocity the activity characteristically shifts to the muscles of the proximal links.

Thus, the factors just discussed are extraordinarily important in so far as their influence on the working-effect of the movement and the specificity of the strength developed. Therefore, these factors ought to be considered in accordance with the peculiarities of the concrete athletic activity when selecting strength exercises with resistance.

It is necessary to bear in mind the distinctive traits associated with the moment force in resistance exercises. For example, in the starting position for squat and squat jumps (before beginning the active working effort) the muscles of the legs and torso have already developed tension equal to the weight of the apparatus being held. On the other hand, with the snatch or clean and jerk the fundamental working force (which accelerates the apparatus) is developed practically from zero. Thus, we can divide resistance exercises into two groups: exercises in which the working force is developed after preliminary muscular tension (equal to the weight of the apparatus), and exercises in which this force is developed from zero (without appreciable preliminary muscular tension).

The main difference between these groups of exercises is that the exercises in the first group do not provoke an appreciable influence on the processes connected with chemical and physical transformations in the muscles, the excitation -- tension link. Consequently depending upon the amount of weight used, conditions are created chiefly for the development of muscular strength or the speed of muscular contraction but not the speed with which muscles switch to the active state. The conditions of muscular work in the second group of exercises have the simultaneous potential to develop dynamic-strength, speed of movement and chiefly starting-strength. It is not difficult to see that this is not simply a nuance of movement biodynamics. It has great significance for the perfectioning of strength-training methods.

Finally, based upon the conditions under which force is applied, exercises ought to be distinguished by force directed against the weight of a load and by force directed against the inertia of a load. In the first instance, lifting a barbell for example, the working force of the movement is quantitatively equal to $F = m(a+g)$, i.e., determined by the mass of the load and the acceleration of the force gravity. In the second instance, the force of the movement is equal to $F = ma$, i.e., dependent only upon the load's force of intertia, moving with a certain acceleration. Examples of such conditions are throwing, jumping out of the starting blocks, punching, i.e., those situations when strength operates in a direction perpendicular to the load's gravitational force.

The differences in the biomechanics of the movements examined are quite significant. In the first, muscular force initially becomes equal to the amount of weight to be lifted (developed practically under isometric conditions) then exceeds it (beginning of the movement), accelerates the apparatus and then the muscular force becomes larger the more it exceeds the weight of the apparatus. The preliminary isometric muscular tension causes a large gradient of acceleration-strength. In the second case, if friction and the resistance of the surroundings are excluded then the movement of the load begins (in principle) with the most insignificant external strength. Further changes in the latter are caused wholly by the speed of muscular contraction or more precisely the muscles' ability to "raise" the load by displaying simultaneously maximal strength and speed of contraction. Consequently, conditions where strength resists the weight of a load stimulate primarily the strength component and conditions in which strength is directed against a load's force of inertia to a large degree stimulate the speed of muscular contraction.

Thus, in the second case, it is not difficult to see the possibility for overcoming the dialectical contradiction between the weight of the burdon and the speed of muscular contraction. Unfortunately, the necessary special equipment for muscular work at overcoming the inertia of a load are as yet still not being utilized in training. However, in one's effort to rationalize the methods of special strength-training one is ultimately compelled to think about this seriously. The practical possibility exists for two solutions: the application of force (for example, the thrust) through a horizontal wheel or suspension (the same principle as a pendulum) of the load or untwining a flywheel (figure 49). In the first example, one can vary the amount of weight and in the second -- alter the moment of inertia of the flywheel to affect speed of contraction.

Work with weights should be examined as a special case. Weights are utilized extensively as a means of increasing the difficulty of movement in order to develop various qualitative motor abilities. Elastic bands (bands, tubes, plaits) are frequently utilized as a means of resistive movement although the character of the force displayed is dependent upon the elastic qualities of material; limiting the usefulness of these means. Therefore, elastic materials should not be utilized for the development of starting-strength in ballistic movements or for developing explosive-strength. Now this is another matter if one is speaking of strength-endurance. In this instance, one can select the length and the elasticity of the band so that its resistance will change insiginificantly within the working amplitude of the movement. This method is utilized by swimmers for developing strength endurance in the "pulling" movements (figure 50).

The methods of resistive movement are extraordinarily diverse. In each concrete case they are determined by the athletic exercise and the resolution of two tasks: the stimulation of muscular contraction and the creation of a facillatory effect for transference to the natural conditions of the movement (for example, putting a regulation shot after training with an overweight one). Movements can be made more difficult with small weights, insignificantly increasing the bodyweight as a whole or its

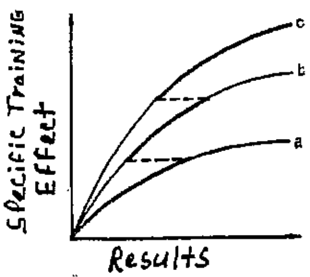


FIGURE 46 - Introduction of means with higher training effect.

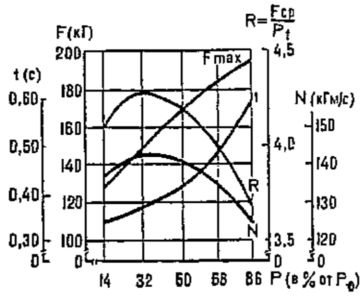


FIGURE 47 - Changes in maximal force (Fmax), movement time (t), coefficient of reactiveness (R) and work power (N) for leaping (barbell on the shoulders) with increasing weight.

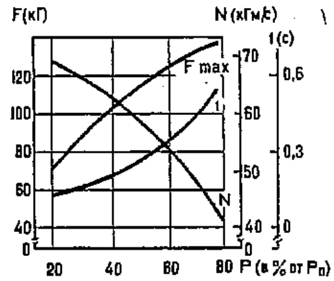


FIGURE 48 - Changes in maximal force (Fmax), work power (N) and movement time (t) for a leg-press with increasing resistance.

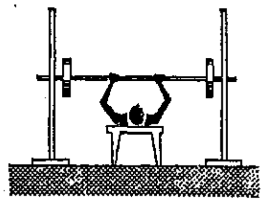


FIGURE 51 - Pressing a barbell after it has fallen from some height.

FIGURE 49 - Turning a flywheel by flexing the forearm.

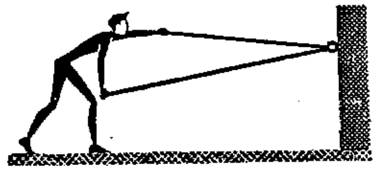


FIGURE 50 - Cable exercise for developing strength endurance in the swimming strokes.

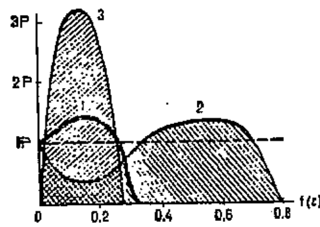


FIGURE 52 - Development of force for various vertical jumps: leaping from a low squat (1), the usual jump with amortization (2), after a depth-jump from 0.4 M (3). The heights of the jump were 0.67, 0.74 and 0.80 M respectively. The subject's weight is on the ordinate.

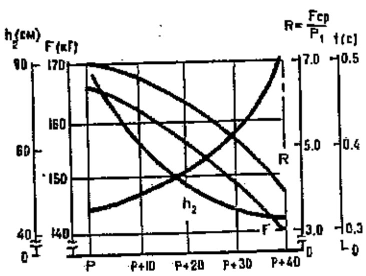


FIGURE 54 - Take-off characteristics after an unloaded depth-jump (P) and with 10, 20, 30 and 40 kg; t-time, h2-height of the jump, F-mean of total force, R-coefficient of reactiveness.

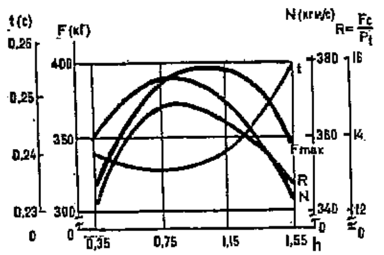


FIGURE 55 - Take-off characteristics after depth jumping from gradually greater heights (h); t-time, Fmax-maximal force, N- work power, R-coefficient of reactivity.

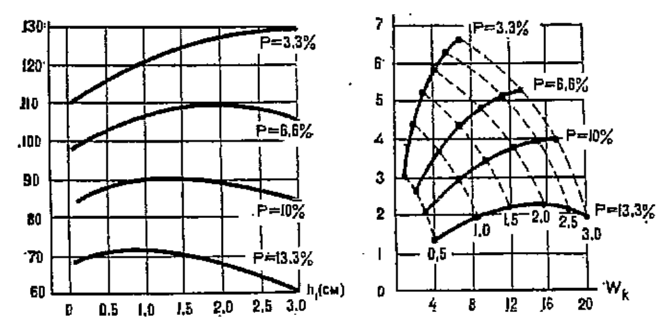


FIGURE 53 - Changes in height (h2) of thrown objects of different weight (P) after having fallen from different heights (h1) and the coefficient of reactivity (R), depending upon the kinetic energy of the falling object (Wk).

links. This is accomplished with belts, weights, cuffs, sandbags, boots and others. This effect can also be obtained by running in water, deep snow, up a hill, or rowing against a hydro-resistor. Based on a review of the principles of neuromuscular stimulation with weights and supported by the facts stated in the preceding chapters an orthodox conclusion should be formulated. Exercises with weights are not adequate means for the development of speed of movement (the speed of unloaded movement or movement against a relatively small external resistance), especially for highly-qualified sportsmen. Careful analysis of experimental and empirical data indicates that increasing speed of movement through resistive exercises (i.e., through absolute muscular strength) is primarily for novice sportsmen. This is completely justified for augmenting muscular strength; and from a physiological standpoint promotes a quicker realization of movement. However, this factor quickly exhausts itself and at first a positive influence, it becomes negative, because resistive exercises not only improve the physiological mechanisms essential for the rapid realization of movement but also have a negative influence on them.

If one speaks of speed-strength movements (characterized by explosive force) associated with overcoming significant resistance, then resistive exercises are definitely useful but only in those cases when they are executed in certain (specific to the special exercise) regimes of muscular work, at a reasonable volume, at specific stages of training.

3.2.2 Kinetic Energy

Let's consider the instance where a training apparatus, say a barbell, has some velocity obtained as a result of falling from some height and the sportsman's task consists of first actively stopping it then quickly thrusting it in the opposite direction, i.e., upward (figure 51). Under similar circumstances the mean sum of the muscles' working force developed by yielding amortization then active overcoming work is:

$$F = m\left(\frac{V_1^2}{2S_1} + g\right) + m\left(\frac{V_2^2}{2S_2} + g\right).$$

Principally, as regards to muscle dynamics, a pecularity of such a movement is that in the amortization phase the kinetic energy of the apparatus is transformed into some potential muscular tension which is then utilized in the overcoming work. In principle, the magnitude of this potential is equal to the kinetic energy of the apparatus at the end of its fall (depending upon the weight and the height of the fall). The absolute muscular force developed at the instant of switching from yielding work to overcoming will be greater the shorter the amortization path and shorter the braking time. Naturally, this applies to those conditions when the action as a whole is oriented to thrusting the apparatus with maximum speed immediately after it has been stopped. Thus, what we are talking about is completely different from the traditional stimulation of muscular tension. The external mechanical irritant is not so much the weight (and its force of inertia) as the energy accummulated after its free-fall.

If one considers dynamics of muscular work with different variations of the take-off in the vertical jump for example (figure 52), it is not difficult to see that such a means of stimulating muscular tension has significant advantages. First -- it secures a very quick development of maximal dynamic force. Second -- the magnitude of this maximum is significantly larger than in the other cases. Third -- a large (and this should be emphasized) magnitude of maximal force is achieved without utilizing additional resistance. Fourth -- switching from yielding to overcoming work occurs far faster than in the other cases. Fifth and lastly -- the significant potential muscular tension accumulated in the amortization phase (without additional resistance) secures muscular work of greater power in the thrust phase and faster muscular contraction; which can be adduced from the greater height the body attains in the subsequent jump upward.

Thus, stimulation of muscular tension by means of absorbing the energy of the sportsman's falling body or a training apparatus can secure a significant force of muscular contraction (which is impossible with other means of mechanical stimulation) without using weight or with a small burdon; and not only without slowing the speed of muscular contraction, but even increasing it in comparison to the usual conditions. It is not difficult to see the even greater possibility of overcoming the fatal contradiction between external resistance and the speed of movement than in the aforementioned case where muscular strength is acting against the force of inertia in overcoming a weight.

The first experimental steps taken to study the features of this principle of muscular stimulation revealed its exclusive effectiveness for developing explosive-strength and principally its components, such as starting-strength. The potential to develop starting-strength is limited because it is dependent upon man's ability to concentrate to this or that degree on a volitional effort. This strength is acquired very slowly in training. Particularly stressful conditions are required -- an irritant of such strength that it provokes the appropriate adaptive reaction. Even the variety of strength exercises (with resistance) in practice does not fulfill these requirements although the element which includes muscles in the active state (i.e., the emphasis is on the phase where force is developed from zero) is lacking in the majority of them.

A number of studies suggest that such exercises can have a place if, for example muscular tension is achieved through an abrupt stretch (R. Ramsey, 1944; A. Hill, 1955; A. Tweit, et.al., 1963) which occurs at the instant a falling body or apparatus is stopped. It should be emphasized that significant and instantaneous development of muscular tension in this instance is due to the extraneous mobilization of the latent motor resources of the motor apparatus which creates the conditions for the development of starting-strength and the explosive-abilities of the muscles.

Thus, we are speaking of a specific work regime which no resistance exercise can imitate. Stimulation of muscular activity with resistance slows the movement from yielding to overcoming work. The utilization of energy of a falling body or apparatus for mechanical stimulation requires the muscles to initially develop significant potential tension, utilize it in overcoming the inertia of a relatively small weight, then quickly switch to overcoming work and display a high speed of contraction.

Kinetic energy ($W_k = \frac{mv^2}{2}$) is determined by the weight of the body and the height of its fall. Therefore, in the interests of methodology it is important to know how the stimmulatory influence of energy changes. In order to do this in the laboratory we constructed a special experimental stand to measure the height a load attains when a subject throws it upward after it has first fallen from some height (from 0.5 to 3.0 meters). The kinetic energy utilized for muscle stimulation varied according to the weight (3.3; 6.6; 9.9; 13.6% of the maximum isometric strength) and the height of the fall. The experiment showed that an increase in kinetic energy due to an increase in the amount of weight causes the height to which a load is thrown to decrease, but an increase in the distance a load falls increases the height to which it is thrown. An analogous picture emerges from research on reactive ability (figure 53). This tendency in general, is peculiar to movements executed under other conditions although there, they have their own peculiarities (figures 54 and 55). These examples show that it is clearly not advantageous to increase kinetic energy by means of the amount of weight. It is therefore necessary to examine a better means of increasing height. The depth-jump (figure 55), which has immediate practical significance for developing jumping ability is an example. Thus, maximum force increases up to a height of 1.5 meters then diminishes sharply; movement time begins by changing insignificantly, then it increases sharply. Maximum power and reactivity are achieved at a height of 0.75 meters. Thus, the optimal range of depth jumping for the stimulation of muscular activity is 0.75-1.15 meters because at the onset of work the muscles are working at maximal power and at the end at maximal dynamic force. This data is the basis for the recommendations to utilize depth-jumps for qualified jumpers (Y. V. Verkhoshansky, 1963, 1964, 1966).

Apparently, this fact merits attention -- subsequent increases in the height of the depth-jump significantly lessens the dynamic parameters of the take-off. The support time increases quickly, primarily because the instant of switching from yielding to overcoming work is lengthened. The maximum dynamic force and the speed of muscular contraction stablize. There is a clear division of the take-off into two actions -- the amortization -- where the kinetic energy of the fall is absorbed and the thrust proper. The amortization is characterized by the increasing depth of the squat and the thrust proper by a constant speed of muscular contraction.

Thus, the positive effect of muscular stimualtion by absorption of kinetic energy from a fall can be utilized successfully only under certain conditions, taking into consideration the optimal heights of the fall, bodyweight, or weight of the apparatus; as well as in that instance if the action as a whole is oriented to a quick take-off. However, the working conditions of the neuro-muscular apparatus at the instant of the amortization of the falling body from a significant height can have independent training significance. Tension developed instantaneously during this perfects the ability of the muscles to quickly switch to the active state. At any rate experience indicates that this is of no detriment to speed-strength preparation and the support apparatus. Although additional research is required in order to seriously speak of practical recommendations in this area.

Well then, muscle stimulation through the absorption of energy of a falling body or apparatus is a very effective method. The basis for it lies in the ability of the muscles to contract with more power after a sharp preliminary stretch. Nature created this mechanism in order for man to successfully struggle with the force of his body's inertia in extreme situations; it is preserved well by utilization in the practice of sport.

Preliminary stretching of muscle has a place in a number of strength exercises such as squats and jumps with a barbell on the shoulders. However, it is not as intense as braking the velocity of a preliminary fall which is characteristically sharp, and a shock. Therefore, the method of muscle stimulation by means of absorbing the kinetic energy of a fall was called the "shock method" (Y. V. Verkhoshansky, 1966, 1968). Our research (1958-1976) has taken only the first steps in studying and formulating this method. A lot of research (V. V. Kuznetsov, 1966; V. N. Papysheva, 1966; V. I. Chudinov, 1966; L. Y. Chernesheva, 1967; V. G. Semenov, 1967; V. P. Savin, 1974; V. V. Tatian, 1974; A. V. Khodykin, 1975) has corroborated the effectiveness of this method. However, more work is needed in the laboratory and under natural training conditions before its uses are exhausted.

3.2.3 Volitional Effort

Situations are possible where external factors are indispensable conditions to the display of muscular strength but do not have essential significance for its magnitude. Isometric tension (the magnitude of which is determined primarily by volitional effort) is utilized extensively for strength development. The idea is to create tension in a muscle group by applying force to an immovable object and hold this tension for some time period. The length of the muscle does not change and the muscular force remains relatively constant.

In athletics, isometric exercises were very popular abroad in the mid-fifties as a result of the search for economical and at the same time effective methods of developing strength. T. Hettinger and E. Mueller (1953, 1955) established that one daily effort 2/3 maximum for a period of six seconds over a period of 10 weeks will increase strength about 5% per week; H. Clark, et. al. (1954) found that static strength continues to increase even after the conclusion of a four-week program of exercises.

The success of isometric training provoked a chain reaction of research. Naturally for the most part, much of it was concerned with the question: which is more effective -- isometric or dynamic training. This research produced rather contradictory data (for a detailed review and analysis of the works see Y. V. Verkhoshansky, 1970). However, the general conclusions which are drawn from an analysis of the factual material are as follows: isometric training can be more effective than dynamic in those cases where the special exercise requires a muscular contraction of large magnitude. If the special exercise is of necessity a high-speed movement, then isometric training is less effective. Research indicates there is need for discretion in similar discriminations between the training-effect of static and dynamic exercises. The fact is, muscular tension should increase slowly and be held for a relatively long time when executing isometric exercises because the purpose of isometric training is to develop absolute-strength. Maintenance of muscular tension for a long time requires a corresponding energy expenditure which stimulates an adequate adaptive displacement in the neuro-muscular apparatus; determining its strength potential. This displacement can be more significant than momentary dynamic tension. If one takes into account the fact that a number of authors have not discovered an essential difference in the growth of strength utilizing tension of various intensities, then it is obvious that the fundamental training factor is not so much the magnitude of the isometric tension as it is its duration.

If isometric exercises are executed with the accent on the speed of developing force, then they can be as effective for the development of explosive-strength as dynamic exercises. The steepness of the force-time curve (see figure 29) and larger (than dynamic) maximum force is the basis for this assertion. Therefore, it is doubtful whether it is worthwhile to place a border between dynamic and isometric exericse. In general, the more the muscles work (in raising large loads) the closer the work is to isometric tension; and even greater explosive-force can be displayed isometrically than with the dynamic regime.

In connection with this, it makes sense to distinguish isometric training to develop absolute-strength and isometric training to develop explosive-strength and utilize one or the other in appropriate circumstances. However this still requires experimental corroboration. At any rate, isometrics ought not be neglected for strength development and the negative expression of the inappropriateness of this method which can be found in the methodical literature is very premature.

It is necessary to bear in mind the following advantages of isometric training, as demonstrated by its adherents:

1- The popularity of isometrics lies in the simplicity of the equipment.

2- The possibility to locally influence any muscle group at a specific joint angle. During dynamic work the display of maximal effort at the necessary joint angle can be achieved only for a fraction of a second. In some cases, this is generally not possible since the movement's inertia quickly moves the apparatus through that position at which the muscular tension would yield the greatest effect. Such a joint angle can be fixed precisely during isometric training.

3- Taking into consideration the time expended; the training is very productive. Each 6-second isometric contraction is in its effect equal to many dynamic contractions (ballistic type) in which maximal force is of a duration no more than 0.1 seconds. From a practical standpoint this means that 10-minutes of isometric tension in specially selected exercises replaces a fatiguing hour of training with weights.

4- There is an insignificant increase in muscle mass and body weight in comparison with dynamic strength work -- particularly with pressing exercises.

5- There is by far a lesser expenditure of time and energy than dynamic training with weights. It is possible to preserve a high level of speed-strength in the period of crucial competitions.

6- There is a greater potential for visual and kinesthetic retention of the position needed than in the dynamic regime. This gives isometrics a decisive advantage for studying and correcting errors.

Isometrics have the following negative aspects: they fatigue the nervous system and have a harmful influence on the cardio-vascular system, decrease coordination and speed of movement; and worsen the elasticity of the muscles. However, with the proper uniform breathing, sequence of work and rest, pauses between exercises for relaxation, and limiting the length of contraction to no more than six seconds (some authors recommend 10 seconds) the harmful after-effects of isometric exercises are eliminated.

The following methods of execution are recommended for the development of absolute-strength with isometric exercises:

1- Tension is executed against an immovable solid structure or against the resistance of a partner. The shortcoming of this type of exercise is that the increase in tension resulting from training can only be determined subjectively.

2- Tension utilizing a weight which is raised and held for a specified period of time. A variation of this method is the interval of tension when the load is slowly shifted through a wide working amplitude with stops. This enables one to work the muscle's entire amplitude and assess the growth of strength by the increase in weight.

3- Tension through a preliminary lifting of a weight to a support (Hoffman method). This method begins with a short dynamic phase and gives the sportsman a specific idea of the magnitude of the tension. He can lift the weight several times between the stops then execute an isometric contraction for the necessary duration.

4- Tension utilizing a dynamometer or other resistance permitting control of the strength of muscular tension.

In all cases it is necessary to 1) apply force gradually to the immovable object; 2) hold the maximal tension no longer than 6-seconds; 3) limit the duration of isometric tension to 10-minutes; 4) finish off the training session with relaxation exercises.

It should be added that if the purpose is to develop explosive-strength then the isometric tension should be generated with the maximum speed possible to a magnitude of 70-80% of maximum.

Isometric exercises can be extraordinarily diverse depending upon the purposes for their use. It is impossible to recommend exercises for each case. Athletes who are aware of the basic methodological tenets of isometric training (with some creativity and based upon the known principle of dynamic correspondence) are able to select the necessary exercises.

3.2.4 Some Additions

It has already been stated that the interest in studying the peculiarities of muscular work in athletic activities is associated with the determination of those regimes which during the execution of the special exercise would ensure that the sportsman's motor potential will be utilized to the fullest and the training conditions yield the highest effect from the special strength training. In the latter case, research has been done in basically two directions. The purpose of one (with a basic comparative experiment) was to determine the most effective regime. The purpose of the second was to determine the most effective combination of the various regimes of muscular work or combination in one exercise or the application of a complex within a specified period of time.

It should be asserted, however, that research projects of this sort are not very numerous and have a number of deficiencies. First, they are carried out with sportsmen of low qualification; second, in many cases there is a distinct tendency to deliberately show a preference to that regime which is fashionable -- for example with isometrics and then with eccentrics. Therefore, to speak of anything definitive in terms of effectness (more so in absolute terms) of this or any regime or combination of them is premature. One can only closely represent the state of this problem and draw preliminary conclusions.

From the "new", if you can call it that, regimes of muscular work utilized for strength development, we should consider two: isokinetic and static-dynamic.

The isokinetic method was very popular in the latter part of the 60's and early 70's particularly in the U.S.A. Essentially this method involves the use of a special apparatus which automatically changes the external resistance to the movement, limits its speed and ensures a maximum load on the muscles throughout the entire working amplitude. In other words, the limiting factor is the speed with which the exercise is executed not the magnitude of the resistance as it is in weightlifting exercises.

The resistance increases as the speed increases.

In isokinetics, the resistance is a function of the force applied. The isokinetic trainer slows the velocity of the movement so that the sportsman can fully utilize the working amplitude of the movement for muscular tension. The trainer is constructed so as to permit loads of various magnitude: from the force of finger pressure to hundreds of pounds. The sportsman applies maximum force and the apparatus automatically varies the resistance. Because muscular force and work-capacity vary in the course of executing a concrete movement the resistance automatically accommodates to the muscles' ability at each point in the working amplitude. The isokinetic device provides the muscles with a near-maximal load on each repetition of the exercise independent of mechanical advantage. This, accommodating resistance spontaneously correlates with the specific work-capacity of the sportsman's muscles.

The basic advantage of the isokinetic method over others (as considered by one of the pioneers and one who popularized its utilization in training sportsmen, James Counsilman 1971, 1972) is that this method forces the muscles to work with maximal effort all the time and renders a larger, faster increase in strength; even for very strong sportsmen. Even allowing for the commercial motives of the trainer's authorities it is noteworthy that their claims have been already corroborated by considerable research (D. Chu, G. Smith, 1971; I Rosentswieg, M. Hinson, 1972; M. Hinson, I. Rosentswieg, 1972; I. Wilson, 1972). The results of these studies tell of the following advantages of the isokinetic method of strength-training.

1- The isokinetic device accommodates to the sportsman's capabilities throughout the range of motion (not the sportsman accommodating to the resistance). It is due this that the sportsman is unable to do more than he is capable under these conditions. The trainer automatically accommodates to muscular fatigue or pain as well as the increase in strength resulting from the training. Such a method eliminates the possibility of injury.

2- The necessity of a warm-up (for weightlifting exercises) is eliminated with isokinetics; and in five minutes one can get a very good workout. Despite the fact that sportsmen may train as a team and have different strength capabilities, it's not necessary to adjust the trainer to each sportsman, thereby saving time.

3- By utilizing resistance which automatically accommodates to the force applied significant strength can be achieved with a lesser number of repetitions per exercise since each repetition "loads" the muscle throughout the entire range of motion.

4- The sportsman is able to see his results displayed on a special meter or on a graph (which is available on some isokinetic trainers) while exercising and thus is able to compete with himself or with other sportsmen.

A number of studies have compared isometric, dynamic and isokinetic regimes for effectiveness of strength development (H. G. Thistle, et.al., 1967; I. Rosentswieg, M. H. Hinson, 1972). It has been established that isokinetic exercise is characterized by a larger electrical activity in the muscles, the best growth, maintenance and loss of muscular strength indices. More significant gains in muscular strength in a shorter period of time as well as a shorter period of time devoted to strength training are possible with isokinetic training. Besides this, it ensures the necessary qualitative specificity of trained strength because of the trainer's ability to control and dose the speed of muscular contraction.

The static-dynamic method of developing muscular strength involves the sequential combination (in one exercise) of two regimes of muscular activity -- isometric and dynamic (auksotonic) which can express their own distinct quantitative characteristics. For example, these variations of static-dynamic exercise have been shown to be effective -- a 2-3 second isometric tension (80% of maximum) followed by dynamic work of an explosive character with a load 30% of maximum or in both the isometric and dynamic components, a constant load of 75-80% of maximum is utilized. In the latter case the sportsman lowers into the half-squat position with a barbell on his shoulders, holds this position for 2-seconds then with maximal speed, jumps upward. After landing he repeats the exercise. It has been established experimentally that the first variant of static-dynamic exercise is better for developing speed-strength than only dynamic exercise. The second variant has an equivalent affect on the improvement of speed-strength and absolute-strength (I. M. Dobrovolsky, 1972, 1973).

Of all these regimes, which is the most effective?

It is difficult to answer this question for a number of reasons. First, all encompassing research which could evaluate the effectiveness of all the diversity of regimes has not been conducted. An attempt for example, to study the effectiveness of yielding, overcoming, holding and combined regimes revealed some advantages of the overcoming over the yielding and holding but the main method -- the combined regimes had the obvious advantage (B. A. Pletnev, 1975). Second, similar research is difficult with respect to controlling the training loads of the different regimes (without which the research loses its meaning). And finally, it is not right to raise the question of the absolute effectiveness of this or that regime. Each of them can be the most effective depending upon the stage of the yearly cycle, qualification of the sportsman, the primary regime of muscular work in the special exercise, that qualitative specificity of the strength ability which one must acquire as a result of training, and others.

Today it can be ascertained with reasonable certainty that the most rational means of raising the effectiveness of special strength preparation is to combine the various regimes of muscular work. This has been corroborated by a number of studies (A. N. Vorobyev, 1966; V. A. Andrianov, A. N. Vorobyev, 1969; V. V. Kuznetsov, 1970; Y. V. Verkhoshansky, 1970, 1972; A. P. Slobodyan, 1972; V. V. Tatyan, 1974; B. A. Pletnev, 1975; A. V Khodykin, 1975; V. P. Savin, 1974 and others). Such a combination is selected by taking into consideration the cummulative effect inherent to it and the correspondance of the qualitative specifics of those requirements of the concrete conditions of the athletic activity.

Recently training devices for strength development have become very popular. They are specially constructed to provide resistance to various movements. Depending on the setting they are suppose to imitate the athletic exercise or certain elements of it in order to provide the necessary specific loads in the different regimes of muscular work (I. P. Ratov, 1976). Research on the utilization of training devices in the practice of athletics (G. P. Semenov, 1970; V. V. Petrova, G. D. Gorbunov, 1970; Y. V. Verkhoshansky, 1970; D. N. Deniskin, V. V. Kuznetsov, 1972; I. M. Dobrovolski, 1972, 1973; V. V. Kuznetsov, L. P. Aiunts, 1974; V. P. Savin, 1974; and others) has shown them to be highly effective for the special strength-training of sportsmen. This can be explained by the fact that they permit the strict regulation of the spatial characteristics of the movement and dosage of the load in order to utilize extensively, the effective regimes of muscular work and to program the character of the displayed force over time. They reproduce stereotypical training movements and are economical for the athlete in terms of time and energy. One enormous advantage of training devices consists of the fact that it is possible to secure crucial visual information about the qualitative and quantitative characteristics of the movement as well as to control the sportsman's special strength-training. All of these advantages create significant potential for perfecting the system of the sportsman's special strength-training. Therefore, the introduction of various types of training devices is a very important task.

3.3 The Principle of "Dynamic Correspondence" as a Means of Strength-Training for the Special Exercise

Devising methods of special strength-training is associated first of all with the selection of the means and methods for the development of muscular strength.

Each of man's movements are concrete and purposeful. Therefore, the strength displayed in the execution of each movement is also concrete and purposeful. One shouldn't speak of strength in general but only in the context of the movement task and the character of the realization of this movement task. In other words, the means and methods of strength-training should provide an adequate work regime for the motor apparatus in the special exercises and further qualitative improvement.

The methodological essence of this assertion is formulated in the so-called principle of dynamic (strength) correspondence which includes a number of theoretical and experimentally based criteria; that should be a guide in the selection of the means and methods strength development in conformity to concrete athletic activities. Such criteria take into consideration the biomechanical peculiarities of muscular work during the execution of the sport movements and are naturally, of a general character. One of them can be of large, another of lesser importance in carrying-out the demands of the special strength-training; depending on the athletic activity. Therefore, the coach and athlete should always take a creative approach to the realization of these demands.

3.3.1 The Amplitude and Direction of Movements

The criteria of correspondence with respect to the amplitude and direction originates from the spatial characteristics of the movement relative to the adjacent body part. It determines which muscles are involved in the work and allows for anatomical peculiarities and the external conditions of work; especially the direction of the external counteraction to the muscles' pull, the movement of the system's links. Thus, the movement of the shoulder girdle of a rower or a shot putter is about the same in amplitude but the direction of the working force is different (figure 56). In the first case the pulling of the oars involves shoulder extension and in the second -- shoulder flexion acting in opposition to the shot's force of inertia.

The importance of the correspondence of muscular work, in terms of the criteria examined can be illustrated by the following example. In track and field, jumpers and sprinters do exercises to develop the hip flexor muscles such as hip flexion with a barbell plate on the thigh in a standing position. However, the amplitude of the thigh's movement in running and jumping (moving the legs forward) is significantly greater than the amplitude of this exercise and begins at an angle of about 210° in the iliofemoral joint, relative to the torso (figure 57). Therefore, the execution of this exercise in the standing position does not duplicate the mechanism of the movement in the special exercise (jumping, sprinting, Ed.). If the sportsman's position is changed (figure 58) the criterion of the correspondence is met not only with respect to the amplitude of the movement but also the criteria of correspondence of the external opposition of muscular force, since the resistance (in the movement with resistance) will imitate the inertial resistance of the mass of the leg rotating at the iliofemoral joint in the special exercise. By altering the amount of weight, the number of repetitions and the tempo of movement the task of educating the strength to display the force required and also the strength endurance, will be solved. Thus, in order to realize the criteria of correspondence with respect to the amplitude and direction of movement it is advisable to select the exact initial position and posture of the sportsman as well as calculate the direction of the action of the force of gravity of the system's working links and the additional load.

It is necessary to take into consideration that the direction of the external resistance of the movement is important and also the loaded movement as a whole. For example, in middle distance running, skiing and skating a knapsack full of sand or a weight belt is utilized for resistance. However, the muscles which bear the load are those resisting the weight of the body. This can increase the vertical makeup of the dynamic interaction with the support and develop general strength-endurance but does not strengthen those muscles which move the body. In an analogous position a skater executes jumps on one leg on the floor or from a bench. These exercises strengthen the leg muscles supporting the body and the static-endurance of the back muscles but do not fully imitate the working of the muscles for the push-off where the force is directed backward. Skaters should utilize another method of resistive movement by means of changing the direction in which the force of resistance is acting (figure 59). These methods, to the greatest extent, conform the training exercise to the dynamics of the special exercise.

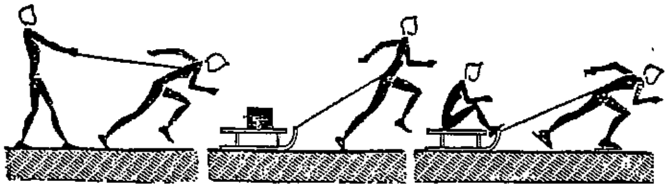
In athletics, the working-force is developed by the simultaneous coordinated tension of the muscle groups which move the various segments of the body. The most characteristic example of such cooperation of the working muscles is the simultaneous flexion and extension at the iliofemoral joints (running, jumping, fencing, figure skating, basketball, tennis and others) where the angular movement of one leg furthers the push-off movement of the other. It is useful to imitate this combination with a special strength-exercise which takes into account the working amplitude of the movement and the direction of the opposing force (figure 60).

3.3.2 The Accentuated Part of the Working Amplitude of Movement

Muscular effort changes in the course of movements and maximum force is developed at the necessary instant. In ballistic movements this instant corresponds to the beginning part of the working amplitude and in movements of mixed regimes of muscular work -- at the instant of switching from one regime to another. Thus, the working amplitude always has an accentuated part at which the maximum dynamic force occurs and which corresponds to a specific joint angle. Based on this, the criteria of correspondence anticipates the necessity to display the required force at a specific joint angle.

Looking back to the previous example it should be noted that the accentuated part of the working amplitude of the leg movement is the beginning (see figure 57), as indicated in the graph of the rotation moment; during the rotational hip flexion in the air (figure 61). Consequently, the sportsmen of whom we spoke not only do not maintain the requirement of reproducing the full amplitude of the movement but lose the potential to train the muscles to generate the necessary force at the necessary angle in the iliofemoral joint.

This example vividly depicts the importance of the starting



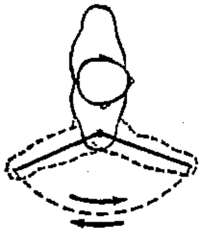
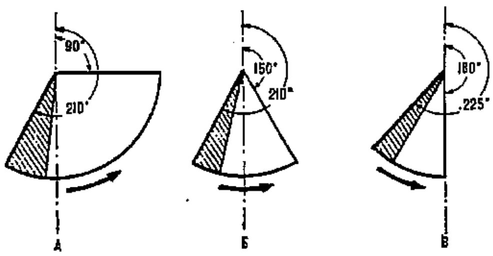


FIGURE 56 - Amplitude of shoulder movement of a rower and shot-putter.

FIGURE 59 - Means of increasing the skating resistance.



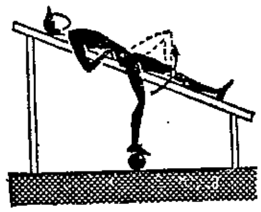
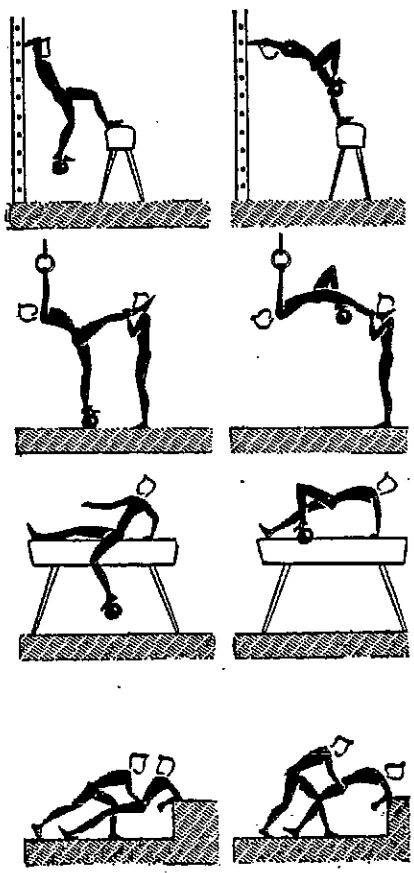


FIGURE 57 - The most common working amplitude of movement for flexion (A), extension (B), at the iliofemoral joint and extension at the knee joint (C) in sport exercises. The amplitude is shaded.

FIGURE 58 - Exercise for developing hip flexion strength by taking into consideration the accentuated part of the amplitude and the resistance to the force of muscle pull.



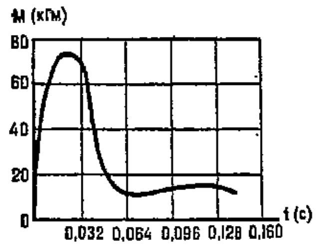


FIGURE 61 - Change in the rotary moment force during repetitive flexion-extension of the leg during the take-off for the triple jump.

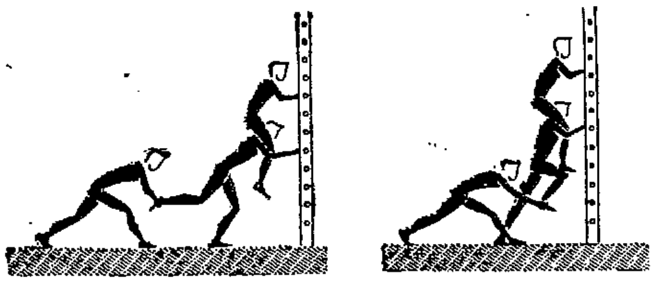


FIGURE 62 - Special strength exercise imitating flexion-extension at the hip joint.

FIGURE 60 - Complex strength exercise for the simultaneous strengthening of the hip flexors and extensors and knee extensors.

position for the execution of the special strength exercises that have a local affect on the motor apparatus. The strength exercise should not only reproduce the full amplitude of the movement but also the specific direction of the opposition to the pull of the muscles. Following these requirements can sometimes lead to such initial positions which are incongruous and artificial (figure 62), however this only occurs when an exercise is attempted without taking into consideration the criteria examined.

It is possible to develop force at the required joint angles with isometric exercises and they have particular value in this regard. With isometrics one can locally influence certain muscle groups by taking into consideration the accentuated parts of the amplitude of the movements they are involved in. Therefore the selection of these exercises should be based on the joint angle at which maximal motor force is developed in the special exercise.

3.3.3 Dynamic Effort

The criterion of dynamic effort is the correspondence of the dynamics of the training means of the special exercise from the standpoint of its quantitative characteristics. This criterion expresses and specifies the known methodical principle that according to the magnitude of the training irritant it should not be inferior to the conditions of the execution of the exercise at the corresponding level of mastery, but in principle exceed it. In other words the effort generated in training should not be inferior to the effort generated in the special exercise.

What characteristic of force should be considered the criterion of correspondence of strength: it's maximum or mean magnitude?

Depending upon external conditions man can display limit strength in two forms: in moving significant or light loads. The maximum force can be larger in the second case than in the first, however it is not necessary to select only the second exercise even if the maximum achieved corresponds to the dynamics of the special exercise. At this point it is important to proceed first of all from the duration and character of the effort. The fact is that the external force (according to its qualitative characteristics) displayed in these two cases is different: in the first, maximum force is achieved by the absolute-strength of the muscles; and by the speed of contraction in the second. Therefore, the working potential of the strength and training effects of the respective movements are also different. From this it follows that in striving for a high maximal effort in training the sportsman should accurately acquaint himself with what sort of strength he needs and realize the criteria of correspondence according to the amount of effort and be sure to take into consideration the movement time in the special exercise. In other words, correspondence with respect to the maximum and mean magnitude of strength can be determined only by calculating the speed of movement. If the sportsman finds the means for securing this possibility he can be confident that he is on the right track in the organization of the special strength-training.

The following can be ascertained from a general examination of conditions. If in the special exercise the sportsman is to overcome a large resistance, for example a load of constant magnitude moved with a relatively low speed or active resistance created in opposition, then training primarily should be oriented to developing maximal effort. If the sportsman has to deal with a small resistance in the special exercise and must execute the movement with maximal speed then as the criterion of correspondence he should apply a moderate amount of effort, taking into account the movement time.

3.3.4 The Speed of Displaying of Maximum Effort

The criterion of correspondence as regards to the speed of developing maximum effort compliments the criterion of force and is particularly important in those athletic activities requiring explosive-strength. We have already said that the strength displayed in training should be examined by taking into account the speed with which it is displayed, which is the same as the time taken to execute the movement. In this case it is of necessity oriented to a moderate amount of force which includes such characteristics as impulse force (Ft), power of work

$(N = \frac{A}{t} = \frac{FS}{t} = FV)$
and the coefficient of reactivity $(R = \frac{f}{pt})$.

These methods are more than adequate for evaluating explosive-strength although depending on conditions the significance of each of them can be different. Thus, evaluation with the impulse-force, objectively characterizing the working potential-force, is acceptable only in that instance where it is not necessary to compare different movements. If such a necessity arises then the objectivity of the given evaluation is preserved only if the time is constant. However, the latter does not correspond to the biomechanical specifics of man's movements. Therefore impulse-force as a practical measurement loses (in this concrete case) its universalness.

There is a specific tendency in the quantitative perfectioning of movement that is expressed by the constant shortening of movement time by the action of increasing muscular force. It is therefore methodologically more correct to base power of work (N) or the magnitude of dynamic overload of a working organ on unit of time (R). Such an evaluation to a large degree expresses the essence of the quantitative additions to the movement and consequently is a more objective criterion of comparison.

In those cases where the working-effort is displayed in a limited amount of time a necessary condition of the movement's effectiveness is the speed with which maximum effort is developed. In other words, if it is necessary for the sportsman to display a large force within some time limit; he should do it quickly. Such a necessity is dictated by the conditions of the activity and by the anatomical peculiarites of man's motor apparatus, especially the limited working amplitude of movement.

Thus, the speed with which the required maximum effort is developed (assessed by the gradient-force) is an important criterion of correspondence for the resolution of the task of special strength-training. This qualitative characteristic is directly connected with the specific peculiarities of the neuro-motor mechanisms of movement and requires their direct perfectioning.

It should be pointed out that the realization of the criterion of correspondence in regards to the strength and the speed with which it achieves maximum creates its own intricate problem, the successful resolution of which is primarily dependent upon the efficiency of the training process.

3.3.5 Regimes of Muscular Work

The criterion of correspondence with respect to the regime, presupposes the necessity to determine the character of muscular work in athletic activities. The regime of muscular work should be taken into consideration for the selection of the means of special strength-training. However, this criterion has great significance for determining the method of developing strength. The fact is, depending upon the character of its execution, one and the same means can resolve different tasks. For example, boxers and shot putters can execute the same exercise (say, doing a thrusting movement with the arm, against the resistance of a pulley device) with different weights, tempos, number of sets and repetitions; because one of them requires primarily quick unloaded movement and the ability to repeat it many times without decrease in quality while the other a quick movement and a specific resistance.

The selection of a regime of muscular work is difficult where a concrete motor act is concerned. However, it is even more difficult in all around sports like the decathlon in track and field, gymnastics and modern pentathlon. Therefore, the problem of selecting a regime of muscular work involves two very obvious questions: selection of the regime for a concrete motor action (for example -- the key elements in an athletic exercise) and the selection of the main regime which will best perfect all of the diverse muscular activities in training for the "all-around". The last question is still far from being answered and is apparently, foremost, although the evolution of training methods in sport indicates there is some hope that it will be correctly illuminated.

Almost one-hundred years of experience in training "all-around" track athletes indicates that the fundamental training regime is the speed-cyclic regime with dynamic tension, primarily of the explosive type. This was corroborated by isolating the key exercises in the "all-around" complex with a special statistical analysis (V. M. Zatsiorsky, 1966; R. I. Lukauskas, 1967; V. Mamdzhanyan, 1976). To corroborate this idea one should look at the preparation of gymnasts. For a long time they adhered to primarily static training and with respect to this many included dynamic elements, particularly jumping. The progress of mastery and the necessity to master such complex elements of jumping as a longitudinal rotation from 540 to 720° compelled them to appraise the worth of the cyclic work regime and reconsider in favor of the dynamic type of muscular tension.

Thus, perhaps it can be asserted that cyclic and phaso-tonic regimes, should be the most important in training for the "all-around". It is necessary to add other regimes, determined by the motor specifics of the concrete type of sport. However, this idea needs serious experimental substantiation.

In conjunction with perfectioning the motor potential in a specific regime, one should bear in mind the importance of switching from one regime to another in those exercises where this is necessary. Thus, an athlete's results in the long jump are for the most part determined by the sportsman's ability to switch from the cyclic regime of muscular work in running, to explosive-effort in the "take-off"; good gymnasts are capable of switching from dynamic-explosive-effort to isometric-tension, etc. It is true for the present, that the methodical aspect of this principle is the destiny of technical preparation in sport, however it is logical that its resolution is the goal of special strength-training.

3.3.6 Determining the Criteria of Correspondence of the Strength Means to the Special Exercise

The most common notions about the strength moving the body or its links and the character of muscular work are obtained through observations and analysis of the sportsman's movement systems, i.e., the entire complex of motor acts, united on the basis of the expediency of their interaction, which secure the resolution of motor tasks in the best way. The simplest way to do this is to cyclograph movement based on a movie camera at a constant film and shutter speed.

The movie analyzer is a sequential series of positions depicting to scale the time and spatial (the more experienced the trainer the better) organization of the motor complex, its kinematic and dynamic structure and the executional peculiarities of individual movements.

The kinematic structure characterizes the interrelationship of the movement in time and space, helps enhance the meaning of the interaction of separate movements and aids in singling out those which have the fundamental role in the resolution of motor tasks and those which contribute to its resolution. From here it is easy to take one more step to determine the means of perfectioning movement and especially the means and methods of developing strength. Naturally, knowledge of the movement will be more precise if it is based on objective quantitative characteristics which can be obtained only from special methods of movie analysis.

The ahalysis of the kinematic integrity of a motor act in order to construct a representation of its mechanims can be based on the phasic structure of the movement (according to D. D. Donskoi). The act as a whole or its elements can always be divided into separate phases in which the direction of movement, the application of force and character of muscular work are distinguished. The phases are divided between their moments (bordering positions of the links or poses of the body) and can be combined in periods according to some general (for separate phases) characteristics. The interrelationship between separate phases enables one to get some idea of the muscular work and the act as a whole, particularly in those phases in which the meaning of the task is resolved. Such a representation will be more complete if force is simultaneously recorded along with the pictures and thus the total interaction of the person with the external objects is expressed.

As has already been stated, full reproduction of the complex and constantly changing interaction of the strengths and the corresponding quantity of their expression is not always possible in training. The necessity arises to locally influence the working muscle groups, crucial for this or any movement in the whole motor complex, which suggests that their load in training be increased. Such an influence should be based on the peculiarities of the formation and development of the biodynamic structure of the motor act. It has been established, that in the course of mastering a motor act the elements of the biodynamic structure develop in a quantitatively expressed heterochronicalness depending upon their origin and manner of interdependence. The development of some elements is determined by the direct interaction with external objects, others with the indirect interaction with these objects; therefore they have a slower rate of development. An indispensible condition for the formation and development of the biodynamic structure is the relatively harmonious development of its elements. This task can be successfully resolved only with a corresponding organized system of special strength-training.

Thus, once more this assertion must be emphasized: success in the selection of the means of special strength training is determined by knowledge of the biomechanics of the movement.

Chapter IV
Fundamentals of Modern Strength Training Methods

The correct selection of the means for the development of strength is based upon the criterion of correspondence of the special exercise (covered in the preceeding chapter), which is already a significant guarantee for successful training. However, this is only half of it. The final word in the realization of the principle of dynamic correspondence lies in the means and methods of strength development.

Unfortunately, the problem of the methods of strength development (inspite of the significant advances in science and practice) is far from being solved. The higher the curtain to this unknown region is raised the larger the horizon that is opened to researchers. Newer facts are uncovered, particularly of late, which are in conflict with established ideas they one day threaten to destroy: therefore, an enormous purposeful, and primarily, a combination of creative study and practice is necessary in order to generalize, to analyze in depth and correctly raise pertinent facts (often contradictory), to organize new research and create a strictly methodological system of information that formulates a scientific basis for methods of strength development.

4.1 The Problem of Methods

First of all we must point out a number of methodological errors that are associated with attempts to devise methods of developing muscular strength and direct one's thinking to the wrong track.

Muscular contraction is the foremost cause (in the mechanical sense of course) of any volitional movement; determining, in particular, its speed and the working-effect as a whole. However, this idea originated with the Archemedes postulate that the initial prerequisites for development of speed of movement are only possible by taking into account the muscles' ability to acquire this or that qualitative form in the display of strength.

In physics, force and speed are connected as cause and effect. The mechanical velocity moving the body is dependent upon the full impulse force, i.e., from the integral of forces

$$I = \int_{o}^{t} F(t)\,dt,$$ but not upon the detailed type of function F(t).

In other words, the equivalent final velocity equal to the ordinate $V = \frac{I}{m}$ can be obtained with any form of the function F(t) with equal squares under the force-time curve (figure 63). Nevertheless, undoubtedly man's mechanical position during movement is preserved only within a known range since the shape of the F(t) curve is determined by the characteristics of the neuro-muscular apparatus; concretely conveying to it the ability to develop the muscular force with the speed necessary for the required effect of the speed of movement. This ability is a specific acquisition of the neuro-muscular apparatus and is distinct among the means utilized in training. A lack of this in training leads to errors and costs the sportsman many years of hard and fruitless work.

The subsequent errors are caused by the first. The motor qualities of the neuro-muscular apparatus, at a high level of development, are connected by an inversely proportional dependence. It can be stated with slight exaggeration that over development of both is not required in athletics because they are not realized in isolation but are only aspects of characteristics inherent to any motor activity. Depending upon the character and the objective of the movement one of these qualities obtains a greater potential development but to a greater or lesser extent is very much like the other.

Thus, it can be said that speed-strength, strength-endurance and speed-endurance are not derivatives of strength, speed and endurance but are totally independent qualities which should be placed with the latter in a group, which require adequate and specific to them, means and methods of development (Y. V. Verkhoshansky, 1963). However, the first attempts to devise methods for developing these "new" qualities were based mainly on a logical approach which lead to a Solomonic resolution as expressed by the analytical-synthetic method: the qualities should be developed separately with the appropriate means and then they should be integrated into the special exercises.

With respect to the analytical-synthetic method, it is considered appropriate for gymnasts and weightlifters to do sprints and other track and field exercises for developing speed; and for track athletes, barbell exercises are recommended for strength. Furthermore, cross-country, swimming, cross-country skiing and other cyclic exercises are considered good for developing endurance. Although it is impossible to deny the convincingly demonstrated recommendations; they are appropriate only for the initial stages of training and it would be a serious mistake for highly-qualified athletes to utilize them.

A purely practical consequence of looking at this position is the assertion that the so-called "multi-sided" preparation in athletics should be the leading training principle. However, such an assertion can only be partly true and only for certain circumstances. The appropriateness of multi-sided preparation is based on visual observation of unidirectional functional displacements to the body without the necessary quantitative analysis of their interrelationship. However, a number of recent works indicate that unidirectional functional displacement does not mean interconditionality. This concerns the synthesis of motor qualities and the transferance of them from one movement to another and that such a phenomenon is possible to a certain degree, primarily in the initial stages of sport ontogenesis (see N. N. Yakovlev's review, 1968; N. V. Zimkin, 1965; V. M. Zatsiorsky, 1965, and others). This is not the basis to consider multi-sided preparations as the leading methodical principle of universal significance. With the growth in athletic achievements, multi-sided preparation inevitably operates in opposition to the law of gradual development (in the process of attaining sport mastery) and can be a hinderance to the body's structural-functional specialization.

The danger of still one more mistake in devising and substantiating methods of strength development should be pointed out -- the danger of an excessive passion for structural correspondence of the training means to the special exercises. A formal understanding of the principle of dynamic correspondence can unjustifiably limit the arsenal of training means; and the very misinterpretation of the idea of this principle, which consists not of literally copying the special exercise in training movements but the selection of a specific arsenal of means corresponding to the latter's most important motor characteristics; and the control of their perfectioning by creating such conditions under which they receive steady development.

4.2 General Tenets of Modern Strength-Training Methods

The problem of rationalization of the methods of strength-training inevitably leads to the necessity of classifying the means of developing muscular strength.

The basic prerequisite for classification is associated first of all with the general traits in the motor regimes of the various athletic exercises. Four-types of sports are grouped according to these traits. Physical and especially strength-training methods should be examined in the context of these groups: 1) types of sports, characterized by maximal intensity of the working effort; 2) types of sports characterized primarily by the display of endurance with optimal efforts of various intensities; 3) types of sports characterized by a high level of dexterity and movement precision; 4) types of sports characterized by a complex display of motor qualities at different (relative) levels of development (V. M. Diachkov, 1961).

This grouping of the athletic exercises determines the primary emphasis of the strength-training, which determines the appropriate methods. The necessity to develop explosive-strength, strength-endurance and strength-dexterity (V. M. Diachkov, 1961; V. V. Kuznetsov, 1970) relative or absolute-strength and strength-endruance (V. I. Chudinov, 1961) comes from this grouping. The classification can also be the basis for these tenets: the magnitude of the main load used (see V. M. Diachkov's review, 1961; V. I. Chudinov, 1961; V. M. Zatsiorsky, 1966; A. N. Vorobyev, 1971), the specific tendency to change the training weight (F. DeLorme, 1945, 1946; A. Zinovieff, 1951), and the method of combining in a complex, means for making use of the "after effect" of previous work (Y. V. Verkhoshansky, 1970), and others.

Maximal-tension, speed-strength loads and strength-endurance loads (S. P. Letunov, R. E. Motylyanskaya, 1955: M. Y. Nabatnikova, 1972; V. N. Platonov, 1974; V. M. Mikhailov, G. M. Panov, 1975) are differentiated. An outcome of the creating maximal tension (repetitively lifting a certain weight to the point of fatigue or until failure, lifting a limit weight with maximal velocity) is that three methods for developing strength can be distinguished: repetitive, maximal and dynamic effort (V. M. Zatsiorsky, 1966).

Apparently it is expeditious to systematize the methods of developing special-strength, according to the specific type of strength they develop and to divide these into four basic groups of methods which are designed to develop: absolute-strength, speed-strength, explosive-strength, reactive-ability and strength -endurance. Within each group it is possible (and necessary) to differentiate methods with respect to the type of muscular tension in the athletic exercises.

4.2.1 The Development of Absolute-Strength

Absolute-strength is the maximal tension a man can dvelop, as measured on a dynamometer or the heaviest weight that is lifted. In other words, absolute-strength is the maximal force displayed under isometric conditions or in a slow movement with a load. There are two basic methods of developing absolute-strength: the method of repetitive effort and the method of brief maximal tension.

The method of repetitive effort consists of repetitively lifting a weight the amount of which is increased in conjunction with the growth of muscular-strength. The effect this type of training produces is dependent upon the proprioceptive sensations which accompany the slow lifting of weights; the corresponding accommodative reconstruction in the body which takes place is a result of the strong excitation of the neural pathways from the cortex to the muscles and the increase in the number of motor units recruited (H. Kabat, 1947; F. Hellebrant, S. Houtz, 1956).

A variable method of repetitive effort is the "progressive resistance method". Initially, the weight which can be lifted 10 times is determined (it is designated the 10 RM, i.e., the repetition maximum*). *[According to R. Berger's data (1961) the weights corresponding to the 5 RM and the 10 RM are, for any muscles, roughly 89.8 and 78.9% of the 1-RM weights respectively.]. Training sessions consist of three sets of 10 slowly executed repetitions each. A weight which is equal to one-half the 10 RM is lifted 10 times -- for the first set; 3/4 of the 10 RM is used for the second set and the 10 RM weight is used for the third set. Progressively increasing the resistance has practical value for the development of strength and endurance (E. Faulkner, 1950; A. Lindervold, 1952; A. Montgomery, 1954).

Other modifications of the DeLorme method (D. Hoog, 1946; S. Houtz, et.al., 1946; A. Zinovieff, 1951; A. Watkins, 1952; R. McGovern, H. Luscombe, 1953; I. McQueen, 1954) are associated with decreasing the number of repetitions, increasing the amount of weight and different variations including sets and the sequence of weights in the training cycle. Thus, execution of the exercise in the reverse order is called the Oxford or Zinovieff Method (A. Zinovieff, 1951), and the 1/2 10 RM, 10 RM, 3/4 10 RM sequence is called the McCloy Method (C. McCloy, 1954). Comparison of these modifications indicates they add nothing new to the DeLorme method although the strength developed is slightly different: the DeLorme system produces a larger increase in strength than the McCloy system (154% versus 142%). However, the McCloy system increases endurance more (212.8% versus 186%) than the DeLorme system (E. Faulkner, 1950). Training first with heavy then with lighter weights provokes a larger increase (5.5%) in muscle size in comparison to first training with light then switching to heavier weights; although the statistical reliability of these differences was not corroborated (R. McMorris, E. Elkins, 1954). Training with a weight equal to 25% of the 5 RM for the first set, 50% in the second and 75% for the third (5 repetitions per set) was just as effective for increasing strength as training with the 5 RM for the first set, 125% of the 5 RM in the second and 150% in the third (E. Krusen, 1949).

A. N. Vorobyev (1971) showed that the fundamental portion of the training load of today's weightlifters is with weights of 70% (of maximum) and higher. The portion of the load devoted to lighter weights is about 10% of the entire load.

It is natural that in perfectioning the methods of developing absolute-strength, consideration is given to such questions as the number of sets with a given weight, the number of repetitions per set and the tempo of the movement. Thus, an experiment was conducted on the training effect of nine different programs with the bench press. It was discovered that three sets of six repetitions (with the 6 RM weight) was the most effective (R. Berger, 1962). This actually corroborated an earlier work by E. Keipen (1956) who demonstrated the effectiveness of three sets of 5 repetitions with a maximal weight. Later on, R. Berger (1963) studied the question as to why six repetitions per set is more effective than either 2 or 10 repetitions. He came to the conclusion that training with a heavy weight does not ensure the optimal number of repetitions necessary for increasing strength and just the reverse, training with light weights and a large number of repetitions is too weak of an irritant. A significant difference in the growth of strength was not discovered as a result of training with weights of the 2, 5 and 10 RM; training with maximal (10 RM for one set three times per week) and submaximal (90% of 10 RM twice a week and the 10 RM three times) weights as well as a difference in the effectiveness of two and three training sessions per week.

It is known that in all instances training with a rest-interval of two days between sessions is significantly more effective than a rest-interval of one day (I. G. Vasiliev, 1954).

Five training programs were compared. They were distinguished from each other primarily by the maximum weight used in one set: 1) 2/3 of the 1 RM twice a week and the 1 RM the third time; 2) 2/3 of the 1 RM twice a week and 80% of the 1 RM the third time; 3) 2/3 of the 1 RM twice a week and 90% of the 1 RM the third time; 4) the 1 RM once a week; 5) 2/3 of the 1 RM three times a week. The only program which did not produce an increase in strength was the fifth. The increases in strength from the other programs were approximately equal (R. Berger, 1965).

Thus, the following conclusions can be drawn:

1) Training with submaximal weights (2/3 and more of maximum) twice a week and with maximal weights once a week is as effective for developing strength as training with maximal weights three times per week.

2) The increase in strength resulting from training with 2/3 of the RM twice a week and with the 1 RM the third workout is due mainly to the training with the 1 RM.

3) To obtain the optimal increase in strength with three workouts per week the amount of weight per set should be between the 3 and the 10 RM.

4) Training once a week with the 1 RM for one set will increase strength significantly for up to 6-weeks.

5) Training twice a week with 3 sets of the 10 RM is as effective as training in the same manner three times a week.

6) If the 10 RM is used for one set subsequent lifts with less weight have no significance.

It should be emphasized that these conclusions were based on research with untrained or subjects who had very little training experience prior to the experiments. Significant increases in strength have been observed in novices training one and five times per week. The recuperative powers of the body deteriorate under the influence of a large number of workouts per week. Since the optimal number of training sessions per week is dependent upon the body's capacity to recuperate no recommendations whatsoever with respect to the number of sets and repetitions can be made, and no program can be ideal for everyone (R. Berger, 1962, 1963).

According to A. N. Vorobyev (1971), variation in the number of lifts from 1 to 6 is the optimum for the training of highly-qualified weightlifters. Decreasing or increasing this number has a negative affect on the development of strength.

The movement tempo of resistance exercises has great significance for the development of muscular strength (see A. N. Vorobyev, 1971). Recently it has been established that the largest increases in muscular strength are obtained by the execution of resistance movements with a moderate tempo: strength increases occur over a period of 30 training sessions; strength increases over a period of 15 sessions with other tempos. It has been established that the most effective variant is a combination of different movement tempos. Thus, the increase in strength with this type of training over a period of 10-weeks was 22.6 ± 0.6 kg; and 16.3 ± 0.5 kg for the execution of movements with a moderate tempo (S. I. Lelikov, 1975).

It is interesting that under certain conditions the amount of strength developed by the repetition method is not determined by the amount of weight lifted but the quantity of work executed. Thus, according to I. G. Vasiliev's (1954) data; after 40 training sessions of equivalent work (in kilogram-meters) with all loads (20, 40, 60, 80% of maximum strength) at a tempo of 45 lifts per minute and with different muscle groups, the results obtained were almost indistinguishable. The 80% load produced a slightly larger training-effect, but not for all of the muscle groups exercised. Similar training at a maximal tempo was less effective, the heavier the weight. A high tempo of movement was not very good for the development of strength and only with a load of 20% in some muscle groups was the increase in strength approximately the same as it was the training at a tempo of 45 lifts per minute.

Experiments with frogs as well as pedagogical observations using ergographic methods have revealed that up until the onset of fatigue, muscles execute the same number of contractions with a load of constant magnitude as in the case when the load was increased gradually to this level. And, since the larger the load the faster the onset of fatigue (and fatigue changes the influence of the training work significantly) it is expedient to shorten the period of gradual increase in the amount of weight so as to switch to the optimal loads early and work with them throughout the entire training session (S. P. Narikashvili, et. al., 1960).

If the quick display of absolute-strength is required, then the Brief-Maximal-Tension Method is given priority in training. It is distinguished from the progressive resistance method in that significant weights (85-95% of maximum, i.e., 3-5 RM) are primarily utilized and are combined with the lifting of lighter (in one training session) and larger, i.e., limit (one repetition once or twice a week) weights. However, the number of sets should be increased to more than three (R. Berger, 1962). Thus, it is recommended that weightlifters execute 5-6 exercises for 6-10 sets of 1-3 repetitions in one training session (A. S. Medvedev, A. N. Vorobyev, 1967; 1971). The brief-maximal-tension method develops the ability to concentrate neuro-muscular effort and yields a larger training-effect than the progressive resistance method for the development of absolute-strength; and associated with it, the necessity to display it quickly (V. M. Diachkov, 1961; V. I. Chudinov, 1961). It produces an increase in strength without an accompanying increase in muscle mass which is important for those sports which primarily require the development of relative-strength (V. I. Chudinov, 1961).

The brief-maximal-tension method has another important feature. Lifting limit and near-limit weights improves the sportsman's mobilization ability and leads to an increase in special work-capacity as expressed by the skill to develop a brief concentrated effort of large power.

Isometrics can be useful to develop absolute-strength which does not require "rapid display", although it has not been sufficiently established which type of training -- dynamic or static renders the quickest or steadiest increases in strength. Isometric training consisting of 2-15 tensions in one minute executed four times a week does not increase strength significantly more than lifting weights with the same frequency (N. Salter, 1955); the same can be said of 5-10 stretches and 6-second isometric tensions (T. Denison, et. al, 1961). Similar conclusions were obtained in other studies (E. Asmussen, 1949; H. Darcus, 1955; D. Rose, et. al., 1951; R. Berger, 1962). It has been shown that dynamic work executed for 3 sets of 5 or 6 repetitions is more effective than the corresponding amount isometric work (P. Rasch, L. Morehaus, 1957; R. Berger, 1962).

There has been considerable interest recently in studying the potential of the yielding regime (eccentric exercise, Ed.) with weights for the development of strength (Y. Verkhoshansky, 1961; G. P. Semyonov, V. I. Chudinov, 1963; Y. N. Ivanov, 1966; G. P. Semyonov, 1968). The first positive results in this direction were supported by specialists and served as the basis for their recommendations of yielding work for the development of strength (A. S. Medvedev, A. N. Vorobyev, 1967). However, until more reliable results are obtained the evaluation of this method's effectiveness should be guarded. The results of a three month experiment in which the effectiveness of overcoming, yielding and static work were compared showed that the largest increase in squating with limit weights was obtained with yielding work (average 15 kg), and the smallest was obtained with static tension (9.2 kg). The largest increase in static-strength (as it would be expected) was obtained with static tension (30.2 kg), and the smallest increase was obtained with overcoming work (14.6 kg). An increase in the vertical jump was obtained only with the overcoming regime (3.7 cm). The vertical jump heights decreased by: 1.6 cm for the yielding regime and by 5.4 cm for static tension (Y. N. Ivanov, 1966). Thus, the data presented is not so much indicative of the effectiveness of yielding work as it is a rather vivid corroboration of the hypothesis of the neuro-motor specificity of strength; which stipulates the method of its development.

So, significant increases in absolute-strength can be obtained to an equal measure by the repetitive effort and brief-maximal-tension methods as well as with isometric tension. However, the strength acquired from each of these methods has its own "coloring" (specificity, Ed. note).

The repetitive effort method is appropriate in the initial stages of strength development and when strength and the speed of its display are not important. Repetitive work with moderate weights (50-60% of maximum) and a large number of repetitions produces an increase in muscle mass. Strength increases faster with large weights (90-95% of maximum) and a limited number of repetitions with an accompanying lesser increase in muscle mass. The training-effect is enhanced by increasing the amount of weight and the volume of work.

The brief-maximal-tension method increases absolute-strength without appreciably increasing muscle mass and simultaneously improves the ability to display strength relatively quickly. It is appropriate to use this method when the repetitive effort method has become ineffective for strength development and when it is necessary to increase strength quickly in a relatively short period of time with a small volume of work. The brief-maximal-tension method is effective for maintaining the achieved level of strength, general tonus of the neuro-muscular apparatus and the acquisition of sporting-form. The training-effect is enhanced by increasing the maximal weight as well as the average weight lifted per session; with some reduction in the number of sets and repetitions.

Isometric tension (by slowly increasing the effort) is good for developing absolute-strength without an accompanying increase in muscle mass and it secures the general tonus of the neuromuscular apparatus. This method can be utilized for maintaining the achieved level of strength development, is appropriate in those instances where speed of movement is not important and in the prepatory training of athletes. A rise in the training-effect is achieved primarily through maximal tension; by increasing it as muscular strength increases.

4.2.2 The Development of Speed-Strength

The notion of speed-strength is highly generalized and conditional. The strength displayed in quick movements has many qualitative nuances and it is rather difficult to make distinctions between them. With a rough differentiation, movements requiring speed-strength can be divided into two fundamental groups: 1) movements, in which speed of movement plays a fundamental role in overcoming a relatively small resistance, and 2) movements, in which the working-effect is associated with the quick development of motive effort in overcoming significant resistance. Absolute-strength is for the most part unimportant for the first type of movement, but it plays a decisive role in the working-effect of the second type of movement. In the first group one can differentiate movements associated with a fast reaction to some external signal or situation as a whole, with rapid, brief tensions and finally with frequent repetitive tension. In the second group it makes sense to divide the movements according to the type of muscular tension: explosive-isometric tension (associated with overcoming a relatively large load and of necessity the quick development of maximum force); explosive-ballistic tension (the rapid overcoming of insignificant resistance) and explosive-reactive-ballistic tension (the fundamental working-effect is generated immediately after a preliminary muscular stretch).* *[It is necessary to deal with such questions that have been unanswered concerning the development of starting-strength and the reactive-ability of muscles. Therefore it is appropriate that recommendations for this method are presented in a separate section (see 4.2.3)].

Thus, the display of speed-strength is extraordinarily diverse; it has by nature a high degree of specificity; its transference from one movement to another is relatively poor and it is developed relatively slowly. The method of perfectioning speed-strength is very specific and theoretically is far from being substantiated. The method of developing speed-strength is applicable to the types of movements mentioned and has its own peculiarities.

Practice and specially organized research indicates that the development of speed-strength is more effective the more speed loads there are in training and the lesser the time spent with slow movements (N. N. Yakovlev, et. al., 1960). Exercises with small weights, approximately 20% of maximum, is the principal method of developing speed-strength (A. V. Korobkov, 1953; I. G. Vasiliev, 1954; V. S. Gerasimov, V. N. Yakhontov, 1954; N. V. Zimkin, 1956; N. G. Agdgomelashvili, 1964; B. I. Butenko, 1967). With this method speed of movement increases with and without loads and the general increase in speed can reach 146% of the beginning level. Movements should be executed with maximal effort; the apparatus should be accelerated as soon as possible. To direct the influence to the muscule recruiting mechanism in the active state, exercises with light and heavier weights (up to 40% of maximum) should be combined (the variable method) and the load should be lifted with the emphasis on acceleration at the beginning portion of the movement. "Shock" types of exercises should also be included (see the next section) as well as exercises where isometric tension is generated quickly in the range of 60-80% of maximum. The optimal combination of the volume of exercises with small and significant weights can be expressed by this ratio 5:1. As regards to the sequence of execution of this or that exercise, the best variant is an alternation of exercises.

To develop speed-strength in acyclic movements "shock" loads or projectile types of weights should be selected based on their affect on the execution of the exercise. For example, to develop strength for the water-polo throw, better results are obtained by throwing a medicine ball weighing 2 kg than with a 4 kg ball. The increases in throwing distance were 13.6 and 8.9% respectively; throwing the 4 kg ball also had a negative influence on technique (G. Rogener, 1961). Training with a light (2 ounces) and a heavy (6.5 ounces) ball for throwing resulted in improvements for both, however the transfer of trainability was non-uniform; throwing the light ball improved the precision for throwing the heavier but the reverse did not occur (G. Egstrom, et. al., 1960). The optimal weight for javelin training, which did not disrupt technique, was 3 kg (E. N. Matveyev, 1967).

Methodical ways of developing speed-strength are an outcome of the search for specific combinations of means for the utilization of the traces phenomenon of previous work to increase the effectiveness of the subsequent work.

Results of model experiments show that the working-effect of an explosive movement, as measured by the height to which a load was tossed (figure 64), increased an average of 38-40% after executing barbell presses 3 sets of 3 repetitions with 80% of maximum (there was a rest interval of 10 minutes between the pressing and the throwing); movement time decreased, the "working path" increased, speed increased significantly, and the acceleration-force and power-output increased (table 9). Thus, the repetitive action of the same irritant leads to a more expressive reaction by the body and yields a larger effect in the development of strength and speed of movement.

Available data shows that speed of movement is enhanced to a large degree by the variable method (for example, putting the shot "fresh" from the muscular sensation obtained from putting a lighter apparatus). The differences between the mean results of isolated putting of shots of various weights are significant and statistically reliable. Lighter and heavier shots differing in weight by 250 grams are thrown with different velocities. A statistically significant difference was not discovered in the average results of alternately putting different weighted shots. However, distances close to the average were obtained only with a difference in weight of 250 grams; with a difference of 500 grams the nearness to the mean was not observed (L. S. Ivanova, 1964; L. A. Vasiliev, 1975).

Thus, the transfer of throwing speeds from a lighter to a heavier (normal weight) is apparently only possible by alternating throwing different weighted shots.

The effectiveness of the variable method of developing speed of movement was established in the training of hockey players (successively hitting a normal and heavier puck). The optimal weight of the heavier puck is between 0.6-0.8 kg. However, it is necessary to select a weight for each player individually. This

TABLE 9

Arm Movement Characteristics
for throwing a weight before and after
Tonic Work

Arm Movement Characteristics	First Effort	Second Effort	Difference (%)
Height of the Throw, M	0.440	0.610	+38.8
Movement Time (Sec.)	0.266	0.250	- 6.8
Working Path (M)	0.620	0.650	+ 4.8
Average Speed of the Movement, M/Sec	2.330	2.600	+11.7
Average Acceleration Force (Kg)	5.550	7.430	+33.8
Work Power (Kg M/S)	1.310	1.930	+47.3

should be based on the sportsman's potential to hit the heavier puck (V. P. Savin, 1974).

Considering the conflict between the weight of the load and speed of movement in the development of speed-strength; possible elimination of these contradictions should be sought. In this instance such a possibility exists if the display of strength is in opposition not to the weight, but to its inertia. Unfortunately this method is still not used in practice therefore, it is difficult to give concrete recommendations. For the present this is a hypothesis; but the hopes it raises are unsupported.

This brings us to the rest interval between sets of exercises. The rest interval is determined by the level of trainability, the special-endurance to repeat maximal tensions and the intensity of the strength displayed. Model experiments show that with an optimal pause in the range of 0.5 to 1 minute the qualitative characteristics of strength can be maintained at a high level for a rather long period of time without significant changes. The possible gradual decrease of these characteristics with fatiguing, monotonous work can be eliminated with a favorable emotional state.

Speed-strength as displayed in speed-cyclic movements is characterized by repetitive tensions which are separated by relaxation phases. Depending on the special exercise the effect of speed-strength in this case, can be determined by the ability of the neuro-muscular apparatus to maintain the qualitative characteristics of strength for a long period of time at a specific work-tempo. Thus, to develop speed-strength in speed-cyclic exercises the optimal resistance, the movement-tempo and the duration of work are of great significance. There is an inversely proportional dependence between the resistance and the movement-tempo. In other words, an increase in the resistance decreases the movement-tempo and causes the rapid onset of fatigue. Therefore, the optimal combination (resistance and tempo) should be selected in each concrete case, based on the coordination structure of the special exercise. It is necessary to bear in mind that speed of movement decreases over a long period of training at a slow tempo and increases through training at the optimal speed (A. V. Korobkov, 1953; V. D. Monogarov, 1958). The ability to correctly execute the full movement cycle including the required tension and muscular relaxation should serve as a criterion. The movement-tempo should increase gradually, close to the tempo of the special exercise and even exceed it (V. M. Diachkov, 1961); and time of work should lengthen.

All that has been said concerning the development of speed-strength is related first and foremost to directing the influence to the working muscle groups outside the integrity of the special exercise. However, good results are achieved by making the execution of the special exercise as a whole, more difficult. Thus, the use of hydro-resistance in rowing, insignificant loads on the limbs of track and field athletes and gymnasts promote the development of speed-strength under conditions as close as possible to those of the special exercise. In certain cases power can be increased without additional loads. For example, when jumping from one leg to the other the dynamic characteristics of the push-off are greater than in running. Therefore, these jumps are excellent for the special strength-training of sprinters. It is only necessary to execute them correctly by: not accentuating the push-off of the body (which doesn't happen in sprinting) but the active gathering-in of the planted leg (hip flexion, Ed.). These jumps should be executed repetitively in segments from 50 to 100 meters for a time at maximum speed. The addition of small cuffs weighing from 100-150 grams on each thigh makes such exercises more effective.* *[This is based on the author's practical experience with sprinters and in particular on the preparation of U.S.S.R. Champion, B. Zubov].

Thus, in view of contemporary ideas concerning methods of developing speed-strength; exercises, primarily with small resistance (20% of maximum) and the combination of them (for acyclic exercises of brief duration) with weights up to 40% of maximum in a ratio of 5:1 are recommended. The work regimen should correspond to the special exercise (cyclic, acyclic) and take into account the initial conditions from which force is developed (with the muscles relaxed, in a state of preliminary tension or stretched).

Ways of the perfectioning methods of developing speed-strength are an outcome of the search for a specific combination of means, taking into account the positive after-effect of the preceding work on the subsequent and the utilization of exercises in which muscular force acts in opposition to the inertia of the load and not in opposition to its weight.

There should be no place for fatigue when one is trying to develop speed-strength for acyclic movements. However, fatigue is a necessary component of training for speed-strength in cyclic movements which require speed-endurance. A detailed realization of these tenets is possible only under concrete training conditions; for the present an empiricist has the final say.

4.2.3 The Development of Explosive-Strength and Reactive Ability

Before speaking about effective methods to develop explosive-strength and reactive ability we ought to examine how they are perfected with traditional speed-strength methods.

Let us assume athletes develop explosive-strength in the legs with heavy barbell-squats. In this case the athlete's muscles are working slowly with a constant tension equal to the weight of the barbell. Consequently, the muscles primarily develop isometric-strength, but it is by no means impossible for them to execute fast dynamic contractions. It should be added that in striving to increase the weight of the barbell (which is frequently considered a basic indicator of special-strength preparedness) an extraordinary and mainly unjustified load is placed on the vertebral column from squating.

However, to solve the task of speed-strength preparation athletes use smaller weights. Jumping for example, with a 60 kg barbell on the shoulders involves large dynamic-maximum-force. Therefore, we believe that exercises with heavy weights increase the strength potential of the muscles while exercises with small weights improves quickness. Nevertheless, these means are not the last word in the development of explosive-strength. Explosive-strength is a motor quality requiring specific moments and training means. The aforementioned means of strength-training do not secure to the necessary degree the perfectioning of such specific components of explosive movements as the rapid switching of muscles to the active state and the rapid switching from yielding to overcoming work. These skills and others require a specific training regime which is impossible to imitate in one resistance exercise. Indeed, striving to stimulate muscular activity with slow resistance movements, and lifting a barbell in preparation for squating or jumping with it, excludes the possibility to control the influence on the mechanisms crucial to the rapid switching of muscles to the active state. At the same time, a decrease in the resistance results in a loss of dynamic effort. This creates a vicious cycle from which there is no apparent exit.

Thus, if a sportsman develops a high level of explosive-strength, then it can be said it is due to those means "spontaneously" inherent to his training. Consequently, the problem amounts to this: single out these means and methodically organize them in order to rationalize the special strength-training.

A multi-year search in this direction lead to the development of the so-called "shock" method of developing explosive-strength and reactive ability. Basically it consists of stimulating the muscles by means of a sudden stretch preceding the active effort. Kinetic energy should be utilized for this (not weights). The kinetic energy is accumulated by means of dropping down from a certain height (see section 3.2.2). Practical application of the "shock" method to different muscle groups is illustrated in the following exercises (figure 65). The range of motion should be greater than the required coordination structure of the exercise in order to avoid injury. With the examples presented as a guideline a sportsman of any specialization requiring explosive-strength can select the necessary complex of exercises himself.

It is necessary to take into account the following for the execution of "shock" type exercises:

1- The magnitude of the "shock" load is determined by the weight and the height of its "free fall". The optimal combination is determined empirically in each concrete case, however preference should be given to a large height over a large weight.

2- The amortization segment should be minimal but still sufficient to create a "shock" tension in the muscles. Therefore, the initial posture (with respect to the joint angles) should correspond to the same position in which the working movement begins in the special-exercise.

3- The "shock" training should be preceded by a good warmup of the intensely "studied" working group of muscles.

4- The dosage of "shock" exercises should not exceed 5-8 movements (as a guideline) in one series. A more precise way of determining this is to calculate the load utilized and the athlete's level of preparedness.

In those cases where the "shock" method is used for the development of jumping power (i.e., explosive-strength and the reactive ability of the extensors of the torso and legs) one can do without additional weight and utilize only body weight for the "shock" stimulation. For example, energetically jumping upward or upward and forward after a depth-jump from some height (figure 66). The optimal depth of the jump is determined by the sportsman's preparedness and should ensure that significant dynamic force is developed without slowing the switching from yielding to overcoming work by the muscles involved. One should land with the legs almost straight, slightly tensed and on the balls of the feet in order to avoid an excessive shock. The depth of the amortization should not be significant and the subsequent take-off needs to be executed quickly with an energetic throwing up of the arms. In order to stimulate a powerful take-off it is necessary to strive with the hands or head to reach some height oriented by a ball, flag, etc.; if the take-off is executed upward or to land at some point if it is directed upward and forward. An increase in height or distance of the jump is a grahic reflection of improvement in special preparedness which always has a positive affect on the sportsman's emotional state.

Our experience with depth-jumps for the development of jumping power enables us to make the following recommendations:

1- Depth-jumps require special preliminary preparation such as a significant volume of jumping and barbell exercises. One should begin at a relatively low height and increase it gradually to the optimal. It makes sense to start out by jumping upward and forward and only after sufficient training, jump strictly upward. Good results are obtained with depth-jumps by making use of a complex of vertical jumps (figure 67). Each exercise is executed in series of 10 repetitions, with 1 to 15 minutes of rest between series. Fatigued or painful muscles as well as incompletely healed injuries are contraindications to depth jumping.

2- The optimal dosage of depth-jumps (with an energetic vertical take-off) should not exceed 4 series of 10 jumps for well conditioned athletes and 2-3 series of 5-8 jumps for lesser conditioned athletes. Easy running and relaxation exercises for a period of ten to fifteen minutes should be done between series.

3- Depth-jumps executed in the volume indicated should be done once or twice a week in training sessions devoted to special strength-training. These sessions can include (besides the jumping) localized exercises for other muscle groups and general-developmental exercises executed in a small volume. Well conditioned athletes can execute depth-jumps three times per week for 2 series of 10 jumps at the completion of technical training in the particular type of sport.

4- Depth-jumps render a strong tonic influence on the nervous system, therefore they should be executed no less than 3-4 days before a training session on technique; and sessions devoted to general-physical preparation with a small volume of work should be done following depth-jump workouts.

5- Depth-jumps have a fundamental place in the second half of the prepatory period of the yearly cycle. However, they can function as a means of maintaining the achieved level of special-strength preparedness in the competition period. During the competition period they should be included once every 10-14 days; but no later than 10 days before competition.

The training-effect of depth-jumps (for the development of explosive-strength) is exceptionally high. They have no equal in comparison to the other means of strength-training. This has been corroborated by a number of studies (V. G. Semyenov, 1971; V. V. Tatyan, 1974; I. M. Dobrovolsky, 1972; V. P. Savin, 1974; A. V. Khodykin, 1974; V. N. Deniskin, 1976) the results of which are spoken of further in a whole series of works (V. N. Papysheva,, 1967; S. G. Kharabuga, 1967; L. Y. Cheryeshneva, 1967; V. V. Kuznetsov, 1970; A. M. Burla, 1973; K. I. Makhkamdzhanov, 1973; T. N. Press, 1974, and others). The "shock" method of developing explosive-strength already occupies a firm place in athletics. Many distinguished athletes utilize it.

The "shock" method of developing explosive-strength and reactive-ability solves to a significant degree the problem of economization of training since it ensures that a high level of special conditioning is attained in the minimum amount of time. Thus, a comparative experiment revealed that a group of track and field jumpers executing primarily depth-jumps (all of them did 475 jumps) over a 12 week period (in the preparation period) showed greater improvement in reactive-ability then the group which trained with traditional methods and executed 1,472 general push-offs (squats, jumping and hopping with a barbell weighing 90-95, 70-80 and 30-40% of maximum) and lifted 93 tons!

Thus, specially organized studies and first hand practical experience are convincing evidence that the "shock" method should have a primary place in the training program for the development of explosive-strength and the reactive abilities of the neuromuscular apparatus. However, it is necessary to construct the method of developing explosive-strength as a whole by taking into account the sportsman's level of preparedness, the stage in the yearly and multi-yearly training cycle and stipulate the specific combination as well as the sequence and continuity of the means and methods used. Although it should occupy a prominent place in the training program the "shock" method should not be combined with resistance exercises like the brief-maximal-tension method in the beginning stages. In those cases where explosive-force is associated with the overcoming of large resistance preference

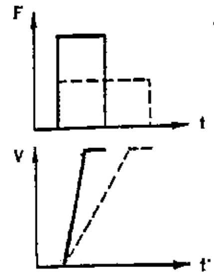


FIGURE 63- The same final speed of body movement for different forms of function.

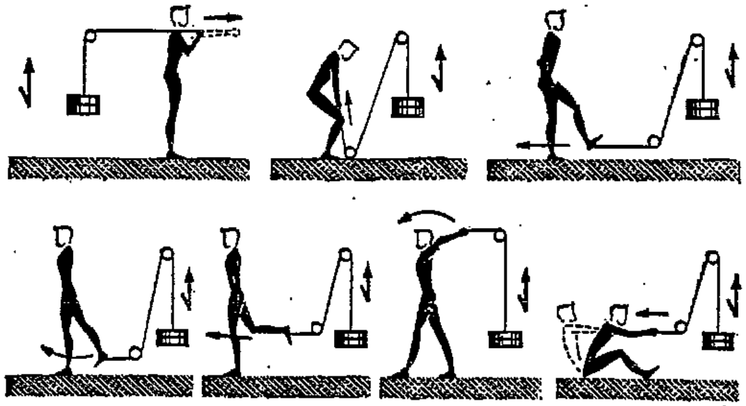


FIGURE 65- "Shock" exercises for strength development.

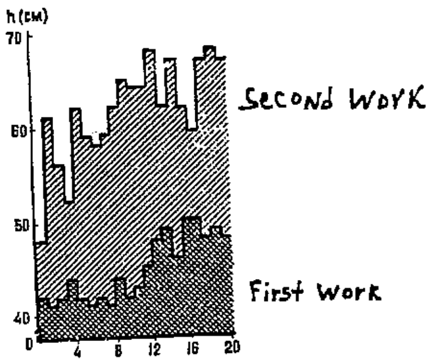


FIGURE 64- The after-effect of prior tonic work on the height (h) of a thrown object.

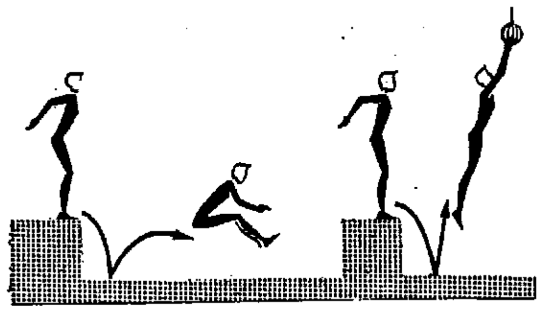


FIGURE 66- Depth-jumping.

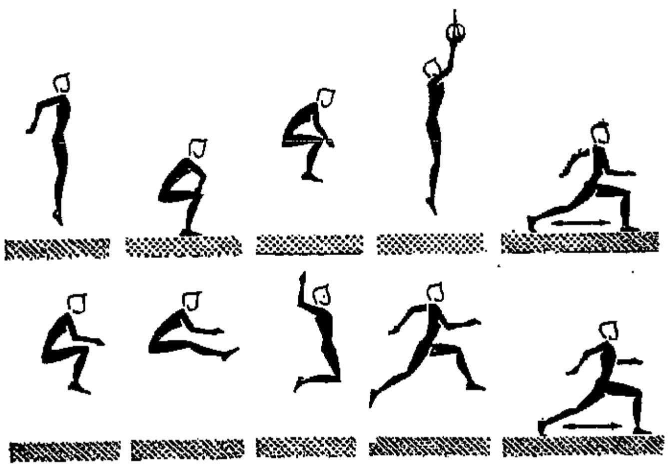


FIGURE 67- Two jumping exercises for developing reactive ability.

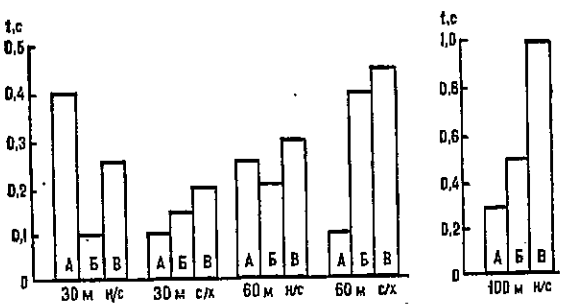


FIGURE 68- Sprint times (L/S-low start, S/S-standing start) of various distances (a-short, b-long jumping exercises, c-combined).

should be given to the brief-maximal-tension method; and in those instances where the resistance is small and the working-effect dependent upon the reactive-ability of the muscles, the "shock" method should be given preference. In subsequent stages, the "shock" method should be the main method in the training of highly qualified sportsmen for the development of explosive-strength and reactive-ability.

Means directed to affecting and perfectioning the ability to quickly develop significant effort from zero as well as to switch from yielding to overcoming work under conditions of great dynamic effort deserve a place in works on the development of explosive-strength. Thus, effective use of the overcoming regime to develop explosive-strength involves exercises with maximum effort and weights equal to 40% of maximum (or 30% of maximum with mixed regimes) (Y. V. Verkhoshansky, 1963; V. N. Papysheva, 1966). Explosive-isometric tension up to 80% of maximum should be utilized in conjunction with this.

4.2.4 The Development of Strength-Endurance

Strength-endurance involves muscular tension without a decrease in working effectiveness over a long period of time. Strength-endurance like explosive-strength has several forms depending upon the coordination structure of the athletic activity. Strength-endurance should be divided into dynamic and static endurance. Dynamic-strength-endurance is typical of exercises with repetitive and significant muscular tension at a relatively slow speed of movement as well as cyclic or acyclic exercises requiring speed-strength. In the latter case we are speaking of the specific endurance to execute special speed-strength and explosive work without a decrease in effectiveness for a relatively long period of time. Static-strength-endurance is typical of activities associated with the maintenance of limit and near-limit tension as well as the moderate tension necessary for holding a specific posture (in shooting for example or speed-skating, etc.).

The development of strength-endurance is an inherent peculiarity, and consequently, a fundamental methodical principle of training for the development of general endurance. Training for strength-endurance basically is determined by: 1) the magnitude of the load, 2) the tempo of movement, 3) the duration of the work and its coordination structure, 4) the rest interval between training sessions, 5) the length of the training period, 6) the initial levels of strength-endurance.

Repetition work with weights 25-50% of maximum at a moderate tempo (from 60 to 120 times/minute) is utilized for the development of strength-endurance. The effectiveness of strength-endurance development, utilizing equivalent weights and movement tempos, will be higher if the work is executed to absolute fatigue; although, work of shorter duration (60% of the work-capacity time) yields sufficiently good results (Y. A. Agolinsky, 1953; A. V. Korobkov, 1953; V. D. Monogarov, 1958; V. M. Diachkov, 1961 and others).

Strength-endurance, as are the other qualitative characteristics of muscular activity, is specific. However, the specificity of strength-endurance is expressed to a lesser degree than say the specificity of speed; and its carry-over from one activity to another is greater. When the fundamental activity involves repetitively overcoming significant resistance (more than 75-80% of the maximal strength), one cannot train endurance; one is limited only to the development of strength (V. M. Zatsiorsky, 1966). Isometric-endurance increased 84% as a result of exercising ten times a day for five weeks by holding a 60% maximal contraction as long as possible with the elbow flexors. Dynamic-endurance increased 93% as a result of doing arm curls with a weight of 60% at a rate of 28 repetitions per minute until it was impossible to increase the tempo. At the same time the ability to execute repetitive isometric-tension (60% of maximal strength for 5-seconds of tension and 2-seconds of rest) till failure increased by 219%. A similar experiment with 10 dynamic exercises executed daily with maximal resistance for 5 weeks resulted in increases in both dynamic and static-strength, but dynamic and static-endurance remained almost unchanged (I. Hansen, 1963). This indicates that it is necessary to determine the volume of work for the development of strength-endurance.

It has been established that an increase in strength-endurance contributes to the improvement of endurance in distance runners, skiers and skaters (Y. A. Popov, 1968; M. Y. Nabatnikova, 1972; V. V. Mikhailov, G. M. Panov, 1975). However, it ought to be emphasized that the size of the strength loads are different when on the one hand the key quality is general-endurance and on the other strength-endurance. These options nevertheless are not corroborated by subsequent research that show strength exercises (running with a sack of sand weighing 25% of the subject's bodyweight, barbell pressing, squats, bend overs and twisting with a barbell) not only do not further but to a certain degree will even hinder the development of endurance in cyclic type exercises (M. I. Maisuradze, 1960). However, it is possible in this instance that the increase in strength is associated with excessive muscle hypertrophy which is a by-product of strength training. Endurance and hypertrophy do not increase simultaneously and there is no correlation between them (G. Maison, A. Broeker, 1941; R. McMorris, E. Elkins, 1954).

The lack of a clear-cut correlation between muscular strength and muscle mass in representatives of different types of sports where the key quality is endurance, has been observed by a number of authors (A. A. Chistyakov, 1965; G. I. Chernyaev, 1965; M. Y. Nabatnikova, 1972). This concerns primarily cyclic sports (middle distance runners, skating and skiing). In other cases, with gymnasts for example, a positive linear correlation on the order of r=0.77 is noticed between strength-endurance and relative-strength (A. A. Zhalei, 1964). Therefore, in those instances where endurance is associated with the display of significant strength some muscular hypertrophy does not have a negative influence on training results.

The general methodological principles concerning the development of strength-endurance, which were discussed earlier, are carried-out differently in each concrete case, depending on the fundamental athletic activity. Thus, in the preparation-period skiers should exercise with weights that are up to 65% of maximum in combination with imitation exercises on a flat surface; lifts with up to 10-12 kg and movements on roller-skis (A. A. Chistyakov, 1965). Middle and long distance runners obtain good results from lifting a 40 kg barbell up to head level 8-10 times rhythmically, clean and jerks with various weights (40-60 kg); jumps with kettlebells (32 kg) from a squat position (18-20 repetitions) and squats with a 40 kg barbell until complete fatigue (E. F. Likachyevskaya, T. P. Kovalchuk, 1963). Exercises with weights 60-80% of maximum for multiple repetitions, jumping and hard running are also recommended (Y. A. Popov, 1966). Exercises with large (80-85% of maximum) as well as medium and small weights are recommended for developing strength-endurance in skaters. Exercises with large weights are executed for several sets at a moderate tempo for 4-12 repetitions per set until complete fatigue; with 2-4 minutes of rest between series. Exercises with small and moderate weights are executed at maximum speed for 15-25 repetitions per set, in several series with rest intervals of 5-8 minutes (V. V. Mikhailov, G. M. Panov, 1975).

Male rowers obtain good results with weights of 50-80% of maximum and female rowers with weights 30-40% of maximum (E. S. Ulrich, et. al., 1966). Significant improvement (up to 40% from initial levels) in strength-endurance has been noted in women working with small weights (18-20 kg) and many repetitions (R. S. Chumakova, 1964). Improvement is greater with these loads (by 20%) then is recorded with larger weights (35-50 kg) executed in series of 2-3 repetitions and even greater than a combination of both methods (by 8%).

It is necessary to increase the amount of weight and the number of repetitions as strength-endurance increases. The following method is recommended for skaters to develop strength-endurance in the legs: increase the number of barbell squats with 20-30 kg each week (begin with 50 squats per set and over a period of 2-3 months push this up to 200-300); then increase the amount of weight and begin a new cycle of strength-training but begin with a lesser number of squats (V. V. Mikhailov, G. M. Panov, 1975).

It is appropriate for the development of strength-endurance to always strive to execute the work under difficult conditions but with movements whose coordination and structure are close to the special exercise. For instance, a runner would carry a sack of sand or pull a sled loaded with weights (Y. A. Popov, 1966); gymnasts would use a heavy belt and vest (A. A. Zhilei, 1964); and rowers a special water-resistance device (A. K. Chuprun, 1966). Thus, in the case of the rowers, strength-endurance as measured by the number of pull-ups, the number of arm flexions in the prone position and the number of barbell presses in 30 seconds increased 57.1; 27.8; 9.1% respectively.

Thus, multiple repetition exercises with various weights should be considered the fundamental method for the development of strength-endurance. The amount of weight is determined by the dynamics inherent to the special exercise. In those instances requiring significant effort the optimal large weight should be utilized in combination with light weights or with exercises imitating the regime of the fundamental sport activity. In those instances where the special exercise is associated with the prolonged display of moderate force then it is expeditious to work with light weights in repetitive series until fatigue or failure.

Strength-training should not result in increased muscle mass in those types of sport where the key quality is endurance, with work of a moderate intensity. If strength-endurance is required, especially in those cases where it is necessary to overcome a large resistance, an insignificant increase in muscle mass is permissable.

4.3 Systematic Application of the Means of Special Strength-Training

The expeditiousness of a systematic, chiefly sequential application of the training means has been examined repeatedly in the scientific-methodical literature, however the preliminary studies on the question should be put in order. Thus, there have been attempts to reveal a rational combination of exercises for strength, speed and endurance to raise the body's general work-capacity (N. V. Zimkin, N. N. Yakovlev, A. V. Korobkov, V. M.

Zatsiorsky and others); to investigate the effectiveness of sequential (in stages) and parallel (complex) utilization of the means for the development of endurance and speed-strength (N. G. Ozolin, V. M. Diachkov, V. V. Mikhailov, M. Y. Nabatnikova, N. I. Volkov, et. al., and others); to study the affect of the sequential use of aerobic and anaerobic loads on the crucial training-effect -- the development of endurance (N. I. Volkov, et. al., S. M. Gordon, et. al.); to reveal the appropriateness of the sequential use of strength and speed-strength exercises as one of the conditions for the systematic development of explosive-strength (N. G. Ozolin, V. M. Diachkov, A. N. Vorobyev, V. P. Filin, Y. V. Verkhoshansky, and others). However, research in the area of the systematic use of means is limited and there are no really convincing, practical recommendations given.

The systematic use of the means of special strength-training signifies such a combination that in time results in a cumulative effect which is significantly greater both quantitatively and qualitatively than the separate non-sequential application of these same means. In principle, there are two possible variants for the systematic application of means -- sequential and simultaneous (complex).

The first variant involves a strictly determined, sequential introduction (in the yearly or multi-yearly cycle) of means with a higher training-effect. The logical-theoretical basis for this variant is based upon two indisputable facts: the training-effect of any means inevitably diminishes according to the degree to which the body adapts to its systematic influence; and the necessity for the constant presence of a training-effect in the complex of means utilized, as a condition for the steady rise of the organism's special work-capacity.

Besides this, experience and experimental observations indicate that the ultimate training-effect designed to develop this or that motor ability is to a significant degree determined by the factor of continuity in the sequential changing of means with different training-effects; because of which functional changes to the organism acquired as a result of the use of some means create favorable conditions for the realization of the training-effect of the other, subsequent means.

Necessary conditions for the construction of a systematic sequence of the means of special strength-training are: assessment of the quantitative and qualitative components of the training-effect and the categorization of the means in accordance with the specific level of the sportsman's preparedness. This in effect, is the subject of research, the aim of which is to establish scientifically, theoretical and methodical principles for the construction of rational systems for the sequential use of the means of special-strength training.

The second variant of systematic use of means involves the simultaneous utilization of means close to the organism's work regime but producing chiefly a different training-effect. The logical-theoretical premise for this method consists of the assumption (which has already been sufficiently corroborated experimentally) that the accommodative displacement to the organism rendered by the separate components of the complex of training work is not simply summed in the form of an additive effect, but the functional interaction secures a new qualitative state of the organism; which then has a significantly higher and "richer" work-potential than would result from the separate non-systematic use of these same means, even at an increased volume. Experimental assessment of the cumulative effects of different variations of the combination of means is necessary (and consequently the aim of research) for making use of the complex system of utilizing the special strength-training means.

A number of researchers (E. V. Purvin, A. V. Khodykin, V. N. Deniskin, V. V. Tatian, G. V. Chernousov, and others) studied the systematic use of special strength means in speed-strength sports.

It has been established that the sequence of means in the preparation period (beginning with strength then speed-strength or vice-versa) has no real significance for novice athletes. Consequently, in principle the same effect can be obtained (with equal probability) by utilizing these means in any order.

A relatively larger effect than the aforementioned variants (same volume of training load) occurred in groups who utilized strength and speed-strength means simultaneously by alternating them in "mixed" training sessions. This alternation sequence creates the optimal conditions for functional accommodative-reconstruction. This does not rule-out the fact that this work regimen, with a rest interval between sessions on the same day, secured a positive inter-influence of traces phenomena from the strength and speed-strength exercises. On the whole this provoked more intense and stabile accommodative processes. One should bear in mind that the contrasting of irritants; by alternating (in mixed workouts) means primarily of strength and speed-strength character undoubtedly has a positive influence.

In another experiment one group of novice athletes utilized barbell exercises in the first stage; then depth-jumps in the next. A second group did the same exercises in the reverse order and a third group did these same exercises simultaneously. It was established that the first variant was more effective for the development of speed-strength. The simultaneous utilization of exercises (the third variant) caused significant improvement in speed-strength in the first stage but the rate of improvement in speed-strength decreased noticeably in the second stage. This was due to the monotonous use of means. The second variant of sequential use of these same means produced significant (according to a number of parameters larger than the first and third variants) improvement after the first stage. This was due to the larger training-effect of the "shock" method. However, the acquired speed-strength qualities were the lowest at the end of the second stage.

A special experiment studied this question: will the execution of speed-strength exercises in one workout against the background of the positive after-effect rendered by previous tonic-strength work influence the effectiveness of speed-strength preparation of novice athletes? One group of sportsmen executed (in the fundamental part of their workouts) exercises in such a sequence; another group did the reverse. The pauses between exercises were increased slightly in order to keep to the minimum the affect of the positive after-effect of the preceding work on the subsequent work. A third group executed depth-jumps. The presence of this group in the experiment served two purposes: first, to study the effectiveness of the "shock" method and second to compare this effect with the results obtained with a complex of lesser effective means.

There was no statistically significant difference in speed-strength of the subjects in the first two groups. The largest increase in all the parameters of the control movement was discovered in the third group.

Thus, a rise in the training-effect of speed-strength exercises executed against the background of the positive after-effect of strength work (in the training of novice athletes) has not been corroborated. The means with a higher training-effect (depth-jumps) produced significantly larger improvement in speed-strength preparedness; achieved at a smaller volume of training work. In explaining these results one should take into account that any training influence will leave significant traces in an untrained athlete. The organism is unable to selectively react to a chiefly strength or speed-strength means (in one workout); and the length of time the traces of the training influence are maintained is apparently longer than the after-effect of prior tonic work. Within the confines of one workout, the traces of all the training influences are summed, which leads to the same effect regardless of the fact that there is a succession of these influences.

The appropriateness of utilizing a complex of means in training, which affects the positive after-effect of the preceding strength work and is used for raising the training-effect of the subsequent speed-strength and especially the speed work, should not be considered repudiated once and for all. Since the experiment was conducted on a contingent of novice athletes it is very likely that their lower level of special trainability excluded the possibility of realizing this phenomenon. A well-trained athlete can anticipate that the preceding strength will have a positive effect on the training-effect of speed-strength and speed-work, in training. However, this assumption ought to be understood only as a more precise examination of the hypothesis, the correctness of which can be conclusively established only in a specially organized experiment.

In an experiment with junior class sprinters the specific influence of short (with different variations of repeated jumps on one and two legs as well as variations of triple and quintuple standing broad jumps) and long (multiple jumps on one leg or from leg to leg over distances of 30-100 M) jumping exercises were tested as well as their systematic use. One group of sprinters executed primarily short jumps, a second group did primarily long jumping exercises and a third group did both for a period of eight months. The results of the experiment are presented in figure 68. The short jumping exercises primarily develop length and speed of the running stride. The long jumping exercises to a large degree increase maximum running speed and speed-strength endurance. The combination of short and long jumping exercises leads to a summation of their training-effect and the development of speed-strength abilities -- specific to sprinters.

Under natural training conditions, three equivalent groups of track and field athletes (jumpers of average qualification) compared the effectiveness of a sequential system of strength-training means. All of the groups utilized special jumping exercises in the first stage of the preparation period. Groups two and three switched to barbell exercises in the second stage; group-one continued to do the jumping exercises. Group-three began to utilize depth-jumps in the third stage while group-one continued to do the jumping exercises and group-two, the barbell exercises. The general tendencies are schematically represented in figure 69. It is obvious the special strength-training indicators had a clear-cut tendency to stabilize in groups one and two after the first and second stages respectively; and for group-one, to even decrease in the third stage. Thus, the sequential use of means with higher, specific training-effects has an obvious positive result. At the same time, the use of the same means even with an increase in volume not only do not render a positive displacement, but lead to a decrease in the attained level of special strength-preparedness (Y. V. Verkhoshansky, V. G. Aganin, 1970).

Research with novice and athletes of average qualification enables us to make the following conclusions about the effectiveness of the variants studied for these categories of athletes:

-- the best results are obtained from the use of those means with the optimal, high training-effect;

-- a slightly lesser, but nevertheless significant effect is obtained through the complex use of strength and speed-strength means in one training session or their sequence in mixed sessions;

-- the least effective variant is the sequence of strength and then speed-strength means or vice-versa;

It is necessary to be guided by the following principles for the sequential use of means: strength exercises should be done after speed-strength exercises in training; strong-acting "shock" methods) are done after strength exercises, but not before.

Qualified-sportsmen modeled different variants of weightlifting pre-competition training under laboratory conditions (V. N. Deniskin, 1976). A leg extension movement (the initial knee angle was 90°) lifting a limit weight was utilized as a model. The controls executed this same movement with standard loads at maximum speed. The training-effect of the "shock" method (depth-jumps) was investigated after a stage of intensive work with resistance; the task of which was to increase explosive-strength. Only depth-jumps were utilized in the second and third stages. The necessity of two such stages was dictated by the results of a preliminary investigation which showed that the rise in functional state achieved at one stage is unstable. The fourth stage was a control and consisted only of testing. They were given a complete rest between stages in order to observe the super-restoration phenomenon. Presented in figure 70 are the results of control competitions (the maximum weight lifted is represented by the dotted curves) and load (maximal dynamic force -- F max, time of its achievement -- T-max, Q and I gradients).

The experiment showed the "shock" method produced an additional, significant increase in the level of explosive-strength; attained through resistance exercises. This demonstrates the appropriateness utilizing these means in two stages: the first stage improves explosive-strength and the second -- stabilizes the attained level of special-preparedness.

There was a significant increase in all the control indicators after a period of complete rest; following the first and second stages. This is an indication that rest can be utilized (and this is not paradoxical) as a training means.

A number of researches have studied the systematic use of special strength-training under natural training conditions; with highly qualified sportsmen (E. V. Purvin, V. N. Deniskin, A. V. Khodykin). It was established that utilizing electro-myo-stimulation (EMS) first and then the "shock" method, yielded a larger training-effect than the use of these means in the reverse order. However, a significantly larger training-effect was obtained by using them simultaneously when, for example, EMS and the "shock" method are combined with heavy resistance exercises. When the training is not chiefly for strength EMS and the "shock" method were observed to have the lowest effect during periods of complete or partial rest.

In general, an appropriate and advantageous system of using the means of special strength-training can be characterized in the following way.

A Sequential System of Means

One can assume that the development of specific motor abilities from that level which is inherent to a normal functioning organism of a healthy person to a high degree of perfection (which is indicative of the sportsman's distinguished preparation) occurs with a specific regularity. Because of this regularity, there is an objective necessity for sequential perfectioning of the functioning of the systems and the physiological mechanisms crucial for the development of this or that specific motor ability. Progressive functional changes in some systems and mechanism act as favorable prerequisites for the perfectioning of other systems and mechanisms which are limiting the further development of motor abilities. It is easy to understand that the realization of the given regularity is possible only if the training process is organized so as to secure suitable conditions; the creation of the system of sequential use of means with different training-effects.

It is known that in order to steadily increase the organism's special work-capacity the means used should possess a training-effect, but its magnitude should correspond to the body's current level of special-preparedness and grow in conjunction with the latter. Despite all of the common-sense theoretical ideas embodied in this principle it is nevertheless not always practical to realize. Very often the means are selected on the spur of the moment without considering their training-effect and not infrequently, influenced by what is "fashionable" on the basis of subjective assessment. Highly-effective means are utilized inopportunely in the early stages of the yearly cycle or in the beginning stages of multi-year training. The arsenal of means is extremely limited and is repeated from year to year. This of course, is not a general tendency but a rather typical occurance indicative that even well known and (not calling into question) theoretical tenets of principal significance are voluntarily or involuntarily ignored. Hence; the necessity to construct a methodical system of sequential introduction of means with gradually greater training-effects into training becomes extremely obvious.

Specificity acquires greater significance to the athlete's state of trainability as sports mastery increases. The role of the means utilized to develop trainability grows at the same time. The introduction of the means should be well-timed and the contents of training should be prepared entirely from the preceding stages. These should be new (unexpected by the body) means occupying an utterly specific place in the system of means with a higher training-effect.

Research has dealt with changing the special training means once or twice. However, appropriate variants of the systematic use means with greater training-effects involve multiple changes. The basic scheme of the so-called conjugate-sequence method of systematic special strength-training, is examined on this page.

Complex System of Means

The complex use of means, combined by structural development of the specific motor abilities is the most progressive method of organizing special strength-training. For the most part it responds to the functional mechanism of the specific motor ability (especially in the process of perfectioning) and at the same time economizes time and energy.

In the training of highly-qualified sportsmen the necessity always arises to raise the developmental level of one of the elementary qualities of the motor apparatus which is limiting the further improvement of the specific motor abilities. A simple logical solution is the introduction of means capable of eliminating this insufficiency. However this measure, relying on a very low probability of transference of specific motor abilities, is not very effective. If a complex method is systematically and regularly used in training, then the probability that such situations will arise is minimal; and the situation will rapidly be improved.

As is known, the "contrastness" of the training influences, i.e., an alternation of means with different advantageous training-effects, within the range of some optimal segments of time is a factor which strengthens the functional receptivity of the body. This factor secures, to the fullest measure, (with the complex use of means) the special strength-training.

One should take into account some of the methodical peculiarities of the systematic construction of special strength-training which yield a sufficiently high training-effect. Therefore, it is appropriate to construct their training chiefly on the basis of a system of sequential utilization of means which should achieve the following objectives:

-- to secure favorable conditions for the systematic development of specific motor abilities;

-- to raise the effectiveness of the special strength-training by systematic (periodic) renewal of the means.

Within each stage, specifying the order and periodicity of the change of means, one should use exercises with primarily different training-effects.

It is appropriate for qualified-sportsmen (those who possess a high level of special-strength-training) to utilize (primarily) a complex system of means which should achieve the following objectives:

-- to secure the specific training-effect of the complex of means;

-- to secure the preservation of the quantitative criteria of the training-effect.

The latter should be realized by the sequential replacement of one complex combination of means with another. It should be emphasized that the long term use of one and the same means even if the volume is increased not only will not secure a rise in the sportsman's level of special preparedness but will lead to a clear decrease in the earlier achieved speed-strength and especially, strength.

4.4 Principle Aims in the Organization of the Sportsman's Special Strength-Training

In the initial stages of training the body reacts to any influence with the entire complex of the life-preservation systems and the entire spectrum of the motor potentials inherent to it. As a result of this universal reconstruction of the organism the specific components of the training influences are not displayed, such that they have a determining influence on the body's working potential. Characteristically there is a relatively high correlation between the internal aggregate of motor abilities and the development of even those of them which do not undergo direct influence. The transfer of trainability is very distinct here.

In conjunction with the growth of sport mastery, the organism's accommodative response becomes elective. Functional reconstruction is localized primarily to those organs and systems which are the most active and develops advantageously in those directions which are determined by the specific components of the training-influence. The close connection between separate motor abilities (particularly specific) has a tendency to diminish in the stage of high sport mastery. The rate of development of motor abilities which are not the object of direct influence slows; and the "transfer" phenomenon, already is not displayed as sharply as earlier. The situation arises where the direction of functional progress is determined entirely by the specific components of the training-influence. Since sport achievements at the high mastery level are secured by a complex of specific motor abilities, then the composition of the means used should contain an adequate complex of specific training-influences.

It is now appropriate and expeditious to formulate a series of methodological aims which determine the most general requirements for the organization of the special strength-training of athletes. These aims are based on the specific regularities of the training of the organism and the multi-year dynamics of the PASM; they express, in general the basic leading ideas of the trends in the realization of these regularities. They claim the role of a qualitatively new category of methodological theories of sport training; although not excluding the existing, traditional methodological principle, and its organizational rules.

4.4.1 The Aim of Converging the Partial Effects of Strength-Training Means

This aim expresses the most general requirements for the long-term aspects of organizing strength-training. It's realized by the convergence of partial training-effects, i.e., the gradual convergence of their cumulative training-effect to those important specific characteristics which are inherent to the work regime of the functioning of the organism in athletic activities.

In the initial stages of the PASM the tasks, determining all the diversity of the training means are nominally, far apart. They are connected only by inner logic based on the perspective development of the PASM; and expressed in that inter-conditioned perfectioning of the motor abilities which takes into account the peculiarities of the formation of the structure of the physical preparedness in the given type of sport. Specifically, this is expressed by the organism's adaptation to the motor regime inherent to the athletic activity, i.e., its specialization is advantageously and first of all according to ability (but not to the organ) and is unrelated to the motor form. At the same time, the functional perfectioning of the organism involves raising its functional abilities and expanding its working potential.

As PASM develops the training-effects of the means begin to converge by the specificity of their expression; and the premise determining them involves this principle: the regime in which the body is functioning during the athletic activity determines the requirements of the special strength-training and the level of special-preparedness determines the progress of the PASM as a whole.

Thus, in the high sport mastery stage the point of convergence of the emphasis of the special strength-training is on the specific character of the special exercise's motor regime and its concrete motor form; but the criterion of convergence -- is the correspondence of the effect of the training loads originating from those requirements. Reproduction of the special-exercise in training converges the specific motor characteristics for reproduction in competition: the special training means exceed this level; the general-training-means to a greater degree than earlier, reflect the specifics of the special-exercise. Now there is a close interrelationship between all components that constitute the PASM. The correspondence between each of the components is conditioned by this regularity: the growth of mastery is determined by the organism's level of special-preparedness and the sportsman's ability to effectively realize his motor potentials.

This idea is expressed in the following diagram (figure 71). In the PASM the specific characteristics of the key motor ability "B" gradually move closer to the work regime of the motor apparatus during the athletic activity "A". At the same time the complex of motor abilities securing the key motor ability (designated on the diagram a, b, c) correspond in their development, to a greater extent, to the qualitative specifics of the key motor ability.

It should be mentioned here that this idea has already been studied (Y. V. Verkhoshansky, 1963, 1972) in connection with the so-called, early-specialization. Since this question is directly connected with the beginning stages of PASM constructive consideration was given to the expeditiousness of initial specialization, not in the concrete type of sport (sport exercise), but in the specific motor regime to which the young organism gravitates. In other words, orienting the child to the sport and the motor perfectioning of the organism with the sport means, begins not in the utilitarian form of specialized training aimed at the achievement of classification norms and ranking (which is easily and imperceptibly transferred to forced training); but in the form of systematic management of the future functional perfectioning of the organism. This means that in the process physical education and competition the child's body manifests a predisposition to this or that form of athletic activity (quick reactions, speed of movement, capacity for speed-strength activities of the cyclic or acyclic type, for long duration work at a moderate intensity, for motor dexterity and others). The child begins training in a group specializing in the appropriate motor regime (first stage CSS) [child sport school, Ed.]. The goal of such training is the perfectioning of the organism's functional abilities within the limits of the given regime on a base of diverse, elementary in structure and additional motor forms; without specializing in some specific type of sport. Competitions (primarily team) are indispensible elements of such training since they consist of those same elementary motor forms. During the course of training (with a gradual increase in the requirements for the body) the teacher should determine the child's predisposition to a specific sport and transfer him to the appropriate sport school-group (second stage of CSS) where the process of specialized-training begins.

4.2.2 Outstripping the Emphasis of the Training Influences

This aim emphasizes the key role of special strength-training as a foundation for the development of the PASM and expresses the major requirement for the organization of special strength-training over a long period of time. The idea is this, the specific adaptive-displacement to the body should take-place in advance, forestalling the instant when the logical progressive development of the PASM requires its presence. From a practical standpoint, this means that the task of the functional specialization of the organism (organs and abilities) should be based on a clear-cut representation of the motor organization of the motor act: and the requirements of functional specialization are presented to the organism in the course of the PASM with a specific sequence.

Thus, realization of the main idea of outstripping the emphasis of the training influences is based on foresight of conditions forestalling the subsequent course of the PASM. This secures the steady progress of the PASM, except lagging physical preparedness.

Practical realization of the examined aims requires statistical data reflecting the basic tendencies in the dynamics of the sportsman's specific motor abilities in the given type of sport (see 1.2.3); and taking into account the peculiarities of the specific athletes' physical preparedness.

This can be illustrated with an example of a practical experiment. Novice and qualified women sprinters utilized different means of strength-training over a period of one and two years (respectively). In each contingency the subjects were divided into two equivalent groups: one (control) utilized traditional means and the other (experimental) original specialized means. The purpose of the experiment consisted of a comparative assessment of the training-effect of the two different means.

The study revealed that the experimental means were significantly more advantageous in terms of economy of the training loads (the experimental groups spent an average of 30% less time on special strength-training). The results of the experiment are presented in figure 72. The displacement in relative (F rel) and

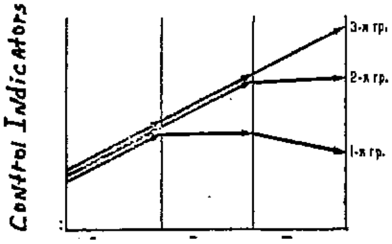


FIGURE 69- Dynamics of control indicators of the experimental group. Explained in text.

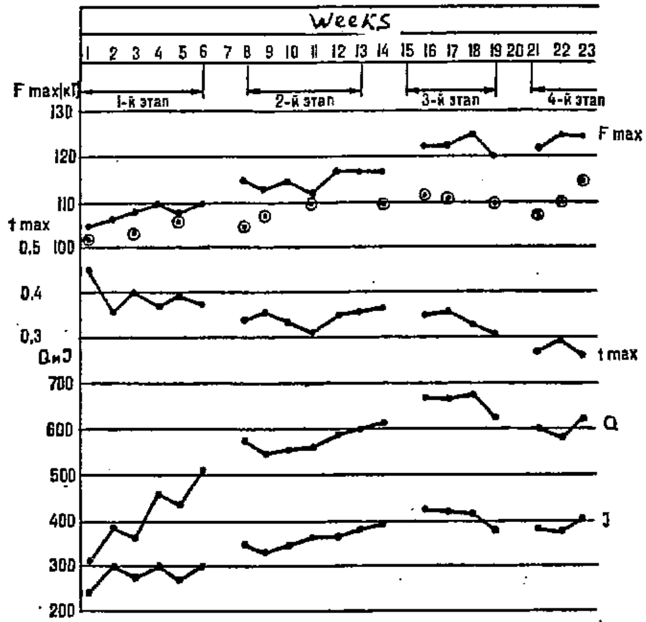


FIGURE 70- Results of an experiment explained in text.

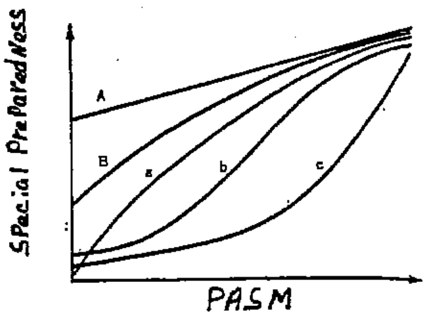


FIGURE 71- The aim to converge the partial effects of strength-training means. Explained in text.

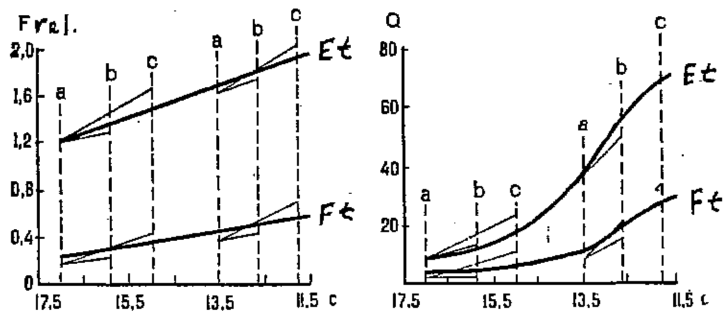


FIGURE 72- Results of experimental training of women sprinters. Explained in text.

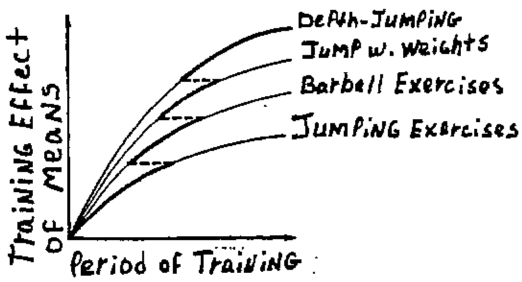


FIGURE 74- The conjugate-sequential method of organizing speed-strength loads.

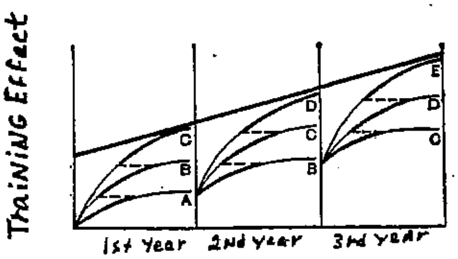


FIGURE 75- Utilization of the conjugate-sequential method of organizing speed-strength loads in multi-year training.

starting (Q) strength of the flexors (Ft) and extensors (Et) of the thigh are shown against a background revealing earlier mean statistical tendencies in the dynamics of these characteristics for the PASM of sprinters. The novices' data is depicted in the graph on the left and the data for the qualified women sprinters is on the right. The graphs also show the improvement from initial levels (a) for the experimental (c) and the control (b) groups (Y. V. Verkhoshansky, V. G. Semyenov, 1971).

Thus, the specialized means of strength-training selected by taking into account the specific movements in sprinting and the female athlete's level of preparedness secured a timely and substantial increase in relative and starting muscular strength; exceeding the average for these indices typical of the training of women-sprinters. It should also be pointed out that the original means of strength-training enabled the qualified-women to avoid the typical slow rate of increase in starting-strength.

4.4.3 Specific Correspondence of the Training-Effect

This aim points to the necessity of correspondence between the general effect of the strength work of a specific character of the motor regime inherent to the athletic activity. The aim is realized on the basis of the systematic organization of means such that the resulting (cumulative) effect secures, to the fullest extent, the formation of the structure of special strength-preparedness, logically required by the current stage of the PASM.

The practical realization of this aim should be based upon the following scheme of the functional specialization of the organism in the PASM (figure 73). Along with the body's general adaptive reaction, it selectively reacts to the predominant motor regime and movement form. This causes local, functional hypertrophy of the motor activities of the kinematic chain's motor apparatus (organ specialization) and it acquires qualities which are appropriate (according to the qualitative characteristics) to the motor specifics of the athletic exercise (specialization according to ability). Subsequently, a definitive, more precise structure of the key muscle groups and the structure of their

External Factors

Primary Motor Regime

Motor Specifics of the Sport Exercise

Form of the Movement

External Mechaical Influences

Internal Factors

Specialization according to ability

Absolute Strength

Acceleration Strength

Starting Strength

Reactive Ability

Speed of Movement

Strength Endurance

Specialization according to organ

Key muscle groups

Functional Muscle Complex

Figure 73. Principle scheme of the functional specialization of the organism in the (PASM).

functional amalgamation occurs; as well as an advantageous development of the necessary specific motor abilities.

Specific correspondence of the training-effect is based on the following tasks: opportunely secure the required level of special strength-preparedness; eliminate where necessary the appearance of hetero-chronological moments; initially suitable for the intense functional specialization of the key muscle groups, as well as liquidate the lag in strength-preparedness of separate muscle groups; intensify the development of the essential strength abilities at the stage of high sport mastery.

4.4.4 Preserving the Training-Effect of Strength-Training

Preservation of the training-effect means the load should always provoke a training-effect despite the progressive functional perfectioning of the organism. This is achieved by the systematic, timely introduction of more effective training means based on logical continuity.

The preservation of the training-effect ensures the realization of the basic condition for development of the PASM -- the uninterrupted, progressive growth in the sportsman's special work-capacity. The very achievement of a constant correspondence between the organism's special work-capacity and the steady growth of demands, produces the conditions under which the special exercises are executed.

The practical realization of this principle is associated with the sequential introduction of training means with larger training-effects, based upon the so-called conjugate-sequence method (see 4.3). The idea of this method (see figure 46) consists of this: as the training-effect of some means decrease, new more effective means are introduced which in turn are replaced by even more effective means. Naturally, for practical utilization of this method, an objective experimental assessment of the training-effect, and based upon this, categorization of the concrete complex of means are necessary. An example of the categorization of means for the development of explosive-leg-strength (jumping) in the preparation period of a jumper is presented in figure 74 (Y. V. Verkhoshansky, 1969, 1970).

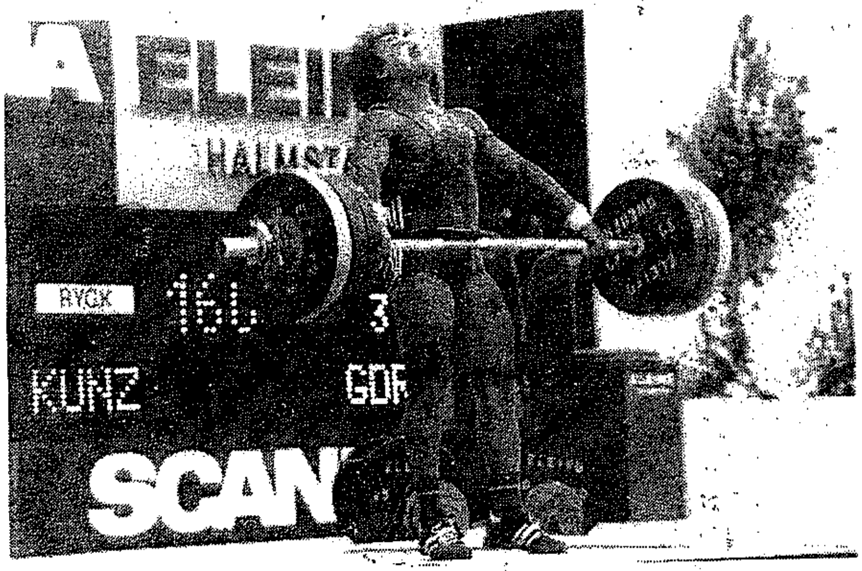
The long term use of the conjugate-sequence method involves a repetitive cyclic, reproduction of the system of sequential utilization of means; but these means are executed with increasing intensity. With this method it is possible and expeditious to renovate the complex of means (figure 75), replacing those which played a progressive role in raising the sportsman's trainability (means A and B) with newer, more effective (means D and E).

Conclusion

-- So, the contours of future systems of the sportsman's special strength-training are as if, visible.

However, there are still many vague questions. Therefore, the author is prepared to understand the displeasure of the reader who anticipated finding the answer to this question in the book: for all that, how do I develop strength? But, hopefully this reader understands the unjustness of his pretensions and the uselessness of attempts to give a prescription in each concrete case if it is represented by all of the infinite diversity of its nuances which determine the training method in its individual expressions. On a similar occasion D. I. Mendeleyev said: "To repair and even build bridges, to treat (medically) and to do other practical things, is of course possible according to prescription, by demonstration, but to find it oneself, that's the best way, i.e., the most advantageous (according to the expenditure of time, means and effort) practical pursuits happen only with a familiarity of the abstract,...the direct use of which is initially not grasped." To wit the basic idea of the book consists not so much of the attempt to answer the question of how to develop strength in each concrete case as it is to show what one needs to know in order to do this. Creative utilization in concrete conditions of those principles and ideas already formed (which have as yet not gone through hypothesis stage and were discussed in the book) will quickly lead to success. At any rate this is of greater benefit than submissively following recipes which do not live long.

It is necessary to mention yet one more task confronting the author -- to emphasize the unsettled problems in the area of strength-training and to outline, if only in general, the paths along which the reader's personnal interests and enthusiam ought to be directed. Such problems are still numerous and the resolution of any of them, even the smallest, brings us nearer to the moment when we can speak about an authentically scientific and consequently, practical, effective system of special strength-training for athletes.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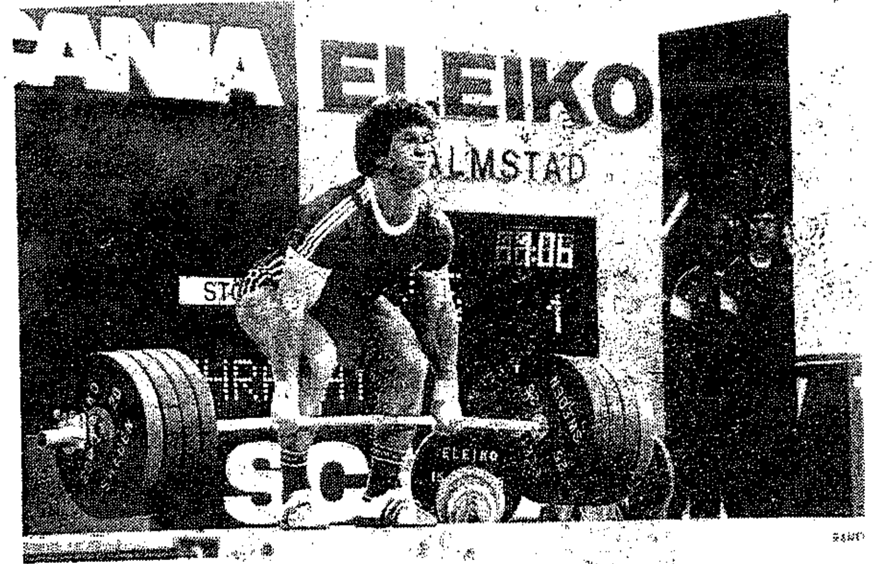
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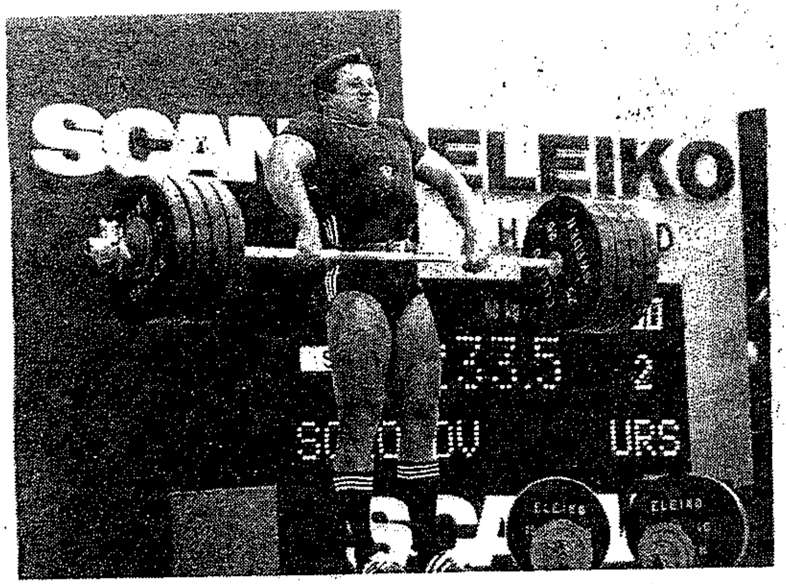
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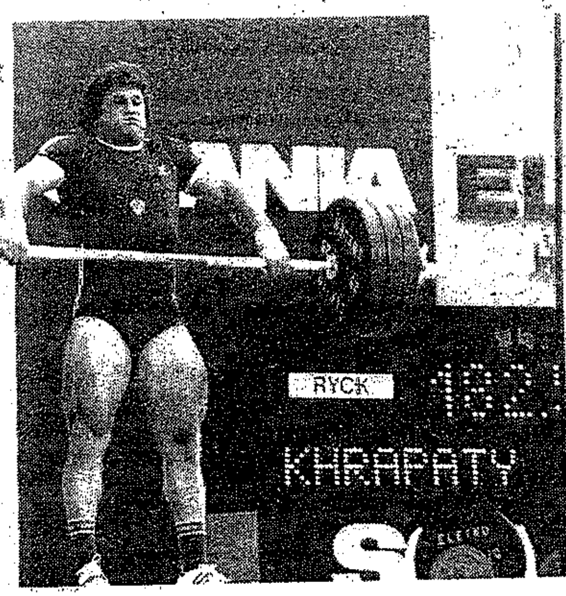
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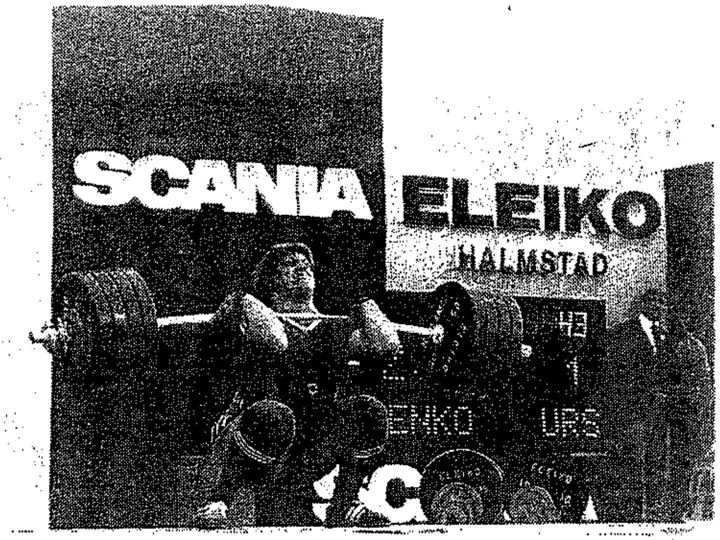
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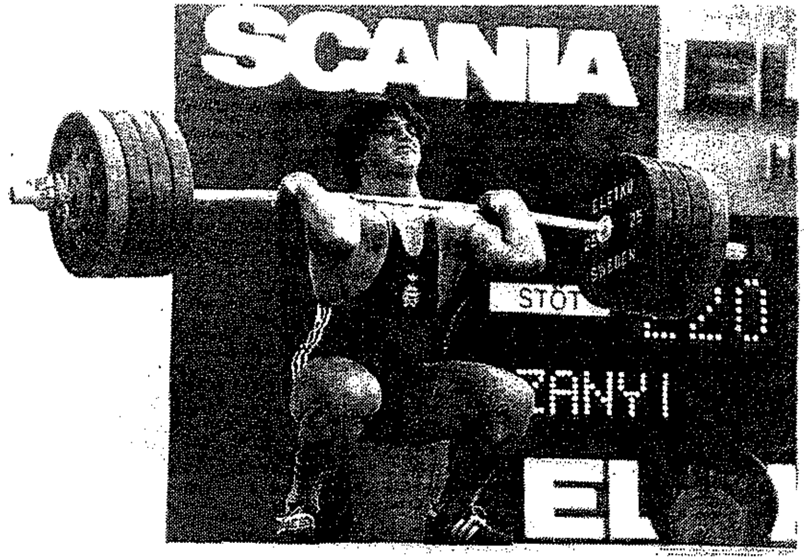
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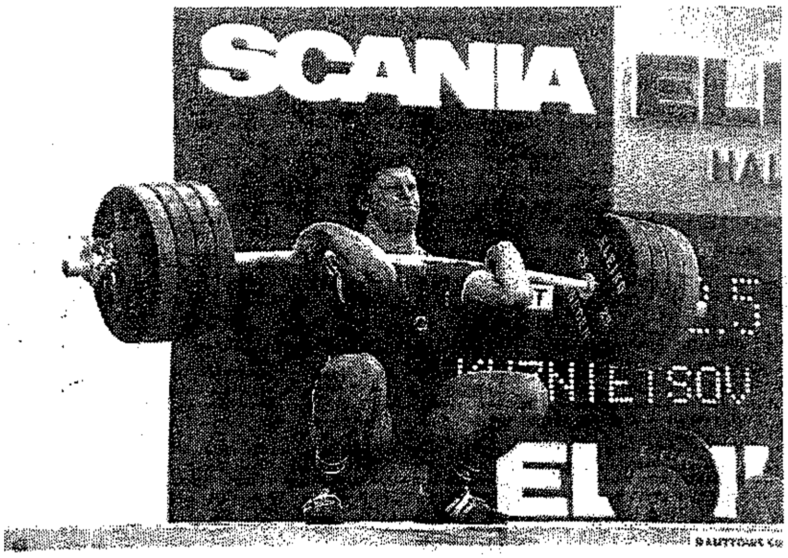
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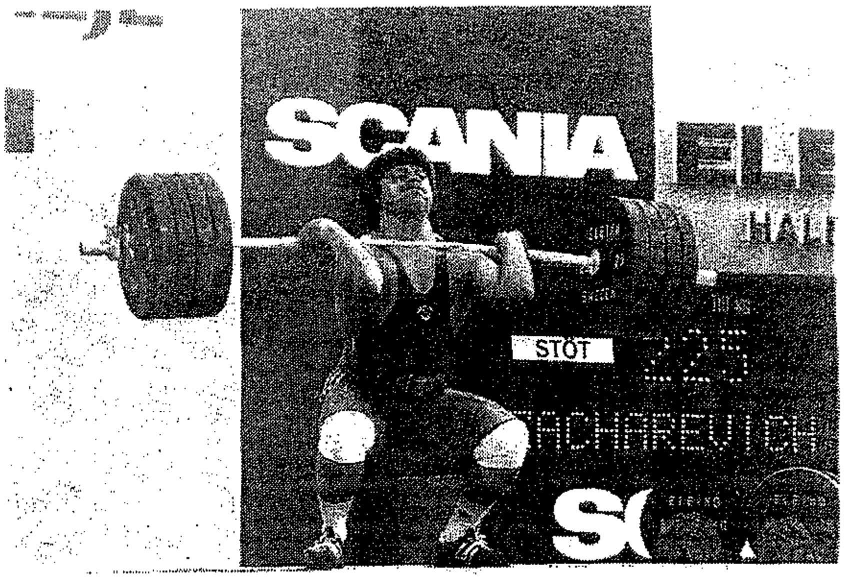
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