

Aspects of strength training in athletics

Günter Tidow

“*The first two parts of this article illustrate the strength requirements for high level athletics and explain the various aspects of strength and their respective influence on an athlete's performance. The last part deals with the use and effectiveness of a selection of strength training methods.*”

In order to cover at least the most important parts of such a complex subject, it seems useful to choose a 'three step approach' of training science:

- The first step consists of an 'analysis' of those specific requirements which confront high level sprinters, jumpers, throwers and combined event athletes.
- The second step refers to the 'diagnosis' of strength.
- The third step concentrates on 'therapy', i.e. strength training 'methods'.

1. Analysis

As any voluntary movement depends on the contraction of muscles, the different techniques in the running, jumping and throwing events are very closely related to, and even depend on, neuro-muscular activity. Generally speaking, 'speed strength' or 'power' is the main form of strength required. As far as the character of muscular tension is concerned, in the sprints speed-cyclical contractions with sub-maximal impulses prevail, whereas in the jumps explosive-reactive-ballistic and in the throws explosive-ballistic accelerations with maximal activation are needed. The term 'ballistic' implies short starting

time, maximum speed and no possibility of correcting or adjusting the movement during execution.

Important information concerning muscular activity and corresponding demands can be derived from the fact that the duration of the support phases in the sprints is limited to 80-100 ms, whereas the take-off phases in the jumps vary from 120 ms (long jump) to 240 ms (straddle). The central phases in the throwing events do not last longer than 300ms, while the releasing action of the throwing arm takes place within less than 100 ms (see Table 1). In addition, speed maxima of more than 115km/h have been measured in the javelin throw — and the term 'fastest human' speaks for itself.

These findings lead to the conclusion that the neuro-muscular system is extremely highly loaded in athletics. While the actualization time available, in which the strength impulse can work, is in no event longer than 300 ms, the size of the acceleration impulse must be as great as possible. Consequently the neuro-muscular demands for a high standard of performance in athletics can be determined as follows:

1. Maximization of impulse size per unit of time
2. Optimization of impulse duration
3. Minimization of duration of transition
 - 3.1 from eccentric to concentric functioning (sprints and jumps)
 - 3.2 from tension to relaxation (sprints)
 - 3.3 from speed-cyclical to speed-acyclical (swing elements) or

TABLE 1: Actualization times and speed maxima of world class specialists in the sprinting, jumping and throwing events of the decathlon.

The different duration of the start refers to the (rear) swinging leg (160 ms) and to the front leg. The 'F' in the high jump indicates the Fosbury Flop, the 'S' stands for the straddle. 'SF' refers to the Speed Flop, 'PF' to the Power Flop. In no event do the actualization times exceed 300 ms.

SPHERE	DISCIPLINE	DURATION (SUPPORT/ CENTRAL PHASE)	VELOCITY (RUN/ RUN-UP)	VELOCITY (TAKE-OFF/RELEASE)
RUNS	START	160/340 ms	-	-
	SPRINT	80 - 100ms	11,4 m/s	-
	HURDLESTRIDE	120ms	9 m/s	8,5 m/s
JUMPS	LONG JUMP	120 ms	11 m/s	10 m/s
	HIGH JUMP (F)	140(SF)- 190(PF)ms	7-8 m/s	5,5 m/s
	HIGH JUMP (S)	200- 240ms	6-8 m/s	5 m/s
	POLE VAULT	120ms	9,4 m/s	7-8 m/s
THROWS	SHOT PUT	270 (<100)ms	3 m/s	14,3 m/s
	DISCUS	150-300ms (<100ms)	-	26,5 m/s
	JAVELIN	300ms (<100ms)	6-8 m/s	32 m/s

explosive-reactive-ballistic muscle tension.

The analysis has shown that, in the relevant events, ballistic and sub-ballistic movements have to be executed. Thus high speed as well as maximum strength faculties could be identified as primarily performance limiting factors.

Referring to 'maximum strength' a further observation should be mentioned. Comparing the phenotype of 1988 Olympic gold medallists, e.g. Schult (GDR/Discus Throw) or Timmermann (GDR/Shot Put), with that of athletes competing in 'former times', it is obvious that the motto of combined event athletes 'As strong as necessary, as light as possible,' has been adopted — at least to a certain degree — by modern throwers. This tendency towards 'leaner and tougher' indicates that mere maximization of 'brute strength,' often accompanied by a high increase in body weight, should no longer be the main objective of strength training — even referring to the throwing events. (This statement implies what could be attainable for heptathletes and decathletes, if they succeeded in reducing their technical deficits on the one hand and improved their specific strength and flexibility levels on the other).

2. Diagnosis

Diagnosis of strength and its components nowadays has two branches. The older one is closely related to the 'field work' of coaches, applying sport motor tests. The younger one refers to scientific investigations primarily performed in laboratories.

Diagnosis is needed for at least three reasons. Firstly it informs about the conditional background of high level performances, secondly it helps coaches to assess the standard of performance reached by their athletes, thus revealing their strong and weak points, and thirdly

diagnostic results are the decisive part of a feedback system, which should accompany the training process in order to prove and control the efficiency of the methods applied. Finally, diagnosis can possibly help to solve the difficult task of talent identification.

Research work in laboratories all over the world has contributed decisively to the understanding and classification of strength and its components. Several testing instruments and implements have been developed. Before a selection of important findings is presented, it seems useful, in order to speak in the same tongue, to start out with terminology. Many authors use different words for the same thing and others apply the same terms to different things. Studying the English literature on strength, this statement is obviously not restricted to the German language alone.

The following Table 2 (on page 96) is an attempt to arrange strength parameters and terms systematically and to give brief definitions.

First in the hierarchy of strength components is 'absolute strength' covering the entire contractile potential of the muscle. Due to the autonomically protected reserve it cannot voluntarily be activated. Only by means of painful electro-stimulation or by determining the cross sectional area via computed tomography is it possible to assess its size approximately. As a substitute value the 'eccentric maximum strength' is measured. The corresponding test is executed with 150% loading relative to the isometric strength maximum. The violent and sudden extension of the isometrically pre-contracted muscles triggers off a reflex impulse that adds to the voluntarily attainable level within isometric (or concentric) working conditions.

The resulting difference in % between isometric and eccentric

TABLE 2: Parameters of strength and corresponding terms and definitions

TERM	AREA OF REFERENCE/ TESTING MEANS
ABSOLUTE STRENGTH	ENTIRE CONTRACTILE MUSCLE POTENTIAL; ELECTRO-STIMULATION/ MUSCLE CROSS-SECTION
MAXIMUM STRENGTH: -ECCENTRIC	PERSONAL BEST WITHIN YIELDING MUSCLE WORK
-ISOMETRIC	PERSONAL BEST WITHIN SUSTAINED MUSCLE WORK
-CONCENTRIC	PERSONAL BEST WITHIN OVERCOMING MUSCLE WORK
STRENGTH DEFICIT	%-DIFFERENCE BETWEEN ECCENTRIC AND ISOMETRIC MAXIMUM STRENGTH
VOLUNTARY ACTIVATION CAPACITY	THRESHOLD VALUE OF MOBILISATION
SPEED STRENGTH	$\frac{\text{STRENGTH MAXIMUM}}{\text{TIME REQUIRED}}$ $\left(\frac{F \text{ MAX.}}{T \text{ MAX.}} \right)$
EXPLOSIVE STRENGTH	MAXIMUM RATE OF STRENGTH INCREASE PER TIME
STARTING STRENGTH	STRENGTH FIGURE ACHIEVED 30MS AFTER START
RELATIVE DYN. STRENGTH MAXIMUM	PEAK OF STRENGTH ATTAINED WITH VARYING SIZE OF LOAD RELATED TO ISOMETRIC STRENGTH
REACTIVE STRENGTH CAPACITY	ABILITY TO SWITCH FROM ECCENTRIC TO CONCENTRIC CONTRACTION PER TIME

maximum strength indicates the 'strength deficit' on the one hand and informs about the 'voluntary activation capacity' on the other. The latter term refers to the threshold value of mobilization. An example may be helpful to elucidate this diagnostic area. Assuming an athlete has a strength deficit of 15%, i.e. his isometric strength maximum was 85% of his eccentric maximum, so this value of 85% directly can be interpreted as his actual mobilization threshold. Whereas top level athletes have a strength deficit of only 5%, other subjects show much larger deficits (up to 45%). It goes without saying that such findings are of great importance for the correct selection of strength training targets.

A small strength deficit implies a highly developed activation capacity and consequently only small 'reserves' are left. Thus hypertrophy must be the target for this athlete. On the other hand big deficits recommend steps be taken to improve one's neuronal activation

capacity by means of the maximum strength method.

The remaining terms on Table 2 such as 'speed strength', 'explosive strength' or 'starting strength' shall be explained by means of the following graphs called 'force time curves'. Up to now these curves have been available under laboratory conditions only. Extensometers and electronic time keeping instruments make it possible to register the increase of strength per unit of time. This applies to isometric as well as dynamic contractions. The secret behind such a testing apparatus is the integration of presso-receptors in the bar or implement, which the subject has the task to accelerate or to press against with all his will. The exerted pressure changes the inner 'tension' of the receptor — and these changes per time are documented.

Comparison of the graph curves of different subjects shows that the so called 'strength gradient', i.e. the rate of increase per unit of time, varies greatly.

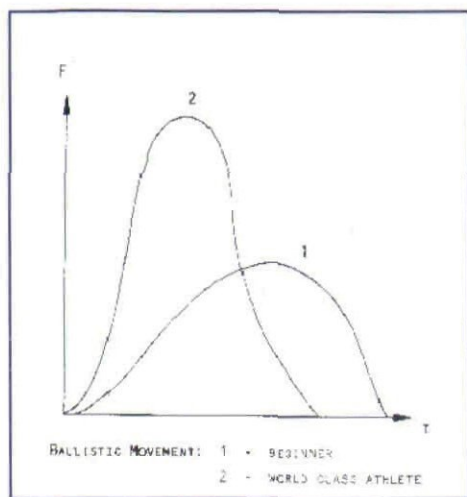


FIGURE 1: Force time curves registered while performing a ballistic movement. Curve 1 symbolizes beginners, curve 2 top athletes. 'F' stands for Force, 'T' for time. Beginners need much longer time to perform explosive accelerations and actualize far smaller peak values. (Figure modified. from Werschoshanskij 1975)

Figure 1 demonstrates the idealized force time curves for a ballistic movement performed by a beginner (curve 1) and by a world class athlete (curve 2; see Figure 1).

Whereas the beginner needed much longer time to reach his peak value, the highly trained athlete achieved his maximum within half the time and realized a far higher value. Consequently curve 2 symbolises the set of characteristics which are primarily needed in athletics.

The question in which way different loadings and different working conditions exert influence on the increase of strength is answered in Figure 2.

Measurements were made while the subject made maximum use of strength in each of the following four cases. (1) When pressing against an immovable resistance (isometric maximum strength) (2) With the sledge he had to accelerate loaded with 50%, (3) 20% and (4) 7% of his maximum strength - in these

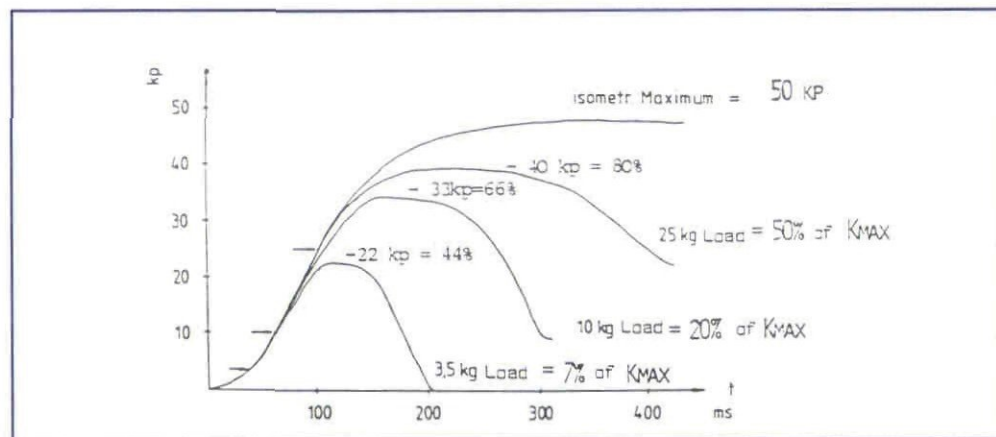


FIGURE 2: Graph curves showing strength increase and relative strength maxima for different loads (from below: 3.5 kg; 10 kg; 25 kg). Horizontal arrows indicate transition from isometric to concentric muscle work. The upper curve represents isometric testing conditions. The other three graphs were registered under dynamic working conditions. The subject's task was to press against the testing sledge to accelerate it with maximal force. Independent from the amount of the load or the differing working conditions the initial part of the curves is identical. (Figure modified from BÜHRLE et al. 1983)

three cases under dynamic working conditions. Comparing the four graphs it is striking that, independent of the load and the character of muscular work, their initial part is identical! This means that even explosive-ballistic muscular tension does not change the strength gradient. In contrast, the curve 'produced' with the 3.5 kg load declines before the steepest rise is reached.

Further information can be derived from the fact that the peak of dynamic force is very different, depending on the size of the load and on the course of the curve's initial part. Thus the subject in Fig. 2 attained 44% of his isometric strength maximum with 3.5 kg loading, 66% when the load was increased to 10 kg and finally 80%, when the resistance equalled 50% of his personal best, i.e. 25 kg. The corresponding parameter is named 'relative dynamic strength maximum'. It indicates that, in athletics

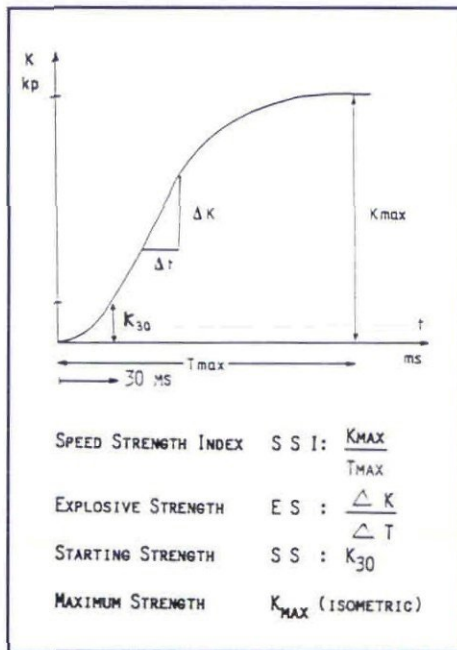


FIGURE 3: Parameters of strength, demonstrated by the force-time-curve. (Figure modified from BÜHRLE 1985)

with comparatively slight resistances, the faculty to accelerate 'right from the start' in order to attain the highest possible relative dynamic strength maximum is of decisive importance.

Further dimensions of strength are demonstrated in Figure 3. The peak of the graph indicates the isometric or dynamic strength maximum. These parameters are in reality very closely related, because the transition from the dynamic, i.e. overcoming, to the static, i.e. sustaining, type of muscular work is almost fluid — similar to the question, in which category the impulse for moving the hand of a clock indicating the hours belongs. If the strength maximum is related to the time taken to reach the peak, the 'speed strength index' or synonymously the 'power index' can be calculated.

The strength value realized 30 ms after beginning the contraction is called 'starting strength'. Thus starting strength is defined as the ability to develop the greatest possible impulse at the beginning of the action. 'Explosive strength' is defined as the faculty of the muscular system to continue the increase of strength at maximum rapidity. The corresponding parameter can be calculated referring to the steepest gradient of the curve. Mostly it is that part of the graph that runs approximately in a straight line. Thus starting strength as well as explosive strength are components of speed strength which determine the initial part of the force time curve.

They are — as has already been pointed out — independent of the size of resistance and 'produce' directly the above mentioned relative dynamic strength maximum, that is the amount of momentum that can be imparted to relatively small loads such as shots, javelins or discs.

It seems remarkable that starting strength and explosive strength appear

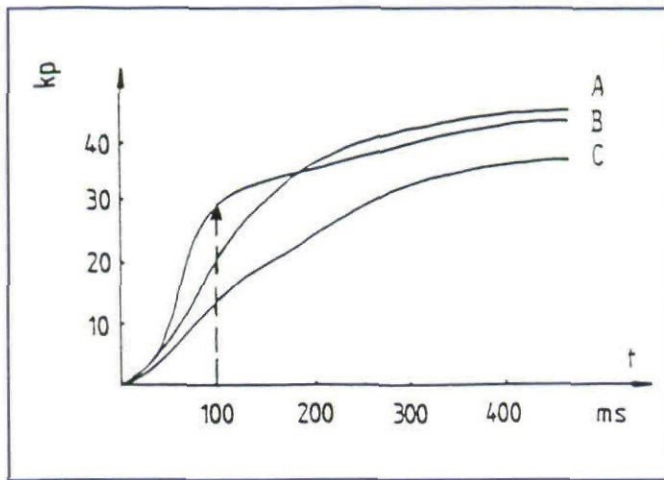


FIGURE 4: Graph curves of strength increase for subjects A, B, C. The vertical arrow indicates the strength impulse realized after 100 ms. A is stronger than B, but after 100 ms — the duration of the sprint support phase — B actualized a far higher value. (Figure modified from BÜHRLE et al. 1983)

not to be very closely correlated. Similarly, no close relationship can be proved between the steepness of rise and the isometric strength maximum. The correlation coefficient is 0.5 to 0.6. This finding can be illustrated by the following example (see Figure 4).

The inter-individual comparison shows force time curves of three subjects (A,B,C) in an isometric maximum strength test. Whereas subjects A and B stand quite close in respect of strength maximum, the strength peak realized at 100 ms — marked by the vertical arrow — shows surprising differences. Here B can claim a clear lead, which gives him an unbeatable advantage in the execution of a movement that is limited in time — for example in the support phase of the sprint, which lasts about 100 ms.

As to the question whether these differences in neuro-muscular faculties are unalterably fixed or trainable, results of recent research prove that both starting strength as well as explosive strength can be increased — at least to a certain extent — by applying suitable training methods. These methods have to take into consideration, that — as far as we know today — probably the following

factors determine both starting and explosive strength:

1. Build-up of (high) impulse frequency/time
2. Synchronization capacity (intramuscular coordination)
3. Contractility of activated fibres
4. Strength of contraction = cross section of activated fibres.

These findings/assumptions indicate clearly, that the quality of the motor units and of the corresponding muscle fibres activated by them, is of decisive importance for high level performances in the sprints, jumps and throws. It is probably known to everyone that samples of muscle tissue taken by biopsy showed that within one and the same muscle there are various types of fibres.

The human skeletal muscle consists of at least four different types of fibres. Slowly contracting, fatigue-resistant Type I fibres and fast contracting, rather rapidly fatiguing Type IIc/IIa/IIb fibres can be identified.

Figure 5 (page 100) is an attempt to demonstrate important differences between myosin filaments and criteria for fibre-typing. It is shown, that each myosin molecule (as the key protein of

FIBRE TYPE	I	IIC	IIA	IIB
MYOSIN	SLOW (S,S)	FAST (F,F)		
FREQUENCY	~ 10/s	~ 25/s	~ 40/s	> 55/s
HEAVY CHAINS (HC)	S	S + F _A	F _A	F _B
LIGHT CHAINS (LC)	s1+s2 (F1) (F1+F2) (F1+F2+F3)	s1+s2 F1+F2+F3	F1+F2+F3	F1+F2+F3

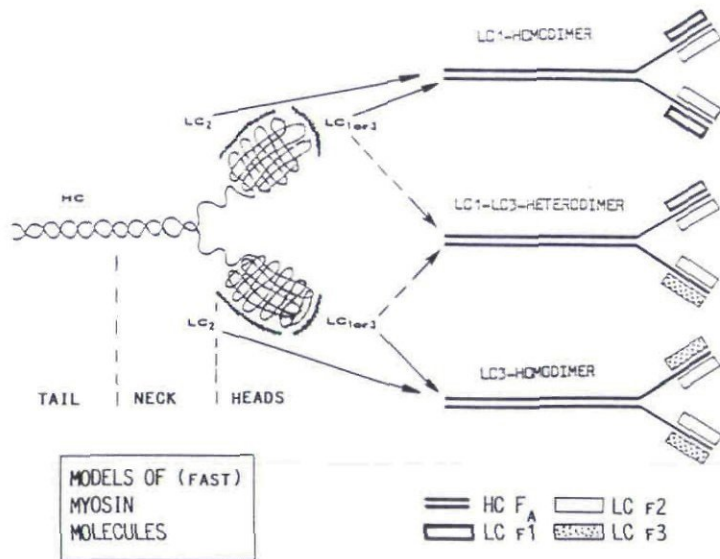


FIGURE 5: Myosin heavy and light chain pattern in the four fibre types (above) and models of myosin molecules (below, left) with corresponding subtypes (below, right). Whereas Type I fibres consist of 2 'slow' heavy chains ('HC') and a variable number of 2 slow ('LC s1'/LC s2') and additionally up to 3 fast light chains ('LC' f1/f2/f3), the type II A and II B fibres possess 2 fast heavy chains ('F A' or 'F B') and 3 fast light chains ('LC1' = 'f1'; 'LC2' = 'f2'; 'LC3' = 'f3'). The intermediate II C fibre is formed by slow and fast heavy and light chains. The arrows indicate the direction of transformation. The heavy chains form the tail and the neck region of the molecule, whereas 4 light chains are noncovalently bound in the head regions (below, left and right). (Figure modified from HOWALD 1982 and RAPP, WEICKER 1982)

muscle contraction) consists of fast or slow heavy and light chains. The 'f' stands for 'fast', the 's' for slow. The arrows drawn between the types indicate that training induced transitions are restricted to the immediate neighbourhood. Thus only the so called intermediate Type IIc-Fibre can adjust its contractile and metabolic properties completely to the prevailing demands of every day life and especially of training.

The models of myosin molecules in Figure 5 are integrated to give an idea of the structure and the position of the above mentioned heavy and light chains.

Though transformation, or more exactly transition, is mainly restricted to the neighbouring 'sub-types', adaptability should not be underrated, because the four light chains forming the

head regions of the myosin molecule show remarkable plasticity (see Figure 5; models of myosin molecules). Apart from this the metabolic capacity of all fibres seems to be much more trainable than assumed some years ago.

The most important factor which determines the fibre type distribution pattern is the frequency of impulses. Only high frequencies activate fast twitch fibres. Thus the ability of particular brain centres or motor areas of the brain to 'produce' the highest possible frequencies in the shortest possible time and to send them via rapidly conducting paths to the muscles seems to be decisive for a high potential of speed strength and its components.

As for training practice, this implies that the fast contracting phasic, and even the ballistic sub-system of motor units,

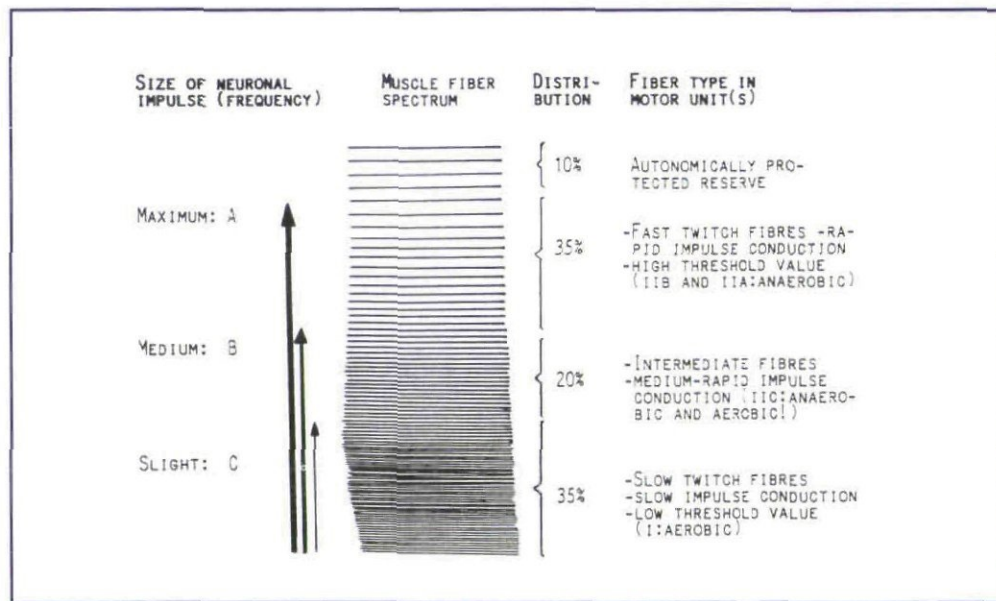


FIGURE 6: Explanatory model for the 'Size principle of recruitment'. Depending upon impulse frequency, the different fibre types (and related motor units) are activated in a hierarchical order from below to above. Low impulse rates lead to the contraction of Type I fibres (C), medium rates integrate Type IIc units (C + B) and the highest frequencies activate the fast twitch fibres (C + B + A). The given distribution is arbitrary. Whereas some authors refer to intermediate fibres as 'very important', others assume that human skeletal muscles consists of only 5% IIc fibres.

can only be stimulated by maximal or at least sub-maximal intensities, since according to the 'size principle of recruitment' only then can the entire capacity of these units be integrated completely within a given movement (see Figure 6).

Figure 6 can be used as a model for explaining the variable and increasing mobilization of the different motor units. Depending upon the alteration of the quality of neuronal impulses, i.e. frequency, more and more units are activated. Low frequencies bring about the contraction of slower and smaller bundles of muscle fibres of Type I, medium frequencies integrate the intermediate fibres of Type IIC (including bigger ones of Type I), while higher and the finally highest impulse frequencies activate the biggest motor units with fast twitch fibres of the types IIA and type IIB.

Whether the activation of 'slow' and 'fast' motor units follows a strictly hierarchical system, absolutely independent of the size of resistance, is not yet clear. At least there is no doubt that, within movements of moderate and medium speed against medium or high resistance, the motor units act intramuscularly synergically up to isometric maximum strength tests, where probably all fibres, which can be activated voluntarily, contribute to the sustaining muscle work.

Probably the size principle of recruitment applies to any kind of contraction, but due to the slower contractility of Type I fibres, as well as to slower conduction of 'their' neuronal impulses, they are at least to a certain degree 'overtaken' by their fast neighbours, when ballistic and explosive muscle contractions are required.

In order to prevent misunderstanding it must be clearly pointed out that all motor units, that can be mobilized voluntarily, contribute to

phasic contractions if the resistance is higher than 50-60%. The main difference is that under these circumstances only the smaller and medium sized units work at highest frequencies, whereas the bigger ones are just activated beyond their thresholds and contract comparatively slowly. By modulation of the frequency the neuro-muscular system can, in addition to the recruitment principle, adjust its performance capacity to a great extent.

Most of the findings summarized here depend on expensive equipment and admission to laboratory investigations. Thus the question might arise, whether there are cheaper and less sophisticated tests at hand to provide coaches with corresponding information.

The answer is that at least some sport motor tests and the resulting so called 'model items' can help to assess the standard of performance 'your' athlete has attained.

The Soviets, especially, have published such model conceptions of the conditional preparation of high level athletes. Table 3 is an example of this kind and informs about maximum strength and the jumping, sprinting and specific throwing capacities of world class men and women discus throwers. The 'items' function in a way as 'set-values' and, to a certain extent, permit weak points to be detected when comparing one's own athletes' performances with them.

Finally a test will be introduced to assess the explosive strength and the fibre type distribution of shot putters. The only difference from a 'normal' bench press station is that two photo cells are installed, thus enabling the tester to measure the velocity of the bar (see Figure 7).

The loading varies from 15 kg, i.e. double shot weight, to 30, 40, 50 or 60% of the personal best in bench press. The

TABLE 3: Model items for discus throwers. (From TSCHIENE 1988)

Elements	Items	
	MEN	WOMEN
THROWS		
With shot 7,25/4kg backward	22 - 23m	21 - 22m
With discus 2,5kg	54-56m	
With discus 1,5kg	76 - 78m	55 - 56m
With discus 0,75kg		78 - 80m
SPRINT		
30 meters flying start	3,1 sec	3,4 - 3,5 sec
JUMPS		
Standing long jump	3,40 - 3,50m	2,80 - 2,90m
Standing triple jump	10,30 - 10,40m	8,40 - 8,50m
High jump/Sargent test	95 - 105cm	85 - 90cm
WEIGHTS		
Cleans kg	180kg	
Squats kg	250 - 260kg	170 - 180kg
Bench press kg	220 - 230kg	140 - 150kg

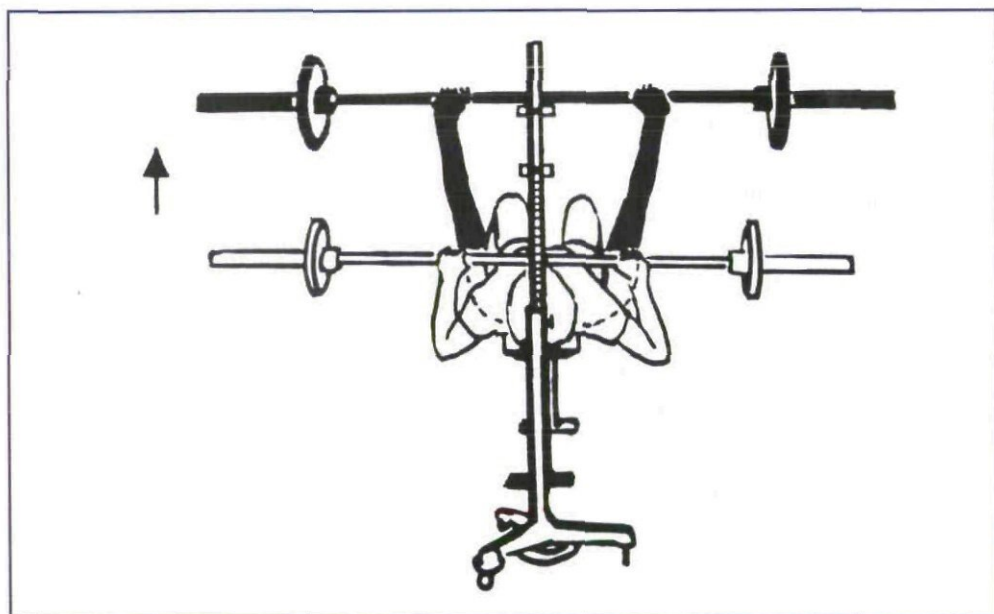


FIGURE 7: Bench Press Test. Starting (white) and final position of the bar bell crossing two beams from photo cells fixed on the upright behind the subject. The arrow indicates the vertical direction of acceleration. Loading varies from 15kg (double shot weight) up to 30, 40, 50 and 60% of personal best in bench press.

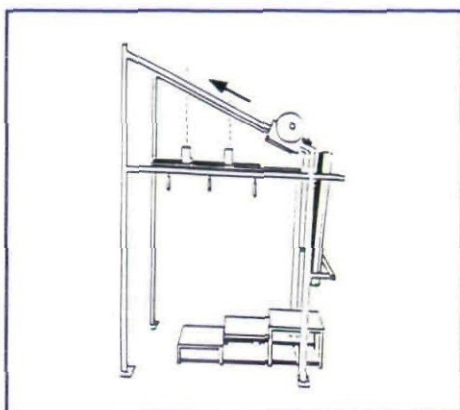


FIGURE 8

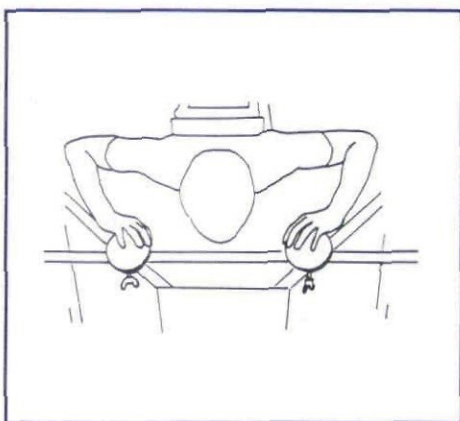
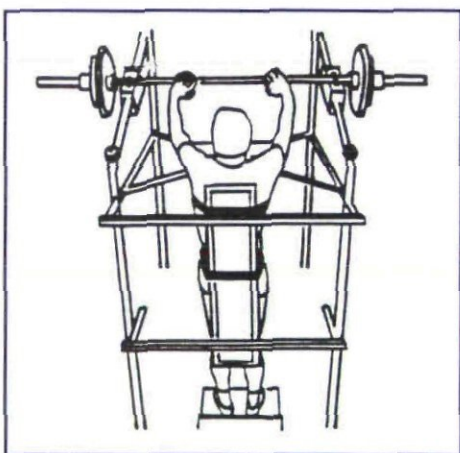


FIGURE 9.1



104 FIGURE 9.2

FIGURE 8: View from the side: The modified Roth'sches Schubgerät as a testing apparatus. The arrow indicates the direction the sledge (with the barbell) is pushed. The dotted lines indicate the 'beams' of the photo cells crossed by the bar. By means of steps (and boards) the starting position (standing) can be standardised.

FIGURE 9.1: Explosive strength test: Starting position with fingers contacting the shots adjusted to the subject's shoulder width.

FIGURE 9.2 Final position (elbow joints extended) of the maximum strength test using the modified Press Apparatus. In order to guarantee best performance and to prevent wrist joint injuries the position of the hands must be slightly different here.

task is to accelerate the barbell as fast as possible by jerking or pushing it vertically upward. On its way upward the bar crosses the beam of the 1st photo cell, which starts the electronic stop watch, and 25 cm higher it crosses the second beam, which stops the watch. The same procedure can be executed standing similar to the putting position in a modified press apparatus (see Figures 8, 9.1 and 9.2).

The results obtained are remarkable in that the assertion, or even belief 'the stronger the faster' could not be testified. If it were true that the stronger one is the faster one, two athletes of the same maximum strength must possess the same speed. In many cases this is definitely not true, due to the varying fibre type distribution.

Whereas body-builders and throwers, with the 'throughout-the-year-target' of hypertrophy, attained poor results — although their personal best in bench press was impressive — explosively trained athletes demonstrated excellent velocities. To

quote an extreme finding: One athlete with a personal best of 100 kg accelerated the 15 kg barbell faster than one with a personal best of 150 kg!

The correlation coefficient between the duration times achieved with 30% of the personal best and the corresponding load was positive ($r = .31$ to $.51$ within different collectives)! This implies that those possessing higher strength maxima tend to be slower.

The interpretation of these findings leads to the fact that 'pure' strength maximization, without paying due regard to the specific demands of the target discipline, might often be the wrong way. The resulting increase of strength can probably be very often traced back to hypertrophy of comparatively 'slow' muscle fibres. In addition to that, even within the fast twitch fibres, an adaptation towards slower contraction times can be provoked.

Finally explosive strength tests with 30%-60% loadings 'mirror' the above mentioned 'lab-diagnosis' of relative dynamic maximum strength. The respective results can be very closely related to the initial part of the force time curve, i.e. to starting and explosive strength.

3. Therapy - strength training methods

Taking into consideration the results of the analysis of the profile of demands and based on the findings of the diagnosis of strength classifications, the third and decisive step can finally be undertaken. It is generally accepted that strength training can be structured, according to the respective targets, in the following three 'sub-divisions':

1. *General Strength Training*
2. *Multiple Objective Strength Training*
3. *Special Strength Training*

In the 'orthodox' or classical approach of the Soviet scientists Matveyev and Verschoshanskiy the

athlete starts, at the beginning of the preparatory period, with general strength training. The objective is here to increase the cross-sectional area of 'all' muscles without taking into consideration the specific demands of the target discipline. Thus a basis is attained for the second phase with its higher intensities and more specific loadings. In this second phase exercises are selected, paying due regard to the target discipline by including the antagonists of the main muscle groups, in order to avoid 'imbalances'. Leaving this phase of the preparatory period and approaching the competition period specific strength training finally takes over. Its main characteristics are that all specific exercises must possess a close structural as well as dynamic-kinematic relationship to the target discipline.

This distribution of strength training elements is, with some reservations and modifications, valid for both younger and advanced level athletes. For top level athletes, however, the significance of general strength training has declined. Furthermore, comparatively long periods up to two months following the same training target have been shortened into sections lasting only 2-3 weeks.

The general reason for these changes is the fact that the 'utilisation' or transference of accumulated 'general' strength into discipline specific strength could not be performed as successfully as expected. This is why strength training in athletics nowadays should consist of alternating general work with a high proportion of specific exercises throughout the preparatory season.

In contrast to the sixties and seventies, when specific exercises took over after 2 months of multiple objective training, today the direct combination or alternation of these two methods within one and the same training unit or within consecutive sessions is preferred.

Table 4 is an attempt to give a synopsis of 'modern' strength training methods in athletics. The respective selection of method depends upon the target, which can be determined by applying the strength diagnosis criteria mentioned above.

- Body-building methods

Athletes with a slight strength deficit should try to increase the cross section of their muscles. Hypertrophy can best be attained by choosing body-building methods. No jerky movements but smooth and controlled concentric or isokinetic actions should be executed within 5 - 8 sets.

The loading of 70 to 85% allows 10 - 5 repetitions. Whether the 'block-system' of constant resistance within the sets is superior to the pyramid system with slightly progressive/regressive loadings and corresponding decreasing and increasing repetitions cannot be said. A more important aspect is intensity.

Very often it is forgotten that the

repetition - best - performance or 'repetition maximum' (e.g. 10 reps with 100 kg) equals 100%. Thus the training load for 10 repetitions has to be definitely lower: best effects can be obtained varying between 85-80% of the 10-repetition-maximum, between 90-85% of the 5 repetition maximum and 95-90% of the 3 repetition maximum. Higher intensities lead very often to stagnation, especially, if hypertrophy training is executed every second day and 5-8 sets are performed.

On the other hand, it must be stated that it is as yet not quite clear whether highly intensified strategies like 'burns', 'cheatings' or 'forced repetitions' might have the same effect. Probably the destruction of contractile protein is too high and the recovery phases are too short to permit immediate transition to technical training without interference.

In order to avoid catabolic effects, Pipes (1988) recommends a system called 'ACT' (ACT= Anti Catabolic

TABLE 4: Synopsis of strength training methods.

The appropriate targets of training are selected on the basis of a diagnosis of the strength profile.

TARGET	CRITERION OF SELECTION	METHOD	TYPE OF ACTION
- CROSS SECTION	SLIGHT STRENGTH DEFICIT (5-10%)	BODY-BUILDING METHODS (MODIFIED)/TRUNCATED PYRAMID/LOAD:70-85%	CONCENTRIC ISOKINETIC
- NEURONAL ACTIVATION	LARGE STRENGTH DEFICIT	MAXIMUM USE OF STRENGTH/LOAD: 90% - 100%	CONCENTRIC ECCENTRIC
- REACTIVE STRENGTH CAPACITY	LONG DURATION OF SUPPORT/ SLIGHT DIFFERENCE ACTIVE: REACTIVE/EMG-ASSESSMENT	PLYOMETRY/ BEAT METHOD/ 'MULTI-JUMPS'	COMBINED
- EXPLOSIVE STRENGTH STARTING STRENGTH	SLIGHT STRENGTH GRADIENT WITH HIGH MAX. STRENGTH	MAXIMUM USE OF STRENGTH/ AGAINST HIGH LOADS (>90%) AGAINST MEDIUM LOADS (30-60%) WITH TIME CHECK!	CONCENTRIC ECCENTRIC EXPLOSIVE-BALLISTIC
- INTERMUSCULAR COORDINATION	TECHNIQUE DEFICITS / SLIGHT SPECIAL STRENGTH	SPECIAL STRENGTH TRAINING (ANALYTICAL/SYNTHETIC/ VARIABLE)	CONGRUENT WITH TARGET DISCIPLINE

Training). The core of this system is to reduce the number of sets to only one (!) per training unit and to restrict the time invested in cross-sectional training to one hour (three times a week). Thus the training induced consumption and the corresponding reproduction of testosterone during recovery can be balanced.

In view of obligatory, world-wide and random doping controls, 'ACT' seems to be especially promising. That the idea of reducing the sets per training unit drastically really works is substantiated by the findings published by Graves (1988).

Personal experiments carried out over 6 months with a few athletes verified that strength training units restricted to one hour and one super set per main muscle group (with the last (of the 10) reps of the 2nd set 'forced') lead to similar muscle growth as units lasting 2 1/2 hours with 6 to 8 sets of 'normal intensity'! (It must be mentioned here that no anabolic steroids were applied throughout).

Thus, much more time and energy (!) is available for technical — i.e. specific strength — training. An advantage, which is of special interest for heptathletes/decathletes as well as for all who, for good reasons, refrain from consuming steroids.

Referring to talent it should finally be noted in the context of 'body-building-methods', that those athletes with a high proportion of Type II B/A Fibres, even if they were to perform hypertrophy training with comparatively slow movements and submaximum use of strength, will run the risk of becoming less explosive only if other methods are neglected for longer periods. In other words: those highly talented in the field of explosive strength might prove any strength training method to be "superior"

- *Maximum-use of strength method*

In order to increase the neuronal capacity, contractions against high resistance must be made. Loadings higher than 90% and up to 100% promise the best results. Of course only 1 to 3 repetitions are possible. Each trial has to be performed with full concentration and maximum effort. Thus, according to the size principle of recruitment, 'higher ranking' fast twitch fibres are integrated. The near maximum loadings and corresponding comparatively slow contractions compel the motor neurons to fire high frequency impulses for comparatively long times. Because of the high intensity, recovery pauses must be complete. 5 to 8 sets can be performed within one training unit. The above mentioned relationship between 3 repetition maximum, i.e. the highest weight that can be lifted thrice (which equals 100%) and the load within the 3 repetition training sets, again, has to be taken into consideration.

Because there is no alternative strategy for overcoming the resistance available, the integration of all fibres that can be voluntarily activated is guaranteed. It can be assumed that an 'intramuscular learning process' takes place. Thus the mobilisation threshold can be 'lifted'.

- *Plyometrics*

If diagnosis of the duration of the take-off phase in horizontal or vertical jumps indicates an underdeveloped faculty of 'elastic strength' or 'reactive strength', i.e. if comparatively long support times are measured in corresponding tests, 'plyometric' methods should be used. So-called 'depth jumps' possess such a high intensity that their application demands extensive and long time preparation and a far over-average loadability. As a sport motor test, however, depth jump results when compared to those attained in the

well-known Reach and Jump Test tell the coach the extent of the athlete's elastic strength.

EMG assessment leads to the conclusion that high standards in elastic strength primarily depend on the faculty of integrating the muscle extension reflex within the concentric part of the jumping movement. Only pre-activation via the muscle spindle system before impact allows one to profit from this effect.

A great variety of bounds and rebounds over hurdles etc. is probably known to everyone. This is why no further explanations are given here.

It should be noted, however, that so-called 'T-Squats' — the 'T' stands for time — form the main training content of top level jumpers. Half squats as well as full squats are performed under time check. The loading depends on the state of preparation the athlete is in and varies between body weight (barbells) and 150% of body weight. 5 sets with 10 and, approaching the competition period, 5 repetitions are executed as fast as possible. Thus the required fast transition from eccentric to concentric muscle work is trained.

- Speed strength method

If explosive as well as starting strength is to be developed, again the 'maximum use of strength method' mentioned above should be chosen. High resistance loadings of more than 90% significantly influence the required capacity, but the 'speed strength method' with loadings between 30 to 60% (or even 70%) is also very effective.

In West Germany discussions have been going on as to whether this assertion is true, but in my opinion and experience, there can be no doubt, that the speed strength method really works. What is forgotten very often by the critics — and by many coaches and athletes as well — is that, with this method, a time

check is an absolute must! The reason for this pre-requisite lies in the fact that there are several strategies available to accelerate low and medium resistance loads. Only by applying a time check, as a precise working feedback system, can athletes and coaches assess the quality of speed strength training. The close relationship of this method to the neuromuscular demands of explosive-ballistic athletic movements is obvious.

Thus reference data e.g. for snatch and the above mentioned bench-press applying loads from 30 to 60%, are needed to assess indirectly the relative dynamic strength maximum. Such data have not been published yet, but according to POPRAWSKI (1988), the former world champion Sarul from Poland was trained in such a way. The same applies to some of the best West German decathletes. In addition, all junior decathletes are tested correspondingly under the target of talent selection.

In order to avoid misunderstanding, it must be pointed out clearly that, in my opinion, each method possesses advantages and disadvantages. That is why both should be applied pursuing different objectives!

Table 5 compares the training effects of these two methods and indicates cons and pros. It can clearly be seen that, for contractility, the speed strength method should be chosen, whereas the neuronal activation capacity can be better improved by applying high resistance loading.

- Special strength training methods

Last, but not least, 'Special Strength Training Methods' must be mentioned. Depending on the diagnostic results and the type of athlete three different approaches can be chosen. If a lack of specific strength is evident, heavier than normal (i.e. competition) implements

TABLE 5: Comparison of effects of different strength training methods.

The disadvantages of the speed strength method are: short duration times of neuronal activation, absence of a precise internal feedback system and different strategy alternatives to accelerate. The disadvantages of the maximum strength method are deficiencies related to contractility and ballistic muscle tension. The pros and cons are indicated by plus and minus symbols.

REFERENCE/CRITERION	SPEED POWER METHOD	MAXIMUM STRENGTH METHOD
1 CONTRACTILITY/VELOCITY	+	-
2 NEURONAL ACTIVATION: -[INTENSITY (I) AND -DURATION (D) OF IMPULSE (D)	+ -	+ +
3 RECRUITMENT: -TYPE I FIBRES -TYPE II FIBRES	? +	+ +
4 CHARACTER OF MUSCLE TENSION: -BALLISTIC -PHASIC -TONIC	+ (+) -	- + +
5 FEEDBACK: -EXTERNAL WITHOUT CHECKING -EXTERNAL WITH CHECKING -INTERNAL	- + -	+ + +
6 STRATEGY ALTERNATIVES	-(3)	+(1)

and loadings are used. Deficiencies in specific speed can be reduced by applying lighter implements and working conditions — such as downhill (slight slope) running or using 'towing-systems'. This approach of constantly putting stress on either strength or speed throughout a series of training sessions is named 'analytical'.

Varying between heavier and lighter weights and working conditions within one and the same training unit is especially effective and named 'variable'.

Finally, applying competition implements and conditions, is called 'synthetic', because the specific strength and speed demands of the target discipline have to be mastered in combination.

As has already been pointed out, 'special strength training' has to pay due regard to the kinematic as well as to the

dynamic characteristics of the respective event.

In summary, one can state that, on the basis of the results of either analysis or diagnosis, it is up to the 'art' of the coach to select and to combine those training methods, which are best to the attainment of training targets. In my opinion, the alternation of objective-oriented and specific strength training methods within one and the same training unit — or within consecutive sessions — is most effective for advanced and top level athletes.

The presented selection of aspects of strength training has been an attempt to prove that the development of an optimal ratio between maximum strength on the one hand and explosive-ballistic faculties on the other seems to be of paramount importance for further improvements in athletics.



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