DEVELOPMENT OF EXPLOSIVE STRENGTH ACCORDING TO MUSCLE FIBRES TYPES

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Internationally acknowledged Hungarian sport scientist, Jozef Tihanyi, discusses development of explosive strength according to physiological, neural and biomechanical factors, taking into consideration individualized training principles. The article is a summarized translation from the author's address to an international seminar "Training and Testing of Muscular Power" held at the University of Tartu, Estonia, 1997. Re-printed by permission of Modern Athlete and Coach.

INTRODUCTION

Power training is a separate part of strength development. When we discuss strength training, we usually overlook the speed or intensity of the performed work. On the other hand, power training involves high intensity work that requires employing fast motor units. The aim of explosive strength training is to develop a synchronized action of muscular motor units and to improve muscular coordination because a high level of explosive strength is the base for high-powered muscular work.

It is a well accepted fact that a correct choice of athletes for an event according to physical and psychological qualities is decisive for reaching top performance. However, it is only rarely that a chosen athlete possesses all the necessary capacities. For this reason individually appropriate training plays an important role in the development of performing capacities. Unfortunately most of the recommended training programs are based purely on experiences or theoretical standpoints, which do not necessarily correspond to every athlete's physique, muscular peculiarities or psychological qualities.

This makes it necessary to individualize training, keeping in mind the following general principles:

- The level of an athlete's physical, physiological and psychological capacities must be established before the planning of training takes place.
- The training must take into consideration the level of an athlete's performance capacities in the choice of suitable training methods.

- The results obtained from the employed training must be regularly tested and analyzed to make necessary corrections.

With the above in mind, the following test will deal with explosive strength training, focused mainly on the physiological, neural and biomechanical factors, taking into consideration individualized training principles.

PHYSIOLOGICAL FACTORS

Characteristics of Muscle Fibers

The human muscles are made up from a mixture of three types of fibers - slowly oxidative (I, or slow twitch ST), fast oxidative glycolytic (IIa or fast twitch FTa) and fast glycolytic (IIb or FTb) fibers. There is a large variation in genetically determined distribution of different types of fibers between individuals, as well as between different muscle groups.

While it appears that the number of fibers in any single muscle cannot be increased through training, training can increase the hypertrophy (cross-section area) of muscle fibers. We are dealing with two main types of hypertrophy, known as general and selective. General hypertrophy takes place when the cross-sections of both, the fast twitch and the slow twitch fibers, are increased. If there is a difference in the increase of fast and slow twitch fibers, it is referred to as selective hypertrophy. As muscles have different fibers distribution, selective hypertrophy can occur in dominating fibers (confirmative hypertrophy), or in minority fibers (compensating hypertrophy).

It is well known that slow twitch fibers are predominant in distance runners while fast twitch fibers dominate the lower extremities of sprinters. However, it should be noted that the distribution of the different types of fibers does not only vary between individuals but variations also occur in different muscles of an individual. As an example, the percentages of fast muscle fibers of m.vastus lateralis in Hungarian l00m sprinters were found to be around 63% and m.gastrocnemius 52%. Surprisingly the corresponding percentages of 400m runners were 58% and 21%, showing that slow muscle fibers were dominating.

As 100 and 400m sprints demand a high level of explosive strength in m.gastrocnemius, the relative shortage of fast twitch fibers has to be compensated by increasing their cross-section area (compensating hypertrophy).

Muscle Fibers and Explosive Strength

One of the best indicators of explosive strength is the speed of muscle tension development (RTD). It can be calculated from a force-time graph. A correlation between the muscle fibers distribution and RTD has been found in many studies, although some investigations have failed to find this correlation. It is likely that

this has occurred because RTD values are influenced by several factors not involved with the distribution of muscle fibers, the number of fibers and also the neural factors in the frequency of nervous impulses and synchronization of motor units.

Latest computer stimulations have shown the importance of the compensating mechanisms in training. A comparison of FT/ST surface areas with RTD has shown that compensating hypertrophy can remove RTD differences in muscles. A selective hypertrophy of fast fibers in slow muscles can compensate for the domination of slow fibers and improve RTD. For example, if a muscle has only 30% of fast fibers, it can still reach a RTD equal to a muscle with 70% fast fibers, provided the ratio of FT/ST surface area is 2.5.

NEURAL FACTORS

The distribution of muscle fibers, their average surface area, and the relationship of surface areas, can be determined by muscle biopsy. The determination of the sequence of the activation of motor units, their numbers and their synchronization is a rather difficult task. It is known that maximal isometric strength depends on the number of activated motor units and it is assumed that the synchronization of the units is helpful in strength development. This leaves the question of how the synchronized effect is reflected in the force-time graph characteristics.

As the muscles belonging to high threshold level contract faster than those of a low threshold level, it can be assumed that activating motor units in reverse order would help to contract the whole muscle faster. Stimulation studies also demonstrate that the number of activated motor units influence RTD through increased maximal isometric strength. This appears to indicate that the normal sequence of activating motor units is more favorable to reaching maximal RTD values in comparison to the reverse order.

Surprisingly, it has been revealed that the largest RTD values can be achieved when the space of time between the activation of motor units is 4ms and not zero. It has been further revealed that RTD values increase through synchronization and this can change the relationship between the distribution of muscle fibers and RTD values. Consequently, synchronization of motor units can compensate the negative influence of dominating slow fibers.

POWER PRODUCTION

Muscular power can be measured by calculating the characteristics of the force-time graph and the level of maximal power. The largest power level is related linearly to RTD. Using Hill’s classical equation reveals that the best power values can be produced in a muscle when the load is between 30 and 40% of the maximal isometric strength. As the characteristics of the force-time graph change

in the participation of activated different types of fibers in a concentric contraction, fast muscles are capable of producing the largest maximal power under smaller loads than slow muscles. At the same time, as maximal isometric strength is not influenced by muscle fiber distribution, slow muscles can produce a higher level of strength than fast muscles.

Different types of muscle fibers differ in their sensibility to the duration of muscular work. Muscular power drops gradually until exhaustion is reached in high intensity work. Bosco et al. discovered that the power drop during the first 15 seconds occurs at the same rate for fast and slow muscles. As work continues, power drops more rapidly in fast muscles.

PRACTICAL APPLICATION

Determination of Physiological and Biomechanical Qualities

The characteristics of muscle fibers should for every athlete be determined from muscle biopsy at least once. The biopsy should take place in the muscles responsible for the performance in a particular event (for example, knee extensors and plantar flexors in jumping events), Of course, it is possible to clarify muscle fiber distribution by non-invasive ways, but the results are not exactly reliable. The following has to be determined:

- Distribution of different types of muscles fibers (FTa%, FTb% and ST%)
- Average cross-section surface areas of fast and slow muscles.
- Direct determination of the cross-section surface area of a muscle.
- Calculation of the number of muscle fibers (the cross-section surface area of the muscle divided by the FT and ST fibers cross- section surface area).

The mechanical characteristics should be determined prior to a training period, during the period, and at the end of it, for primary mover muscles, as well as muscles that work in a specific position or have a specific influence. The following should be determined:

- Maximal isometric strength (Fmax) using specific devices to test one muscle group or combined influence of several muscle groups.
- Muscular tension development speed (RTD, RFD) using same devices as in isometric strength development (for example Cybex, Multi-gym, etc.).
- The characteristics of force-speed-power graph, maximal force (Fmax), maximal power (Pmax) and force on the occasion of Pmax.

- Elasticity qualities of muscles, using the Bosco method.

Choice of Strength Training Methods Based on Physiological and Biomechanical Qualities

The distribution of muscle fibers, the number of motor units and perhaps also the number of muscle fibers belonging to the composition of motor units are genetically determined. It is very hard to change these indicators through training. The cross-section surface area of a muscle and its individual fibers, the number of activated motor units, the frequency of nervous impulses and the synchronization of motor units are all indicators that can be changed through training.

Explosive strength can be developed by increasing general and selective hypertrophy. The selective hypertrophy of fast fibers can be compensating or confirmative. Our calculations show that when the cross-section surface area of fast fibers increases 2.5 times, it will compensate by 30 to 40% the shortage of fast fibers. This was the case in the above mentioned 400m runners, who had a low percentage of fast fibers in m.gastrocnemius, but a surface area of fast fibers twice as large as slow fibers.

Intensity

Training must be as intensive as possible in the development of explosive strength. When the contractive power of a muscle is high, there is a definite possibility that high threshold and fast fatigued motor units are activated. This increases integrated electrical activity and the frequency of nervous impulses. The greatest power can be attained by the activation of fast motor units and with it changing their physiological and mechanical characteristics. The activation of motor units requires an exceptional effort from the athlete and only highly motivated and well trained athletes achieve this. Nordon et al. demonstrated that high threshold motorneurons of m.triceps are called into action in an eccentric contraction only after low threshold units cease operating.

TRAINING EXERCISES

The best methods to develop muscular power are strength exercises that consist of stretching-shortening cycles in plyometric activities. For example, in the performance of a half-squat with a barbell on shoulders, the athlete executes a takeoff at the end of the leg extension to rebound after the landing (rebound half-squat jumps). The range of the movements is here essential to activate the different types of muscle fibers. Slow muscles require restricted movement amplitude to allow fast fibers to work more effectively in the development of muscle power capacities (Bosco et. al. 1983). On the other hand, it is necessary to select training exercises that are based on a similar muscular activity as in the competition exercise to improve internal muscular coordination.

Loads

Exercise loads must be selected by taking into consideration the type of an exercise, isometric strength and muscle fiber distribution. For example, a comparison of the squat, half-squat and ‘high’ squat shows that strength application is the smallest in the performance of the squat and the largest in the execution of the ‘high’ squat.

If the aim is to increase the cross-section surface area of fast muscle fibers, the movement amplitude should be small. However, the movement range also depends on the distribution of muscle fibers. Therefore, the more fast fibers in a muscle, the wider can be the movement range. Faster athletes produce higher power with large loads than slower athletes. Consequently, slow athletes should employ lighter loads than fast athletes in the development of muscular power. The most suitable load in the development of muscular power ranges between 30 to 60% of maximal isometric strength.

Repetitions

It has been constantly asked how many repetitions should be performed when the task is the improvement of muscular power. Until now the choice of the number of repetitions has been based mainly on experience without using scientific experiments or calculations (Tesch 1992). It is well known that the load size is the most important factor in the determination of maximal repetitions. However, when the training aim is to develop muscular power, the maximal number of repetitions is significant because it is necessary to avoid general hypertrophy development.

Power functions drop in dynamic work according to the number of repetitions performed. This trend depends on the size of the load and the type of the exercise. There are reasons to believe that the quickly fatigued fast fibers fail to determine power dynamics when it drops below 90% of the maximum. This is the reason why a repetition of further activity serves no purpose. As stated, the optimal number of repetitions varies according to the load and is also dependent on the type of the exercise. For example, muscular fatigue occurs earlier in the squat than the half-squat because longer movement amplitudes consume more energy.

Sets

The number of sets to be performed can be determined from the average power produced in one set. Training must be terminated when the average drops below 90%. Provided this criterion is applied, well trained and highly motivated athletes are capable of performing 8 to 12 sets using the same muscle groups. Recoveries are in this case between two and three minutes. Increasing recovery duration has no advantage when the 90% limit has been broken.

CONTROL AND INDIVIDUALIASTION

Direct Control

Experiments have provided the base for the planning of power training as far as exercises, repetitions and sets are concerned. The contemporary cyclic loading principle is also well known and applied to explosive strength development. However, it should be kept in mind that the physiological and psychological stage of an athlete changes from day to day and can't be pre-determined. An exact and most suitable loading therefore requires continuous control, particularly when maximal intensities are employed.

Direct feedback makes it possible for athletes to perform exercises with the highest possible intensity and provides coaches information for the necessary changes in training loads, sets and repetitions. This is extremely important to secure inter- and intra-muscular coordination, as well as compensating hypertrophy of fast muscle fibers.

Individualization

The composition of muscle fibers is the most important factor in the choice of training exercises and the number of repetitions and sets to be performed. In general, small loads, high intensities, small or medium number of repetitions and sets are applicable to the training of slow fibers dominated muscles. In contrast, muscles dominated by fast fibers require medium or large loads with a medium number of repetitions and sets.

The exact number of repetitions and sets in explosive strength development can be determined only by continuous training control. Experiments have indicated that it is not sufficient to plan strength training based on energy expenditure. Even the most carefully planned power training therefore requires operative changes, taking into consideration individual feedback on an athlete's actual physiological and psychological state.