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RESISTANCE EXERCISES AS A SPECIALIZED MEANS FOR PHYSICAL PREPARATION OF ATHLETES

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In sport training, the use of resistance exercises has always served one purpose – the increase of muscular strength. From this point of view, the usefulness of resistance exercises for any particular sport is still being debated; however, the fruitlessness of those arguments due to the one-sided perspective is becoming increasingly more obvious.

Modern achievements in physiology and biochemistry of muscular activity have deepened our knowledge of central regulation and the bioenergetics of muscular contraction as well as local improvement of contractility and oxidative ability as a result of training in a specific motor regimen. At the same time, research suggests that when the resistance exercises are used with adequate methods they can be an effective means not only to improve muscular strength, but also to improve speed of movement, local muscular endurance, velocity and frequency of movement without resistance, reaction time, and the rate of muscle relaxation (see tab. 1).

What is the potential of resistance training and how can we use it for the Special Physical Preparation of high level athletes?

The main criteria of the work effectiveness of sport movement, in each form of expression, is the speed of muscular contraction. Speed depends on environmental conditions in which the specific motor task is resolved and is determined by the magnitude of mus-

cular tension and the velocity at which the tension increases.

The higher the external resistance (opposition) that muscles must overcome during the work (exercise), the higher the magnitude of tension that must be reached in order to obtain the necessary speed of contraction. During prolonged (repeating, cyclical) work, the speed of muscular contraction (as an additional factor) is determined by the ability to sustain the required magnitude of muscular tension and the velocity of its development. Usually, these abilities are understood as “strength” and “endurance”, referring to the so named physical qualities (of motor abilities or capacities), but that’s a very simplified view.

Physical qualities (of motor capacities) don’t exist separately from the concrete physical activities. Strength and endurance are valued only as the quantitative characteristics of the working effect of muscular contraction with particular speed.

During athletic performances they don’t develop by themselves out of the speed of muscular contraction (including isometric contraction).

In particular, the speed of muscular contraction is not determined by the simple synthesis of different motor capacities (strength, velocity or endurance). The increase of the speed of muscle contraction, as a result of

training, is obtained through the increase of the following:

- moto-neuron impulse
- muscular hypertrophy
- power and capacity of energy providing mechanisms
- functional supporting physiological systems of the organism
- and through more effective utilization of the motor potential of athlete assured by the appropriation of more expedient bio-mechanics of movement.

All those adaptive acquisitions, taking place on different levels, are very specific, and depend on special demands imposed on the human body during a specific training regimen.

So, the speed of muscular contraction is a specific functional property of an athlete's organism that is fully (completely) expressed and developed in a certain (strictly definite) specific environment. The improvement of the speed of muscular contraction is not based on the mechanism of synthesis of different motor capacities, but it is a result of a morphological and functional specialization of an athlete's (organism) as a whole, provoked by these specific environments.

This is selective adaptation of all systems oriented not simply toward improving the speed of muscular contraction, but also toward overcoming its limiting internal and external factors. In other words, we are talking about perfection of specific speed of muscular contraction during the required tension or duration of an event.

The higher the level of sport mastery and physical preparedness of the athlete, the more specific the base mechanism is that assures the speed of muscle contraction (including its

energy providing mechanism) during the competition activity.

For this reason, the organization of Special Physical Preparation (SPP) of high level athletes requires special attention.

It is important to note that the main cause of what primarily determines the direction and the level (value) of morphological and functional specialization of the organism is the regimen of muscular work during competition or training activity. This regimen leads to specific muscular hypertrophy, participation of certain physiological systems in support of muscular activity, and the development of motor and (vegetative or autonomic) nervous systems to sustain a high volume of work.

For this reason, the specific regimen of muscle work (typical for the concrete sport discipline) must be the main part of the contents of the SPP. Therefore, the aim of SPP is to intensify the regimen of muscular work, and, with that, to activate all physiological systems that functionally support the concrete muscular activity. This regimen, through most of its physiological characteristics, should be very close or even exceed the level required for competition.

The intensification of the regimen of muscle work can be obtained by the use of resistance exercises. Because of the variation of resistance, speed and frequency of movement, and as well as rest intervals between sets, there are great possibilities to reproduce the required regimen of muscular work, and therefore selectively stimulate the muscular-nervous apparatus, the CNS mechanisms of

muscle contraction regulation and energy providing mechanisms.

When using resistance training, it is important to consider the following:

1. these exercises have a constant vector of external opposition force (vertically down), that requires a careful choice of initial position, and the position in which maximum effort is produced
2. resistance exercises should be selected for competition by using two criteria: form of movement (i.e. the muscle groups involved, direction and amplitude of movement), and the regimen of muscle work (i.e. velocity of the force produced, and energy systems involved). One of the advantages of resistance training comes from the regime of ballistic muscle work, just like most parts of the competition. Therefore, it is important that maximum effort is developed at the same joint angle as it is during competition
3. resistance exercises should intensify the regimen of muscle work in consideration of speed of contraction and duration of work for each competitive event. Choosing weight and method of training resistance exercises should be oriented toward the development of:
 - **maximum strength**, when a sporting event requires overcoming great external resistance, and the increase of speed of movement by creating maximum effort
 - **explosive strength**, when a sport requires fast acceleration or change in direction of movement with significant external resistance
 - **speed strength**, when speed of movement is achieved by overcoming relatively small resistance

- **strength endurance**, when force production should be sustained for a period of time, and
- **local muscular endurance**, when a sport requires continuous speed at sub-maximal intensity.

Resistance training may effectively be conducted through any of the following methods: maximal strength effort; series-repetitive; interval; and complex.

The maximal strength effort method is used for the development of maximal and explosive strength, without significant increases in muscle size. It causes adaptations in the central mechanisms regulation of muscular tension, improves anaerobic energy systems, optimizes the speed of muscle relaxation, and improves an athlete's ability to generate powerful concentrated muscular force. Specificity of this method is high intensity with limited volume.

The main variant is 2-3 repetitions with 90-95% of 1RM, with obligatory muscle relaxation between repetitions¹. Training sessions consist of 2-4 sets with 4-6 minutes rest periods.

Periodically – once every 2-3 weeks during off season and once every 1-2 weeks during

¹ The muscle relaxation exercises are conducted between individual repetitions of a single set. For instance, when using this method with the back squat exercise the athlete would perform one squat repetition then rack the barbell and perform the relaxation movements then unrack the barbell and perform another single squat repetition followed by re-racking the barbell and additional relaxation movements, and perhaps one more cycle of this for a third repetition. This series of events equals one set.

pre-season – a different method can be used. After warm up, complete lifts with 90, 95 and 100% 1RM, then 95, 100 and higher. Between each lift, rest 4-5 minutes. Rest between the second set of lifts – depending on how the athlete feels.

Both methods could be used to support an athlete's speed-strength potential during the competition season.

The series-repetitive method is oriented toward the development of morphological changes that support certain abilities of muscle work, thus bringing these abilities to a new and higher level. In general, this method of training creates a load slightly lower than the previous maximum force level. It includes a few variations divided by the impetus to training adaptation, regulated by the amount of resistance, velocity and tempo of movement, as well as the length of rest periods.

Variant 1. Maximum strength development with hypertrophy. Resistance 75-80% 1RM, slow motions until volitional fatigue (10-12 reps), 2 sets with 2 minute rest for 2-3 muscle groups. If working only one muscle group, 3 sets can be used. This method is not effective in improving speed, but useful in the beginning of off season training to prepare muscles for more intense workloads.

Variant 2. Maximum force development with little hypertrophy. Complete 3 sets: 80% 1RM (8-10 reps), 90% 1RM (5 reps), and 93% 1RM (3 times) with 2-4 minutes of rest. During one training session, perform 2-3 series with 6-8 minutes rest in between. As the strength of an athlete increases, resistance should be increased by 5%.

In each two variants of series-repetitive methods, the muscles must not be relaxed between the movements (repetitions)².

Variant 3. Developing the speed force for cyclical and non-cyclical sports. Load is limited to 30-70% 1RM depending on the resistance that must be overcome in a particular sport. Perform 6-8 reps with maximum velocity, moderate tempo with the muscle being relaxed after each repetition. 2-3 sets in each series with 4-6 minutes rest interval. There are 2-3 series in each training session with 8-10 minutes rest between series.

Variant 4. Speed and frequency improvement of unloaded movements. Resistance 15-20% 1RM- execute movement with maximal speed. If emphasizing speed, then frequency of movement should be moderate with muscle relaxing in between. If emphasizing frequency of movement, then exercise should be performed at maximal tempo. Each series consist of 2-3 sets, 8-10 reps each with 2-4 minutes rest in the first case, and 4-6 minutes in the second.

Variant 5. Development of reaction speed of form and muscle coordination. Exercise should copy movements of competition. Resistance 30-40% 1RM. Emphasis on the quick start of movement on the specific competition signal, i.e. visual, tactile, etc. Training is directed toward the improvement of speed of muscle recruitment and coordination. Series includes 4-6 reps with long pauses. There are 2-3 series in one training session with 4-6 minutes of rest intervals. In some cases, exercise can be performed via explosive isometric muscular tension.

Variant 6. Strength endurance development during high intensity performance. Resistance is 90-93% 1RM, exercise performed at slow motion, 3 sets of 2-3 repetitions with 4-6 minutes rest. Sets

² In this case, different from the maximal strength effort method, all repetitions of a single set are performed continuously.

performed until volitional fatigue (but not failure). After that resistance should be decreased by 5%, and another 2-3 sets should be performed.

Interval method – used for the development of local muscular endurance by improving energy storage and its efficacy during cyclical work. This method promotes morphological and biochemical muscular adaptation toward improvement of its oxidative abilities.

Variant 1. Work at maximum intensity for 10 seconds with the frequency of 1 movement per second. Resistance is limited to 30-40 % 1RM, so work would not lead to fatigue and slowing down of the movements. Rest periods are 30 seconds initially, but, with an athlete's improvement, can lower to 10 seconds. Start by performing 5-6 reps and gradually increase it to 8-10 reps. Each workout should consist of 2-3 series with 8-10 minutes resting between each series.

That would provide the increased power and capacity of the anaerobic energy supply including creatine phosphate and lactic acid systems. In addition that would speed up aerobic glycolysis during aerobic system contribution.

Variant 2. Work for 30 seconds with moderate intensity, have a 60 seconds rest interval, then work again for 30 seconds. Resistance is the same as in Variant 1. Tempo –one movement per second. There are 6-8 repetitions in each series; in each training session there are 2-3 series with 10-12 minutes rest intervals in between. Progressive overload in both variants is achieved by either increasing resistance while preserving the same tempo of movement or increasing tempo of movement with constant resistance.

The complex method includes multidirectional development in one training session. The contrast of this method improves the acceptance of the training effect on the body. Secondly, it uses the phenomenon of positive improvement of

the previous workout to increase the effectiveness of the next work.

Variant 1 is used for the development of explosive muscular force. Two sets with 2-3 slow reps using resistance of 90% 1RM. Then 3 sets of 6-8 rep with the resistance of 30% 1RM (with maximum effort and relaxing muscles between reps). Rest intervals between sets are 3-4 minutes, and rest the rest interval after changing the weight for the lighter sets is 4-6 minutes. Perform 2-3 series in one training session with 8-10 minute rest periods.

Variant 2 is used for speed improvement. One series includes 2 sets of 3-4 repetitions with a resistance of 50-75%1RM, and 2-3 sets of 6-8 reps with a resistance of 30%1RM performed with maximum speed and muscular relaxation between repetitions. Rest intervals are 4-6 minutes between sets and 8-10 minutes between series.

Variant 3 is used to improve the speed and frequency of unloaded movements. Perform 2 sets of 3-4 reps in moderate tempo with 50-70% 1RM resistance followed by 2-3 sets of 8-10 reps using 15% 1RM resistance (increasing speed with moderate tempo and relaxation between sets, and increasing frequency with maximum tempo respectively).

Elite athletes have very high levels of SPP; however, it is possible to further raise this level through very intense methods of training. Therefore resistance training should not be used as a complimentary training but rather as part of the main training regimen.

During extensive resistance training the speed of movement temporarily decreases, which is normal. Later, speed not only recovers to the previous level but significantly increases. Therefore, mastery of skills and speed training should be started after the cycle of resistance training.

Resistance exercise can be effective only if it is incorporated into a methodical system as a part of

a yearly cycle. That system should be focused on increasing strength by increasing load, speed or tempo of movement in the interval method. To achieve this goal, it is important to evaluate the training level of individual athletes and the demands of a specific sport:

- determine the main training direction of selected exercises and methods and classify them;
- evaluate amplitude of training adaptation imposed by exercises and methods and rank them based on it;
- divide exercises and methods within certain time frames, define their volume and relationship to other training protocols.

Muscular relaxations and the duration of rest intervals between repetitions and sets are very important factors regulating the training effect of resistance exercises. Muscle relaxation facilitates

ATP re-synthesis via the Creatine Phosphate system and creates conditions for improving energy supply. Rest intervals between sets and series are required for aerobic ATP synthesis and muscle recovery, and facilitate the creation of functional interaction between motor and autonomic systems during a given regimen of muscular work. Ignoring it moves the training effect toward increasing protein synthesis, muscular hypertrophy and endurance, while diminishing development of speed.

Between sets and series (especially in the maximum effort method), muscle should be stretched by performing full range of motion swinging exercises. This preserves elasticity and helps muscle to relax. With the interval method between series, sub-maximal work should be performed which facilitates lactate removal and improves muscle oxidative properties.

Tab. 1 - The primary emphasis of the resistance exercises executed with different overload weight, repetitions, number of sets, and different rest interval durations
 (“La Preparazione Fisica Speciale”, Verkhoshansky Y., CONI - 2001)

Overload weight (% 1 RM)	Number of Repetitions	Number of Sets	Duration of Rest Interval	Primary emphasis/Training Effect (what can be obtained)
70 - 100	1 -6	4 -8	3 – 4 min	Maximal Strength and Explosive Strength expressed with great external opposition
70 - 90	5 -10	4 -8	3 – 4 min	Explosive Strength expressed with moderate (low – middle) external opposition
70 - 80	8 - 12	3 -6	1 – 2 min	Maximal Strength with muscle hypertrophy
50 - 70	10 -15	4 -6	3 – 4 min	Speed (velocity) of movements, and High Speed Strength expressed with a great external opposition
50 - 70	20 - 40	2 - 4	45 – 90 sec	Local Muscular Endurance expressed with a big external opposition
30 - 60	30 - 50	2 - 4	45 – 90 sec	Local Muscular Endurance expressed with a moderate (low – middle) external opposition
30 - 50	10 - 15	4 - 6	3 – 4 min	Speed (velocity) of movements and the Speed Strength expressed with a low external opposition
15 - 30	15 - 20	3 - 5	3 -4 min	Rapidity and frequency of movements without overload