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DEVELOPMENT OF EXPLOSIVE STRENGTH INDICATED BY JUMPING PERFORMANCE AT HIGH SCHOOL STUDENTS

Summary

A sample of 60 subjects was extracted from the population of male students from high schools, 16 years old, involved in regular physical education classes. The sample was divided into two subgroups: 1) the subsample of 30 subjects who had an experimental program for development of explosive strength indicated by jumping performance at B main part of physical education classes (experimental group) and 2) the subsample of 30 subjects who had regular physical education classes toward prescribed curriculum for high school (control group). The aim of this study was to determine the effects of the experimental program of explosive strength indicated by jumping performance development at high school students. Explosive strength tests included: Concentric muscle work: Squat jump – arms at waist, Squat jump – arm swing, Repeatitive squat jump and Continuous jump; Eccentric-concentric muscle work: Countermovement jump, Abalakov jump, Drop jump and Star jump. To determine the effects of the experimental program on the development for development of explosive strength indicated by jumping performance, multivariate analysis of covariance was used. The results showed that the effect is determined at experimental group of students in both types of muscle work, concentric muscle work and eccentric-concentric muscle work. The conclusions of this study indicate positive effects of different forms of exercise in explosive strength indicated by jumping performance, as well as some guidelines regarding its effective assessment through different types of tests and their modifications.

Keywords: *explosive strength, vertical jump, high school students.*

INTRODUCTION

Development of physical ability is being performed by an organized and systematic physical training. There are different organizational forms that are implemented at different levels. In physical education classes, improvement of physical fitness is not too large, due to a small extent and intensity of work. Those students who have other organized sports activities (class off activities), besides regular classes, will achieve better results. However, the regular classes can also affect the proper operation of adaptive changes at the level of physical ability.

Theoretical knowledge of explosive strength indicated by jumping performance

Explosive strength is one of three manifestation of strength (explosive strength, repetitive strength and static strength) and that is ability of maximum acceleration in the development of maximal muscle strength. In physical terms, the explosive strength is associated with the concept of energy, the static strength with the concept of force, and repetitive strength with the concept of power (Matić et al., 1992). In addition to that criteria, there is a division toward neuro-muscular action, so the strength is manifested in the form of isometric, concentric, eccentric or concentric-eccentric contractions. Isometric contraction, understands a situation where the muscle strength is equal to the external force or load, and it does not register the movement of muscle attachment. Concentric contraction of the muscle is the positive result of the muscular force that is greater than the external load. Eccentric contraction is negative muscle work and it is occured when the external load is greater than the power of activated muscle. In real everyday motor situations, eccentric-concentric muscle contraction type is most often occured or even to be called plyometric contraction, and is manifested among other things, like jumping ability.

The most important factors of jumping ability are: the muscular and nervous systems. In the muscular system (by Čoh, 2004), the relationship between fast and slow muscle fibers and elasticity of muscles and tendons is very important. If the fast muscle fibers are dominant, then it results with higher level of strength development. The main characteristic of elasticity of muscles and tendons is using of elastic energy in the concentric-eccentric cycle. The contribution of elastic properties of muscles and tendons depends on the speed of transition from eccentric to concentric muscle work, which must be as short as possible (less than 260 milliseconds: by Bosco et al., 1982; Zatsiorsky, 1995).

Characteristics of eccentric-concentric contraction

The active element of the locomotor system of the body, which is capable of active contraction with consumption and conversion of chemical into mechanical and thermal energy, is a muscle, consisted of basic element - the muscle tissue. Coordinated dynamic action is resulted by muscle contraction, which is performing body movements over articulated system with elements of the skeleton, connective tissue and cartilaginous parts, (Dodig, 2002).

The plyometric muscle work is dominated by eccentric contraction (negative work). Due to lower energy during eccentric contraction, the body activates a smaller number of motor units and consumes less oxygen, so in mechanical view it has a greater effect than concentric muscular work. The movements are performed in moderate to high speed with the involvement of fast, white muscle fibers, which are anaerobic provision of energy, they have higher frequency of work and larger cross-section, thus they are producing more power per motor unit. The production of force during eccentric contraction is larger than during concentric contraction, because of the greater tension of muscles and tendons, which are suffering greater burden (Radcliffe & Farentinos, 2003).

Concentric and eccentric muscle work are mostly complete each other and consist of concentric-eccentric contraction (stretch-shortening cycle). Most of the movements that the body does, are the result of concentric work that shortens the muscle, which is preceded by an eccentric work that stretches the muscles in the opposite direction. Thanks to this process we have explosive strength.

Eccentric-concentric contraction cycle (by Radcliffe & Farentinos, 2003):

It is being started by the amortization phase which is a time limit from the beginning of eccentric to the beginning of concentric contraction. Stretch reflex and reflex of muscle spindles are activating and they are detecting the muscle stretching by sending the pulse into the spinal cord and back into the muscle for dynamic contraction. During eccentric muscle work, elastic energy is being created and released in concentric work. During the stretching, it

is vital for movements to last as fast as they can, because the speed of stretching is more important than quantity and length. If the amortization phase is slow, the muscles while stretching, lose their elastic energy that is transformed into heat. When the impulses reach the spinal cord and brain, they are interpreted and returned to the muscle via motor nerve fibers issuing orders to those motor units whose muscle fibers have to react, to shorten and to perform concentric contraction. The cycle is being ended that way.

Plyometric training

For the main type of jumping training, plyometric training is recommended. It is necessary, however, to determine the age of the children with whom it is working, their level and course of training. Farentinos & Radcliffe (2003) consider that the time for accessing the plyometric training, is the period between the age of 12 and14. However, plyometric training, requires good preparation which is reflected (Bompa, 2000) in the development of joint flexibility, hamstring and muscle strength and then the strength of the torso and the extremities (for example, in adults, squat jump with a load of 1.5 to 2 times of the weight of the respondents is performed as a criterion for getting down to work on drop jumps).

When it is talking about the development of vertical jump with plyometric training, the first association are the drop jumps, type of jumps that are mostly used and they give good results. The requirement is to be technically well done and properly dosed and positive effect on the expression of explosive strength indicated by jumping performance can be expected. The main characteristic of drop jumps is that they allow for active stretching of muscles prior to active shortening. Extensor muscles are stretching in the amortization phase, followed by a strong contraction that produces the takeoff, and this transition must be done in the shortest possible time. Drop jumps are performed with a predetermined height, from which the jump is performing in depth and then in height. The altitude limit for the safe and efficient performance of the drop jump is 1.2 meters (by Birkić, 2003). Anything more would be a great burden for the muscular system. This amount, of course, refers to adult athletes, otherwise the height ranges from 0.2 to 1.1m, depending on the age of respondents and their level of training. When we want to emphasize the eccentric phase, the jump height is higher, while lower height of jump is using to emphasize the concentric phase. Takeoff in drop jumps should be performed with maximum speed swing arms. The duration of contact with the ground should be as short as possible - 120-200ms (Antekolović, Žufar & Hofman, 2003).

The aim of this study was to determine the effects of the experimental program of explosive strength indicated by jumping performance development at high school students.

WORKING METHODS

2.1 The sample of respondents

A sample of 60 subjects was extracted from the population of male students from high schools, 16 years old, involved in regular physical education classes. The sample was divided into two subgroups: 1) the subsample of 30 subjects who had an experimental program for development of explosive strength indicated by jumping performance at B main part of physical education classes (experimental group) and 2) the subsample of 30 subjects who had regular physical education classes toward prescribed curriculum for high school (control group).

1.2 The sample of variables

Explosive strength tests included: *Concentric muscle work*: Squat jump (arms at waist) – SQUAT1, Squat jump (arm swing) – SQUAT2, Repeatitive squat jump – REPEAT and Continuous jump – CONT; *Eccentric-concentric muscle work*: Countermovement jump – COUNT, Abalakov jump – ABAL, Drop jump – DROP and Star jump – STAR.

Chronojump system was being used for testing mentioned tests of explosive strength and it measured time of flight. To determine the effects of the experimental program on the development for development of explosive strength indicated by jumping performance, multivariate analysis of covariance was used.

2.3 The experimental program

The experimental group participants conducted an experimental program to develop explosive strength indicated by jumping performance, which was accomplished with two classes per week for 12 weeks (24 classes) in the B main part of the regular physical education classes. The control group realized regular physical education classes with two classes per week for 12 weeks. The initial and the final testing of explosive strength indicated by jumping performance were organized for both groups.

Exercises for developing explosive strength indicated by jumping performance:

The basic two foot jump, squat jump, jump with attraction of knees, jump on the box, jump with both feet throwing back, contract jump, a quick single jump, drop jump, progressive vertical jumps, lateral jumps, jumping across the obstacles, rocket, alternating jump with step on a bench and two foot jumps on the stairs.

Table 1. Exercise program for development of explosive strength indicated by jumping performance

	EXERCISES	**SERIES AND NUMBER OF REPETITION**	**RECOVERY**
I i II week	The basic two foot jump	3x10	30 seconds between series, 1 minute between exercises (in the case of *Jump on the box* and *A quick single jump* 10 seconds between repetition)
	Squat jump	2x4	
	Jump with attraction of knees	2x4	
	Contract jump	2x-4-6	
	Jump on the box	2x8	
	Rocket	2x4-6	
	A quick single jump	2x	
	Jump with both feet throwing back	2x6	
III i IV week	The basic two foot jump	3x10	30 seconds between series, 1 minute between exercises (in the case of *Jump on the box* and *A quick single jump* 10 seconds between repetition)
	Squat jump	2x6	
	Jump with attraction of knees	2x6-8	
	Rocket	3x4-6	
	Jump on the box	2x8-10	
	Jump with both feet throwing back	2x8	
	Contract jump	3x4-6	
	A quick single jump	3x6-8	
V i VI week	Squat jump	3x6-8	30 seconds between series, 1 minute between exercises (in the case of *Jump on the box* and *Drop jump* 10 seconds between repetition)
	Contract jump	3x4-6	
	Jump with attraction of knees	3x8	
	Rocket	2x8-10	
	Jump on the box	2x4-6	
	Alternating jump with step on a bench	3x4-6	
	Two foot jumps on the stairs	2x4-6	
	Drop jump	1x4	
VII i VIII week	Squat jump	3x8	30 seconds between series, 1 minute between exercises (in the case of *Drop jump* 10 seconds between repetition)
	Jump on the box	2x6-8	
	Drop jump	1x4	
	Jumping across the obstacles	3x3	
	Alternating jump with step on a bench	3x5-7	
	Lateral jumps	2x4-6	
	Progressive vertical jumps	2x3-6	
	Two foot jumps on the stairs	2x6-8	
IX i X week	Jump on the box	3x6	30 seconds between series, 1 minute between exercises (in the case of *Drop jump* 10 seconds between repetition)
	Progressive vertical jumps	2x3-6	
	Lateral jumps	2x4-6	
	Jumping across the obstacles	3x3	

	Alternating jump with step on a bench	3x6	
	Two foot jumps on the stairs	2x6-8	
	Drop jump	1x5	
XI i XII week	Lateral jumps	3x4-6	30 seconds between series, 1 minute between exercises (in the case of *Drop jump* 10 seconds between repetition)
	Progressive vertical jumps	3x4-6	
	Drop jump	1x7	
	Jumping across the obstacles	4x3	
	Alternating jump with step on a bench	3x8	
	Two foot jumps on the stairs	2x6-8	

RESEARCH RESULTS

Table 2. Analysis of covariance between groups in terms of explosive strength indicated by jumping performance (concentric muscle work) at the final measuring with a neutralization of the differences from the initial measuring

Table 2a

Wilks Lambda	*Rao-F*	*P-level*
.305	*5.72*	***.000***

Table 2b

Tests	*Adj. means (e)*	*Adj. means (c)*	*F*	*P-level*
SQUAT1	*0.62*	*0.53*	*2.25*	***.004***
SQUAT2	*0.72*	*0.59*	*3.53*	***.000***
REPEAT	*3.86*	*3.56*	*3.29*	***.000***
CONT	*3.05*	*2.79*	*4.21*	***.000***

The results of multivariate analysis of covariance (Table 2a) between the experimental and control groups at final measurement point to the presence of statistically significant difference in favor of experimental group at concentric muscle work on the level of P = .000, with Rao–F = 5.72. The difference is influenced by experimental program for developing explosive strength – jumping type.

At table 2b there are univariate values of analysis of covariance between the experimental and control groups at final measurement with neutralization of differences in the field of concentric muscle work in the initial measurement. There are statistically significant differences between groups (P< .01) in favor of the experimental group at the level of all explosive strength tests: Squat jump - no arms (SQUAT1 .004), Squat jump - arm swing (SQUAT2 .000), Repeatitive squat jump (REPEAT .000) and Continuous jump (CONT .000).

Table 3. Analysis of covariance groups in terms of explosive strength indicated by jumping performance (eccentric-concentric muscle work) at the final measuring with a neutralization of the differences from the initial measuring

Table 3a

Wilks Lambda	*Rao-F*	*P-level*
.404	*6.85*	***.000***

Table 3b

Tests	*Adj. means (e)*	*Adj. means (c)*	*F*	*P-level*

COUNT	*0.64*	*0.51*	*3.51*	***.000***
ABAL	*0.68*	*0.55*	*3.84*	***.000***
DROP	*0.71*	*0.60*	*4.26*	***.000***
STAR	*0.58*	*0.45*	*3.57*	***.000***

The results of the multivariate analysis of covariance (Table 3a) between the experimental and control group at the final measuring indicate that a statistically significant differences in favor of the experimental group is noted for eccentric-concentric muscle work, at level of P= .000, with Rao–F = 6.85. The difference occurres under the influence of experimental program for developing explosive strength indicated by jumping performance, which has a positive effect on transformational processes of explosive strength indicated by jumping performance at experimental group.

Table 3b shows univariate values for analysis of covariance between the experimental and control group at the final measuring with a neutralization of the differences in the area of eccentric-concentric muscle work from the initial measuring. A statistically significant intergroup difference is noted (P= <.01) in favor of the experimental group for all tests of explosive strength – jumping type: Countermovement jump (COUNT .000), Abalakov jump (ABAL .000), Drop jump (DROP .000) and Star jump (STAR .000).

DISCUSSION AND CONCLUSION

It is important to organize the learning process well and to give to the students the opportunity for high-quality practice, taking the relatively small number of classes of physical education into consideration and the fact that for most students it is the only source of physical exercise and organized sporting activity. This situation will contribute to development of their physical skills which are important not only to attend lectures, but represent an existential factor of human life. It is necessary to physically enable students and to direct practice towards optimizing and not to sport maximum (Višnjić, Jovanović & Miletić, 2004).

Possessing a certain genetic structure, a man has a different level of physical resources that are constantly evolving and improving during the biological maturation, from period of the infants to adults, faced with the demands of everyday life. As a conscious activity, development of physical abilities affects body readiness for work and creativity, and explosive strength has its share of the process. However, it is important to know the laws and mechanisms of its development, as well as the phase of increased sensitivity ranging from 9 to 12 and from 14 to 18 for the boys and 10 to 12 and 16 to 17 for the girls. In teaching practice, a teacher is obliged to respect the basic rules of developing explosive strength, such as frequency of exercise, order of exercises, tempo training, optimal posture. In working with children it should be careful with developing of this capability, because the bone growth during development is very sensitive. Increasing of muscle mass also plays an important role, because it is not always in line with the development of bones, especially during puberty. During this period, a sudden increase in muscle mass occurs, because of greater amounts of testosterone and increased protein synthesis.

Explosive strength indicated by jumping performance researches exist at different categories and ages of subjects: sedentary adults (Herrero et al., 2006, González-Rave et al., 2009), athletes (Gerodimos et al., 2008; McBride et al., 2008; Weber et al., 2008) physical education students (Marković et al., 2007; De Villareal, Gonzalez-Badillo & Izquierdo, 2008). The conclusions of these studies indicate positive effects of different forms of exercise in explosive strength indicated by jumping performance, as well as some guidelines regarding its effective assessment through different types of tests and their modifications.

In order to pay more attention to this issue at high school students, this study was aimed to determine the effects of continuous quarterly performance of the experimental program for developing explosive strength indicated by jumping performance in vertical direction. Results showed that carried out exercise had statistically significant effect on level of explosive strength indicated by jumping performance at experimental group students.

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