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Original empirical article

DIFFERENCES IN MANIFESTED EXPLOSIVE STRENGTH TESTED BY MEANS OF THE VERTICAL JUMP WITH AND WITHOUT PREVIOUS STATIC STRETCHING

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Saša Bubanj, Tomislav Okičić, Mladen Živković, Ratko Stanković, Ivana Bojić, Radoslav Bubanj

Faculty of Sport and Physical Education of University of Niš, Niš, Serbia

Abstract. *Explosive strength is the motor ability of an athlete, which is manifested by the one-shot, acyclic, maximum muscle strain. The vertical jump is a test of muscle strength of the lower extremities. With the aim of increasing performance, reducing the risk of injury and increase the amplitude of the movement in athletes, many coaches recommend and implement static stretching in the training process, just before the competition. The aim of the current study was to determine the differences in manifested explosive strength, under the conditions with and without the use of passive static stretching, just before the physical activity. The sample consisted of 17 male subjects, students of the Faculty of Sport and Physical Education in Niš, divided into an experimental sub-sample (Nes = 7) and a control sub-sample (Ncs = 10). The subjects performed a vertical jump, the so-called Countermovement Jump, during the initial and final measurement. The results of the actual research indicated that the static stretching had neither a negative nor positive impact on the manifested explosive strength, i.e., success of the subjects in the vertical jump. As a precaution, i.e. with the aim of reducing the possibility of a potential injury, the recommendation for athletes is to apply static stretching exercises before a certain physical activity.*

Key words: *explosive strength, countermovement jump, static stretching, initial-final measuring, differences.*

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Corresponding author: Saša Bubanj
Faculty of Sport and Physical Education, University of Niš, Čarnojevićeva 10A, Niš 18000, Serbia
Tel: + 381 (0)18 510 900 (ext. 201) • Fax: + 381 (0)18 42 482 • E-mail: bubanjsasa@yahoo.co.uk

INTRODUCTION

Explosive strength is the motor ability of athletes, manifested by the one-shot, acyclic, maximum muscles strain. Muscle strength depends on the physiological component, the length of the muscle, biochemical processes that take place during work and the metabolism. On the other hand, the mobilization and regulation in the application of muscle strength significantly depends on the central nervous system, the activity of the cerebral cortex of the brain, and to a large extent, the dominance of the motivation. Power is applied in a variety of sports activities, and thus there are different kinds of action manifestation of this motor ability. Explosive strength represents the ability which allows an athlete maximum acceleration of his body toward an object or a partner (Bubanj, R. and Branković, M., 1997). Explosive strength is manifested in modern sports which are dominated by techniques of one-foot and two-foot takeoff jumps (Milić et al., 2008). It is particularly important in athletic throwing, the high jump, long jump and sprint. The amount of manifested explosive strength depends on the percentage and composition of the activated motor units in the corresponding muscle group (Bubanj, R. and Branković, M., 1997). Zatsiorsky (1995) introduced the eccentric (stretching) and the concentric (shortening) phase of muscle fibers into the definition of explosive strength. According to Zatsiorsky, the concentric phase should follow the eccentric one in the shortest time possible. Authors Komi and Gollhofer (1997) reported in their research that the quality of the eccentric-concentric contraction depends on three conditions: 1) forehand activation of the muscles, immediately before the eccentric contraction; 2) short duration of the eccentric contraction; 3) the current transition from the phase of the elongation to the phase of the shortening of muscle fibers. To increase performance, reduce risk of injury and increase the amplitude of the athlete's movements, many coaches recommend and implement static stretching in the training process, just before the competition (Smith, 1994; Shellock and Prentice, 1985). Even the National Strength and Conditioning Association (NSCA) states that static stretching immediately before a competition positively affects the performance and the functional abilities of the athletes (Power et al., 2004). However, studies conducted by Taylor et al. (2009); Brandenburg (2008); Unick et al. (2005); Young and Behm (2003); Cornwell et al. (2001); Knudson et al. (2001), indicated a negative influence of static stretching on the vertical jump height, i.e., explosive strength. The Countermovement Jump (CMJ) represents a plyometric exercise for the lower body. The purpose of its application is to improve the reactivity and explosive strength of the lower body. An athlete takes the upright position with his feet positioned apart at shoulder width and with his hands placed on his hips (in order to reduce arm swing). The mentioned position is followed by a quick descend into the half-squat. Then, the athlete performs a vertical jump. At the landing, the athlete quickly descends into half-squat and jumps again, with minimum contact effectuated with the ground (Bubanj, S. et al., 2010a; Brown et al., 2004). The aim of the current study was to determine the differences in manifested explosive strength under the conditions with and without the application of passive static stretching immediately prior to physical activity.

METHODS

The sample of subjects consisted of 17 male students of the Faculty of Sport and Physical Education from Niš, engaged in different sport disciplines. The main criterion for the inclusion of the subjects in the research was the absence of injury or illness, which could negatively affect their health status and the results of the research. The sample of subjects (N=17) was divided into an experimental sub-sample (N_{es}=7) and a control sub-sample (N_{cs}=10). The experimental sub-sample included subjects with following mean values of age 23.71±1.11 years (Mean±STD), body height 183.57±6.92 cm (Mean±STD), body weight 77.43±6.68 kg (Mean±STD) and the following number of training sessions per week 3.86±4.10 (Mean±STD). The control sub-sample included subjects with the following mean values of age 23.80±1.81 years (Mean±STD), body height 182.60±4.72 cm (Mean±STD), body weight 81.60±6:47 kg (Mean±STD) and the following number of training sessions per week 3.40±3.37 (Mean±STD). For the purpose of explosive strength assessment, a reliable device, the "Myotest", which utilizes the technology of the three-dimensional accelerometry, was used (Bubanj, S. et al., 2010b). The sample of variables obtained after the vertical jumps, the so-called Countermovement Jumps (CMJ), consisted of the following: Height (expressed in cm); Power (expressed in W/kg); Force (expressed in N/kg) and Velocity (expressed in cm/s). The "Myotest" device measures the height of a vertical jump by using the flight time (Myotest, n.d.). All of the subjects were familiar with the aims of the research which was conducted in accordance to the Helsinki Declaration. All of the subjects gave their written consent for the participation in the proposed project. The measuring took place in the sports hall of the Faculty of Sport and Physical Education in Niš. The research consisted of an initial and final measuring. During the initial measuring, as part of the introductory part of the training, following the warming protocol which was conducted without static stretching exercises, all of the subjects performed the CMJ. During the final measuring (two weeks later) as part of the introductory part of training, following the warming protocol (including passive static stretching, performed only by the subjects of the experimental sub-sample), all of the subjects performed the CMJ. Between the two measurings, the subjects of the experimental sub-sample were instructed to apply static stretching exercises in the introductory phase of theirs sport activities, while the subjects of the control sub-sample were instructed to avoid the aforementioned exercises. The warming protocol included: the 800m smooth run, 4x30m skipping forward, 4x30m lateral skipping and 4x30m skipping backwards. The protocol of the passive static stretching involved exercises for the leg and back muscles, with the help of partner. During each stretching exercise, the range of movement increased, until the subject, who was exposed to the stretching, began to feel discomfort due to the stretching. The position in which the subject was in at the time, was maintained for the next 30s. Between the stretching exercises there was a 20-30s break, with the aim of resting the muscles, and the whole complex of stretching exercises was repeated four times. The subjects took part in the measuring in a row, one after the other and carried around the waist a specially designed belt, to which the earlier mentioned "Myotest" device was attached. All of the subjects performed five vertical jumps (CMJ), as described in the introduction. Each subject was instructed that there should be no variation in the take-off spot and the landing spot, i.e. that the jump viewed on the sagittal plane should have the appearance of a vertical shot. During the testing, there was no risk of injury due to the effects of certain external forces, but the subjects were aware of the effects of the myotatic reflex, which is a risk factor in such conditions, especially in the case of subjects who do not apply static stretching and use the plyometric exercises (including the subjects of experimental group at the initial measuring and the subjects of control sub-sample at both measurings). In order to examine explosive strength, and determine the values of the analyzed variables, we used the "Myotest" device software. For the statistical analysis of the data and the interpretation of the results, the "SPSS version 13" software was used. The results are expressed through descriptive statistics, while the t-test was used to establish the statistically significant difference between the variables.

RESULTS

The descriptive statistics of the subjects are shown in tables 1 and 2.

Table 1 Descriptive statistics of the experimental sub-sample at the initial (i) and final (f) measuring

	N	Minimum	Maximum	Mean	Std. Deviation
height_i	7	36.40	43.30	40.03	2.56
power_i	7	50.50	67.40	57.56	5.98
force_i	7	24.28	35.40	28.17	3.85
velocity_i	7	267.00	292.00	280.00	9.20
height_f	7	36.00	44.30	38.64	2.64
power_f	7	47.30	64.10	56.54	5.83
force_f	7	21.40	35.30	28.66	5.09
velocity_f	7	226.00	291.00	268.86	20.10
Valid N (listwise)	7				

Table 2 Descriptive statistics of the control sub-sample at the initial (i) and final (f) measuring

	N	Minimum	Maximum	Mean	Std. Deviation
height_i	10	28.90	52.30	40.71	6.10
power_i	10	49.80	67.50	57.80	4.83
force_i	10	25.00	29.70	27.79	1.46
velocity_i	10	238.00	320.00	281.50	21.31
height_f	10	30.10	53.90	40.92	6.34
power_f	10	47.00	73.00	57.81	7.65
force_f	10	23.80	31.30	28.10	1.98
velocity_f	10	243.00	325.00	282.50	21.85
Valid N (listwise)	10				

The descriptive statistics show that the subjects of the control sub-sample achieved better results (mean values), compared to the subjects of the experimental sub-sample in almost all of the variables at the initial, as well as at the final measuring (except for force_i (N/kg): 27.79 vs. 28.17; force_f (N/kg): 28.10 vs. 28.66), and that the subjects of the experimental sub-sample acheived better results (mean values) under the conditions of the initial measuring, compared to the conditions of the final measuring (except in force_i (N/kg): 28.17 vs. force_f (N/kg): 28.66). The results of the t-test are shown in tables 3, 4, 5 and 6.

Table 3 Differences in the values of explosive strength variables between the initial (i) and the final (f) measuring in the case of the subjects of the experimental sub-sample, established by the use of the t-test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	height_i - height_f	1.39	3.18	1.20	-1.56	4.33	1.15	6	.29
Pair 2	power_i - power_f	1.01	6.50	2.46	-4.99	7.02	.41	6	.69
Pair 3	force_i - force_f	-.489	2.52	.95	-2.82	1.84	-.51	6	.63
Pair 4	velocity_i - velocity_f	11.14	16.59	6.27	-4.20	26.48	1.78	6	.13

Table 4 Differences in the values of explosive strength variables between the initial (i) and the final (f) measuring in the case of the subjects of the control sub-sample, established by the use of the t-test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	height_i - height_f	-.21	2.54	.80	-2.03	1.61	-.26	9	.80
Pair 2	power_i - power_f	-.01	3.56	1.13	-2.56	2.54	-.01	9	.99
Pair 3	force_i - force_f	-.31	1.94	.61	-1.70	1.08	-.51	9	.63
Pair 4	velocity_i - velocity_f	-1.00	8.79	2.78	-7.29	5.29	-.36	9	.73

The t-test results (tables 3 and 4) show that the differences in the values of the explosive strength variables in relation to the initial and the final measuring were not statistically significant ($p>.05$), either in the case of the experimental sub-sample, or the control sub-sample.

Table 5 Differences in values of explosive strength variables between the subjects of the experimental sub-sample and the control sub-sample at the initial (i) measuirng, established by the use of the t-test

		t-test for Equality of Means						
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
height_i	Equal variances assumed	-.28	15	.79	-.68	2.46	-5.93	4.57
power_i	Equal variances assumed	-.09	15	.93	-.24	2.62	-5.83	5.35
force_i	Equal variances not assumed	.25	7.22	.81	.38	1.53	-3.21	3.97
velocity_i	Equal variances assumed	-.17	15	.86	-1.50	8.62	-19.88	16.88

Table 5 Differences in values of explosive strength variables between the subjects of the experimental sub-sample and the control sub-sample at the final (f) measuring, established by the use of the t-test

		t-test for Equality of Means						
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
height_f	Equal variances assumed	-.89	15	.39	-2.28	2.56	-7.73	3.17
power_f	Equal variances assumed	-.37	15	.72	-1.27	3.44	-8.60	6.06
force_f	Equal variances not assumed	.28	7.282	.79	.56	2.02	-4.19	5.31
velocity_f	Equal variances assumed	-1.31	15	.21	-13.64	10.43	-35.87	8.59

The t-test results (tables 5 and 6) show that the differences in values of the explosive strength variables in relation to the initial and the final measuring between the experimental and the control sub-sample were not statistically significant ($p>.05$).

DISCUSSION

Many conclusions regarding the effects of static stretching were based on unsystematic observation, rather than on scientifically based facts (Thacker et al., 2004). The results of the actual research are in accordance with the results of the research conducted by Dalrymple et al. (2010). On the other hand, the results of the studies carried out by La Torre et al. (2010); Nelson et al. (2005), indicated the negative effects of static stretching on the manifested explosive strength. Authors Young and Behm (2003); Cornwell et al. (2001) stated that in explosive sports disciplines, which require the participation of both lower extremities, static stretching applied to only one extremity can negatively affect the ultimate success of the athletes. The authors explained this phenomenon, i.e., the negative impact, by the reduction in the muscle-tendinous stiffness. Namely, the stretching-shortening cycle of the specified unit decreases the amount of elastic energy that is stored and kept in the muscle-tendinous unit and used for the explosive strength (Magnusson et al., 1996; Rosenbaum and Hennig, 1995). The use of the elastic energy that is stored and then used as energy for the work is an important metabolic mechanism (Winters and Woo, 1990). Potential energy and kinetic energy can be stored as elastic energy in the tendons, after which the elastic energy is exempted in order to exert positive work (as in the principle of cycles of walking). The Achilles tendon is one of the most studied structures, and previous research indicated that almost 50% of the total working energy is stored in the aforementioned tendon and the arches of the foot in the stance phase of the run (Ker et al., 1987). It is assumed that other tendons that are quickly stretched in response to the load (e.g., the tendon of the knee articulation during the movement, the extension) play an important role in storing of elastic energy (Roberts, 2002). Not only do the tendons store elastic energy and transform it into the working energy, they also reduce the velocity of the muscle fibers shortening. The aforementioned process increases the efficiency of the contraction, i.e., it reduces the corresponding metabolic claim (Roberts, 2002). Author Moore (1984) explained the negative impact of static stretching from the neurological aspect. The Golgi tendon organ (GTO) is located at the insertion of the skeletal muscle fibers into the tendons of the skeletal muscle and it sends information about the tendon's tension or the quantity in tension changes. The GTO is used entirely or almost entirely, for internal muscle control (Guyton and Hall, 2008). It is believed that GTO inhibition is a protective mechanism that prevents self-injury of the muscle, due to the exceed muscle contraction. A consequence of GTO inhibition is that the person is not able to maximize muscle contractions (as much as necessary).

CONCLUSION

The results of the current study indicated that static stretching had neither a negative nor positive impact on the manifested explosive strength, i.e., success of the subjects in the vertical jump performance. The results may encourage professional and recreational athletes, their coaches, as well as physicians and patients, to use static stretching, immediately prior to the physical activity (before the competition and during the process of recovery), precautions with the aim of reducing the possibility of potential injuries and increasing the range of motion in certain articulations. And if stretching should have only static or even dynamic character, the issue is which should be the subject of future research.

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RAZLIKA U EKSPLOZIVNOJ SNAZI TESTIRANOJ VERTIKALNIM SKOKOM SA I BEZ PRETHODNOG STATIČKOG ISTEZANJA

Saša Bubanj, Tomislav Okičić, Mladen Živković, Ratko Stanković, Ivana Bojić, Radoslav Bubanj

Eksplozivna snaga je motorička sposobnost sportiste koja se ispoljava kroz jednopotezno, aciklično maksimalno naprezanje mišića. Vertikalni skok je test snage donjih ekstremiteta. Da bi se poboljšala izvodljivost, smanjio rizik povrede i povećala amplituda pokreta atletičara, mnogi treneri preporučuju i uvode statičko istezanje tokom treniranja pred takmičenje. Cilj aktuelnog istraživanja bio je da se odrede razlike u ispoljenoj efektivnoj snazi u uslovima sa i bez primene pasivnog statičkog istezanja pre fizičke aktivnosti. Uzorak ispitanika se sastojao od 17 muškaraca, studenata Fakulteta sporta i fizičkog vaspitanja iz Niša, podeljenih u eksperimentalni subuzorak (Nes = 7) i kontrolni subuzorak (Ncs = 10). Ispitanici su prilikom inicijalnog i finalnog merenja izvodili vertikalne skokove, tzv. skok sa počučnjem. Rezultati aktuelnog istraživanja pokazali su da statičko istezanje nije imalo ni negativan ni pozitivan uticaj na ispoljenu eksplozivnu snagu, tj., uspeh učesnika u vertikalnom skoku. Predostrožnosti radi, tj., sa ciljem da smanje mogućnost potencijalnih povreda i da povećaju opseg pokreta u određenim zglobovima, preporuka sportistima je da primenjuju vežbe statičkog istezanja.

Ključne reči: *eksplozivna snaga, skok sa počučnjem, statički strečing, inicijalno-finalno merenje, razlike.*