SPORT - Science & Practice, Vol. 3, №1, 2013, pp. 17-27

Original scientific paper

THE IMPACT OF PLYOMETRIC TRAINING ON THE EXPLOSIVE POWER OF THE LOWER EXTREMITIES OF HANDBALL PLAYER

UDK 796.322.015.136.527

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Abstract: Plyometrics are the modern method that allows individuals a greater power in development than it is possible by using strength training. Explosive power is expressed through the explosive jumping ability of the respondent's neuromuscular system in order to express muscle strain in the shortest time interval. The case study had the aim to determine the effect of plyometric training on the explosive strength of the lower extremities measured by the Myotest. The purpose of the study was to determine the differences between the groups at the initial and final measurement. The study included 30 male respondents, the average age of 20.63 ± 1.58 (Mean ± St. Dev.). Using the Myotest and (CMJ), determined were the following: Height (in cm), Power (in W/kg), Force (in N/kg), and Velocity (acceleration in cm/s). The MANOVA-method was used, and it was reused for repeated measurements. We can conclude that there were no significant differences between the groups at the initial measurements p=0.102 on the multivariate level, as it is in the case of the univariate level height, p=0.130, p=0.906 power p=0.262; velocity, p=0.851, p>0.005. In the final analysis, a statistically significant difference during the initial p=0.002 in the multivariate level was found. The multivariate consisted of Height p=0.009, Power p=0.015. We concluded that at the initial measurement, the group membership did not affect any of the above variables, while at the final measurement it had a partial influence on Height p=0.009, Force p=0.015, an observer at univariate level, while at the multivariate level membership of the group had a large impact on the final measurement. It is recommended, therefore, to implement this program in all sports where a significant explosive power of the lower extremities is important, as concentric-eccentric contractions make an important contribution to the development of the same.

Keywords: *explosive power, Myotest, plyometrics, strength, force.*

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INTRODUCTION

A simple name for the combination of speed and strength is force. For a longer period of time the experts have been trying to increase explosive power using exercises such as jumping, leaping, hopping and throwing. Increasing power and explosiveness by concentric - eccentric contractions is called the plyometric method. Plyometrics is a modern method of working out that allows individuals a greater power development than it is possible by using a simple muscle contraction. The name plyometrics is derived from the Greek word *pleythyein*, meaning increase. Some of the coaches call this method a "shock training method". This term involves stimulating the muscles with the help of a sudden muscle stretching that precedes every voluntary effort. It is a method of mechanical shock that stimulates muscles to create the greatest possible tension (Herodek, 2006). For the implementation of this program the basic props are required: plastic cones, boxes, hurdles, different obstacles, stairs, medicine balls (Nejić, Herodek and Mutavdžić, 2009).

The mechanical traits of plyometric muscle contractions are very important in knowing muscle functions. An eminent mechanical part of the plyometric contractions, along with viscose and contract components, are parallel elastic components. These represent the elastic capacity of the muscle tissue, and according to some authors, one of the important parts is also a serial elastic component in muscle tendons.

Explosive power expressed through explosive jumps is defined as the ability of the respondent's neuromuscular system to express muscle strain in a minimum time interval (Verhosanski, 1979). Vertical jumps and hops are often used to increase the explosive power of the lower extremities (Ebben, 2005). The vertical jump is a specific example of the application of muscle strength in eccentric-concentric conditions that occur in a variety of cyclic, acyclic, and mixed-motor situations. As noted above, the Myotest is a device the size of an MP3 player, a wireless accelerometer and is therefore very applicable in practice. The Myotest automatically processes and analysis the data mean values of the variables tested. The obtained data is transferred to a computer and analysed trough Myotest Pro Software (Ignjatović, Stanković, Radovanović, and Purenović, 2009). The subject of this research was to determine the effect of plyometric training on the explosive strength of the lower extremities measured by the Myotest. The aim of the study was to determine the differences between the groups at the initial and final measurement, and to determine the differences within the groups also at the initial and final measurement.

Marković (2007) in a meta-analysis examines the influence of plyometric training on vertical jumps. Some 26 papers and 1024 respondents were involved in the meta-analysis. As many as 15 papers give positive results of connectivity. Plyometric training has a positive effect on all types of vertical jumps: the half-squat jump (CMJ) - 8.7%, a jump from the squat (SJ) - 4.7%, drop jumps (DJ) - 4.7%, and a jump from a half-squat with arms swinging (CMJA) - 7.5 %. Based on the meta-analysis, we can conclude that plyometric training has a greater impact on eccentric-concentric CMJ jumps, CMJA compared to DJ and SJ, but with very little statistical significance.

Fatouros et al. (2000) examined the impact of a twelve-week long training of plyometrics, strength and combined plyometric and strength training on the vertical jump. Some 41 participants participated in the study, where ten participants made a control group which did not exercise, 11 participants were the plyometric group, and a group of ten individuals were involved in strength training and ten participants were in the combination group. The participants had been practicing three times a week. In the group that was involved in strength training, for the first 8 weeks they were doing classical gym exercises, squats with a load, and the last 4 weeks half-jump exercises with a light load. Plyometric training consisted of jumps from a squat, jumps over hurdles, benches, repeated jumps - and all this in combination with working with one or two legs. The length of benches and hurdles during the jumps were from 30 cm to 80 cm. Combined training had first consisted of plyometric exercises, then exercises with load, 180 minutes after training plyometrics. Upon completion of the program, there was a significant improvement of the vertical jump, and the combined group had the best results, while plyometrics and strength training had the worst results. In all groups there was an improvement of the statistical significance ($p < 0.005$).

RESEARCH METHODS

Participants

In the research, some 30 male participants took part, with the mean age 20.63 ± 1.58 (Mean ± St. Dev.) In years, the mean body weight of 74.38 ± 5.60 (Mean ± St. Dev.) expressed in kg, with an average body height 183.45 ± 6.73 (Mean ± St. Dev.) expressed in cm. The participants were divided into two groups, the first group was the control group (K), and made up of 15 participants, while the other experimental groups (E) consisted of 15 participants. All of the participants who were involved in the training process were completely healthy, without any hidden injuries.

Variables

By using the Myotest and execution of the half-squat jump (CMJ) the following variables were identified:

1. Height (height in cm)
2. Power (strength expressed in W/kg),
3. Force (force expressed in N/kg),
4. Velocity (acceleration expressed in cm/s).

Procedures and measurement instruments

The measurements were performed at SRC Dubočica in Leskovac before and after the program. All measurements were performed by the author and co-author of the research. Before measuring, the respondents performed adequate warm-up exercises, which consisted of high and low-skips 2 x 40 meters, lateral leaping from one foot to the other, 2 x 3 vertical jumps, 2 x 3 long jumps. After warming up, the respondents completed an appropriate program of stretching, as it was determined that stretching has a positive impact on explosive power (Smith, 1994). Then they approached the measurement with the aid of the Myotest. The respondents demonstrated CMJ from the initial upright position with hands placed on their hips without swinging and by a slight flexion, as well as an extension of the lower extremities joints. After completing the jump, the respondents waited for a new beep. Each of the subjects performed five jumps while the accelerometer calculated the mean values.

Training protocol

After the initial measurement, the respondents were divided into two groups. The first group consisted of 15 subjects, this being the control group (K), while the other was the experimental group (E) and also had 15 participants. The experimental group was involved in plyometric training for six weeks, with three sessions a week for 45-60 minutes. The respondents were shown in detail all the exercises that were used in the program and were thoroughly familiar with the procedures of the program. The training procedure included only exercises for the legs, and the structure of the training was designed by the training used by Marković, Jukić, Milanović & Metikos (2007) and the instructions of Dodig (2002). The control group attended handball training daily and played at least one game a week. Each training session began with a fifteen minute warm-up, consisting of easy low and high skips, with various hops forward, backward, and sideways. Plyometric training consisted of vertical jumps above the hurdles with knees raised to the chest (hurdle jumps), and deep jumps (drop jumps). Gradually, during the training process there was an increase of the intensity and volume of training. The total number of jumps in the training ranged from 90 to 140 jumps per session (Marković et al., 2007). The pause between each jump was five seconds (the time needed for the respondent to get back to the box after the jump), and the break between series was 2 minutes. With hurdle jumps, the hurdles were placed at a distance of one meter. The experimental group, in addition to plyometric training, regularly attended handball training, same as the control group. Additional exercises were not allowed in both groups. The respondents performed each exercise with maximum intensity.

Table 1. *A detailed training program for each week*

Week	*hurdle jumps*	*drop jumps*
1	40 cm x 5 x 10	40 cm x 4 x 10
2	40 cm x 7 x 10	40 cm x 6 x 10
3	40 cm x 10 x 10	40 cm x 8 x 10
4	60 cm x 5 x 10	60 cm x 4 x 10
5	60 cm x 7 x 10	60 cm x 4 x 10
6	60 cm x 10 x 10	60 cm x 4 x 10
	height x series x reps	height x series x reps

After the completion of the main part of the training, the participants carried out stretching exercises for 5 to 10 minutes. After completing the training process, the test procedure was repeated with a completely identical protocol.

Data processing

All data was analysed in SPSS 11, and the results presented in tables. This paper presents the descriptive statistics, the Kolmogorov-Smirnov test. To determine intergroup differences in the initial and final measurement between groups, the MANOVA-method was used, and the results are shown in the multivariate and univariate level and the MANOVA-method for repeated measurements was used to determine the difference in the experimental and control groups at the initial and final check.

RESULTS

Table 2. *The descriptive statistics of the initial measurements*

	N	Minimum	Maximum	Mean	Std. Deviation
Height (cm) *HeightPost*	30	30.80 *33.00*	53.10 *52.00*	40.8000 *44.4133*	4.95574 *5.15583*
Power (W/kg) *PowerPost*	30	18.60 *18.70*	64.20 *62.00*	38.5700 *41.0933*	10.37315 *11.11293*
Force (N/kg) *ForcePost*	30	17.80 *18.30*	37.50 *36.10*	24.1400 *26.5333*	4.32735 *4.44912*
Velocity (cm/s) *VelocityPost*	30	128.00 *123.00*	285.00 *286.00*	219.6000 *225.8667*	37.87784 *38.49920*
Valid N (listwise)	30				

Table 3. *Multivariate analysis of variance between the K-group and E-group at the initial measurement*

Effect	Value	F	Hypothesis df	Error df	Sig.
Wilks' Lambda	.743	2.166a	4.000	25.000	**.102**

Table 4. *Univariate analysis of variance between the K-group and E-group at the initial measurement*

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Group	Height	142.572	1	142.572	7.008	.013
	Power	1.587	1	1.587	.014	.906
	Force	24.300	1	24.300	1.312	.262
	Velocity	53.333	1	53.333	.036	.851

Table 5. *Multivariate analysis of variance between the K-group and E-group at the final measurement*

Effect	Value	F	Hypothesis df	Error df	Sig.
Wilks' Lambda	.525	5.662a	4.000	25.000	**.002**

Wilks' Lambda – the value of the coefficient for Wilks' test of the of group centroid equality; F – the value of the F-test coefficient for the significance of Wilks' Lambda; Hypothesis df and Error; df – the degrees of freedom; p – the significance of the coefficient of the differences between the centroids

Table 6. *Univariate analysis of covariance between K-group and E-group at the final measurement*

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Group	Height	170.885	1	170.885	7.975	.009
	Power	401.868	1	401.868	3.539	.070
	Force	111.361	1	111.361	6.739	.015
	Velocity	1203.333	1	1203.333	.809	.376

Based on the results in Table 3, we can conclude that there were no significant differences between the groups in the initial Wilks' Lamb = 0.743, F test = 2.166, the degree of freedom Hypothesis df = 4, p = 0.102 at a multivariate level, as is the case in Table 4 at the univariate level Height, p = 0.130, p = 0.906 Power, Force, p = 0.262; Velocity, p = 0.851, p <0.005. In Table 5, in the final analysis, there is a statistically significant difference p = 0.002 in the multivariate level. Regarding the results in Table 6, where they performed a univariate analysis of covariance in the final and initial measurements between groups, we can see that there are no major statistically significant differences between the variables individually - Height p = 0.009, p = 0.015 Force. From this we can conclude that in the initial measurement of the group, the membership does not affect any of the above variables, while in the final there is a partial influence on the Height p = 0.009, p = 0.015 Force, looking at the univariate level, while at the multivariate level the membership of the group has a large impact on the final measurement.

Table 7. *Multivariate analysis of variance for repeated measures with the K group*

Effect	Value	F	Hypothesis df	Error df	Sig.
Wilks' Lambda	.754	1.194[a]	3.000	11.000	.357

Wilks' Lambda – the value of the coefficient for Wilks' test of the of group centroid equality; F – the value of the F-test coefficient for the significance of Wilks' Lambda; Hypothesis df and Error; df – the degrees of freedom; p – the significance of the coefficient of the differences between the centroids

Table 8. *Multivariate analysis of variance for repeated measures with the E group*

Effect	Value	F	Hypothesis df	Error df	Sig.
Wilks' Lambda	.182	18.024[a]	3.000	12.000	.000

Wilks' Lambda – the value of the coefficient for Wilks' test of the of group centroid equality; F – the value of the F-test coefficient for the significance of Wilks' Lambda; Hypothesis df and Error; df – the degrees of freedom; p – the significance of the coefficient of the differences between the centroids

Based on the results in Table 7, we can conclude that there was no statistically significant difference between the results of the initial and final measurements in the control group Wilks' Lamb = 0.754, F test = 1.194, the degree of freedom Hypothesis df = 3, and the significance of p = 0.357, but this is not the case with the experimental group in Table 8, where there was an improvement of the results between the final and initial measurements of Wilks' Lamb = 0.182, the F test = 18.024, the degree of freedom Hypothesis df = 3, p = 0.000.

DISCUSSION

Kotzamanidis (2006) examined the effect of plyometric training on the racing and jumping ability of boys in the pre-puberty period. The respondents were distributed into two groups of 15 children. One group participated in the plyometric program, and the second group of 15 participants consisted of children who regularly attend physical education classes. The ten weeks of the plyometric program consisted of the so-called speed-bound exercises and vertical jump exercises. The number of jumps ranged from 60 to 100, and the height from 10 to 30 cm. Training was administered two times a week, containing a series of 10 reps with a pause between 3-minute series. The variables tested were: the squat jump (SJ), and running speed at 10, 10-20, 20-30, 0-30 meters. After completing the plyometric program, there was an improvement of SJ, r = 0.911, p <0.001., but not at the running speed in which the results of the experimental group were slightly better, although not significantly so. A slight improvement was observed in the control group SJ, p <0,005, but with much less significance.

The effect of plyometric training and strength at sprint and jumping performance was tested by Rønnestad, Kvamme, Sunde, & Raastad (2008). In their study, 21 Norwegian professional football league players participated, divided into three groups of six, eight and seven subjects. The first group did strength training, the second group plyometric training and the third attended soccer practice from 6 to 8 times a week. The programs of plyometric and strength training lasted for eight weeks, twice per week. The total work-outs consisted of 4 to 6 series of exercises. Both programs lasted eight weeks, twice a week. The first two weeks the respondents did three series, from 3 to 5 weeks the number of sets increased to four, and the last week the respondents did five series. The plyometric program consisted of jumps with one foot forward, step deep foot forward and jumping over hurdles (hurdle jumps). The series ranged between 2-4 and the number of repetitions was 5-10. The results showed that there were no statistically significant differences between the experimental groups, but there were differences between the control and experimental groups. The maximum squat strength (1RM) in the experimental group showed an increase of 25%, and in the control group 2.5% (p <0.001), the jump from a half-squat with load of 20 kg (), 35 kg (), 50 kg (), while the tensiometric panel showed a significant difference, an improvement with the experimental group (p <0.001), while the progress of the control group was only (p = 0.002). The test of the horizontal vertical jump with four rebounds where the total length of the jumps (4BT) was measured showed that the experimental group had an increase in length of the vertical jump by 4%, p <0.001, and 0% for control, and the differences between the groups had high statistical significance of p = 0.001. At (CMJ) there were no significant difference in the jump from a squat (SJ) which showed improvement in both groups, p = 0.002, experimental and control p = 0.003.

The results of these studies are consistent with the results of plyometric training, where they found a high statistical significance in the difference between the final and initial measurements in the experimental group. There are a number of studies proving the effectiveness of plyometric training in the explosivity of the lower extremities (Adams, O'Shea, O'Shea, & Climstein 1992; Faigenbaum et al., 2007; Campo et al., 2009; Shaji & Isha, 2009), which also compare the performance of plyometrics with strength exercises or combined training.

CONCLUSION

This research determined the effect of a six-week plyometric program on variables obtained at CMJ handball players. A total of 30 participants were divided into two groups, control and experimental. There were no differences between the groups at the initial measurement of $p = 0.102$, but this was not the case at the final measurement $p = 0.002$. Also, the differences within the groups themselves were observed between the initial and final measurements, control group $p = 0.357$, $p = 0.000$ experimental group. All these results and the results of previous research (Markovic, 2007; Fatouros et al., 2000; Rønnestad et al., 2008; Kotzamanidis 2006), show us the significance of the impact of the plyometric program on the explosive power of the lower extremities.

Therefore, an implementation of this program in all sports where a significant explosive power of the lower extremities is important is recommended, due to the fact that concentric-eccentric contractions contribute greatly to the development of the same.

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