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Original empirical article

THE EFFECT OF PLYOMETRIC CIRCUIT EXERCISES ON THE PHYSICAL PREPARATION INDICES OF ELITE HANDBALL PLAYER

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Abstract. *The aim of this research was to find out the effect of plyometric circuit exercises on the physical preparation indices of elite handball players in the city of Behbahan. A total of 20 elite male athletes (aged 17-19) participated in this research. The participants were chosen non-randomly from a population of high school male students and they participated in four tests (the vertical jump - shuttle briskness – the medicine ball throw – the 30 meter speed run). After making them homogeneous, the participants were randomly divided into two groups, i.e. an experimental group (plyometric circuit exercises) and a control group (only handball exercises). They participated in the exercises for 6 weeks with 3 sessions each week and each session lasted for 90 minutes. After completion of the course, both groups participated in a post-test. The participants' records were registered in 4 pre- and post-tests and compared. The results of the study revealed that 6 weeks of plyometric circuit exercise have a meaningful effect on the participants' records in four tests (the vertical jump - shuttle briskness – the medicine ball throw – the 30 meter speed run) and have caused improvements in the results of these four tests. Therefore, it seems that plyometric circuit exercises have had an effect on the physical preparation indices of handball players and can improve the athletes' performance in this field.*

Key words: *plyometric exercise, circuit exercise, handball.*

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INTRODUCTION

In the past few years, athletic performance has improved considerably. The number of athletes who are able to get prominent results has increased (Boumpa, 2010). However, in the 21st century, it is difficult to break sports records unless novel exercises replace previous methods. Therefore, conducting research according to the facts and findings of Biological Sciences is very significant (Shahdadi, 1999). Athletes have tried different methods of improving their abilities of running faster and throwing an object higher and farther to the maximum possible extent. Perhaps one of the most successful methods is the one that involves plyometric exercises (Boumpa, 2005). Plyometric exercises first appeared in coaching texts in the 1960s (Radcliffe and Farentionos, 1999). In plyometric exercises, the sudden lengthening and shortening of muscle length by the contraction and stretching of muscles result in a rapid release of energy stored in the muscles, as a result of which these exercises simultaneously enhance three important abilities, i.e. power, speed, and endurance (Khorrami, 1997). On the other hand, for the exercises in which muscle strength is a major factor and cardiorespiratory endurance is a minor factor (handball, wrestling, sprints, etc.), circuit exercises including resistance training with weights are appropriate. It is worth noting that in the case of resistance stations with weight, the weight should be adjusted so that the active muscles become considerably tired after doing repeated exercise within a specified period of time, e.g. 30 seconds (Fox and Mathews, 2007), so the athlete receives optimum pressure. Researchers have carried out many studies to investigate the effect of these exercises on the physical preparation indices and they have drawn different conclusions. After conducting research, Conroy (1998) concluded that plyometric exercises did not lead to a significant difference between a control and experimental group in terms of improvement in the vertical jump. Jensen and Ebben (2003) emphasized that plyometric exercises not only do not improve the participants' vertical jumps, but they also make their vertical jumps weaker. However, other research demonstrates that plyometric exercises have a positive effect on the vertical jump and increase it (Miller, Berry, Bullard, and Gilders, 2002; Potach, Katsavelis, Karst, Latin, and Stergiou, 2009; Rubley, Haase, Holcomb, Girouard, and Tandy, 2011; Sedano, Matheu, Redondo, and Cuadrado, 2011; Sedano, Vaeyens, Philippaerts, Redondo, De Benito, and Cuadrado, 2009). Salehi Golsefidi (2000) in his study also reported that plyometric exercises were not effective in terms of the amount of shuttle briskness nor did they decrease the time needed for it performance. Some other research showed that plyometric exercises have been effective on shuttle briskness (Faigenbaum et al., 2007; Martin, and Lue-Chin, 2010; Thomas, French, and Hayes, 2009). Moreover, some research revealed the positive effect of these exercises on throwing a medicine ball and increasing its distance (Marques, Tillaar, Vescovi, and Gonzalez-Badillo, 2008; Santos, and Janeira, 2011; Schult-Edelmann, Davies, Kernozek, and Gerberding, 2005; Sedano, Matheu, Redondo, and Cuadrado, 2011, Sedano, Vaeyens, Philippaerts, Redondo, De Benito, and Cuadrado, 2009). Finally, Conroy (1998); Robinson, Devor, Merric, and Buckworth (2004); Thomas, French, and Hayes (2009); Zahedi-asl (2009) came to the conclusion that plyometric exercises do not have a significant effect on the athletes' speed and do not decreased their time. However, other studies have drawn different conclusions regarding the effect of these exercises (Chelly et al., 2010; Kotzamanidis, 2006; Meylen, and Malatesta, (2009); Sedano, Matheu, Redondo, and Cuadrado (2011). It is worth indicating that some important and extremely common activities in handball include: jumping and shooting over the head of the opponent into the goal (Shahdadi, 1999), the player's shooting at a speed of more than 70 miles per hour (Amirtash, 2006), rapid redirecting (briskness), and passing the opponent around 6 and 9 meter lines of the handball court and 30 meter speed, which are effective features for elite handball players to execute counterattacks (Agha and Ghahremanloo, 2007). All of these abilities have a considerable impact on the final result of a match and they are proper predictors of successful performance in handball which will determine the winner and the loser. Accordingly, the research question is the one whether doing plyometric circuit exercises is effective for the performance of elite handball players? Therefore, the current research has been conducted to determine an answer to this question and clarify the differences in the scientific results and findings and obtain adequate information about the effect of plyometric exercises on the physiological features of elite handball players.

THE METHOD

In this study, an experimental research method based on a pre-test and post-test scheme with a control group has been used. The experimental and control groups were homogenized randomly and before applying experimental interventions for the experimental and control groups, a pre-test was administered and post-test was also conducted at the end of the intervention. The difference between the results of the pre-test and post-tests with respect to statistical significance was considered. In this regard, plyometric circuit exercises were applied, as the independent variable, to identify their effect on the physical preparation of elite handball players, as the dependant variable. The sample population of this study included all of the young handball players at the high school level in Behbahan in 2010. Out of the sample population, 20 players were non-randomly selected to be the participants, and they were randomly divided into two groups of ten people: the experimental group (plyometric circuit exercises) and the control group. In order to analyze the data, Descriptive Statistics in terms of frequency, percentage, means, and standard deviation, the Levine test (to assess the equality of variances of the variables), the Kolmogorov-Smirnov test (to consider the normal distribution of the scores in the population), and the analysis of covariance (ANCOVA) were used. The significance level for all of the hypotheses was chosen to be $\alpha=0.05$.

In order to familiarize the participants with the test implementation phases, at first they were asked to participate in the pre-test, while adhering to the warm-up rules, and their scores were recorded. For the purpose of grouping, the participants were homogenized and randomly classified into two groups, i.e. the experimental group (plyometric circuit exercises) and the control group. It should be noted that the control group participated only in the handball exercises and experimental group performed plyometric circuit exercises and joined the control group in the end. They participated in the exercises for 6 weeks, with 3 sessions per week, each lasting 90 minutes. In the first three weeks, the training program was carried out with a fixed weight and after the third week, adding weight was applied to the number of sets and repetitions. The control group only did handball exercises three sessions per week.

RESULTS

The important findings of this study revealed that plyometric circuit exercises for a period of six weeks had a significant effect on the vertical jump, shuttle briskness, medicine ball throw, and the 30-meter run (Table 5). The other results from the study are as follows:

Table 1. Mean, Standard Deviation, Min, and Max of height and weight of the experimental and control group.

Variable	Statistical index → Group	Mean	Sd	Min	Max	Number
Height (Centimeter)	Experimental	177/40	4/92	171	185	185
	Control	177/60	6/02	0/168	191	191
Weight (Kilogram)	Experimental	77/00	11/30	57	88	88
	Control	77/40	13/85	60	100	100

Note: Sd= Standard Deviation

As it can be seen in Table 1, the Means and Standard Deviation of the height of the players of the experimental group are 177/40 and 4.92 centimeter respectively, and for the control group are 177.60 and 6.02, respectively. The Means and Standard Deviation of their weight are 77.00 and 11. 30 for the experimental group respectively, and for the control group are 77.40 and 13.85 kg.

Table 2. The results of physical preparation indices of the experimental and control group during the pre-test and post-test.

Variable	Phase	Statistical index → Group	Mean	Sd	Min	Max	Number
Vertical jump	Pre-test	Experimental	47/48	1/32	45/7	49/4	10
		Control	47/33	1/47	45/2	49/8	10
	Post-test	Experimental	54/66	0/748	53/2	55/7	10
		Control	50/54	1/46	49/2	52/8	10
Shuttle briskness (4×9)	Pre-test	Experimental	9/39	0/149	9/22	9/75	10
		Control	9/50	0/246	9/28	10/00	10
	Post-test	Experimental	9/01	0/147	8/82	9/28	10
		Control	9/39	0/210	9/20	9/95	10
Medicine ball throw (2 kg)	Pre-test	Experimental	6/30	0/514	5/40	6/90	10
		Control	6/46	0/864	5/10	8/30	10
	Post-test	Experimental	7/15	0/395	6/40	7/50	10
		Control	6/39	0/707	5/25	7/20	10
30-meter speed run	Pre-test	Experimental	4/25	0/086	4/13	4/36	10
		Control	4/42	0/429	4/02	5/37	10
	Post-test	Experimental	4/05	0/084	3/97	4/22	10
		Control	4/27	0/244	4/00	4/80	10

Table 3. The Levine test results regarding score variance equality and the research variables of two groups in the sample population.

Variable	F	First degree of freedom	Second degree of freedom	Level of significance
Vertical jump	0/056	1	18	0/815
Shuttle briskness (4×9)	2/18	1	18	0/156
Medicine ball throw (2 kg)	0/945	1	18	0/344
30-meter speed run	11/59	1	18	0/003
Height	0/006	1	18	0/937
Weight	0/101	1	18	0/755

As can be seen in Table 3, the null hypothesis for the equality of variances of the scores of the two groups in the research variables (except for the 30-meter speed run) was confirmed. It means that the hypothesis for variance equality of the experimental and control group's scores was verified. However, when the number of samples is the same, the meaningfulness of the Levine test does not have a significant effect on the nominal alpha level.

Table 4. The Kolmogorov-Smirnov test results for the research variables.

Variable	F	First degree of freedom	Second degree of freedom	Level of significance
Vertical jump	0/056	1	18	0/815
Shuttle briskness (4×9)	2/18	1	18	0/156
Medicine ball throw (2 kg)	0/945	1	18	0/344
30-meter speed run	11/59	1	18	0/003
Height	0/006	1	18	0/937
Weight	0/101	1	18	0/755

The table shows that the level of significance of the test for all of the research variables in the pre-test and post-test is higher than p>0.05. Therefore, the hypothesis of the normality of the scores was confirmed.

Table 5. The results of the one-way covariance (ANCOVA) comparing the means of the post-test of the experimental and control group with a monitoring pre-test.

Variables	Change source	Sum of squares	Degree of freedom	Mean of squares	F	Level of significance	Squares	Statistical power
Vertical jump	Pre-test	11/81	1	11/81	16/03	0/001	0/48	0/965
	Group	81/08	1	81/08	110/10	0/0001	0/86	1/00
	Error	12/51	17	0/736				
Shuttle briskness (4×9)	Pre-test	0/183	1	0/183	7/59	0/014	0/31	0/738
	Group	0/488	1	0/488	20/23	0/0001	0/54	0/988
	Error	0/410	17	0/024				
Medicine ball throw (2 kg)	Pre-test	0/698	1	0/698	2/27	0/150	0/12	0/296
	Group	3/21	1	3/21	10/48	0/005	0/38	0/862
	Error	5/21	17	0/307				
30-meter speed run	Pre-test	0/050	1	0/050	1/51	0/231	0/08	0/217
	Group	0/169	1	0/169	5/17	0/036	0/23	0/573
	Error	0/554	17	0/033				

As can be seen in Table 5, with a control of the pre-test, there is a significant difference between elite handball players from the experimental and control group regarding the vertical jump, shuttle briskness, the medicine ball throw, and the 30 -meter speed run ($p<0.0001$, $F=110.10$). In other words, plyometric circuit exercises, with reference to the means of the experimental group and control group, have caused an increase in the means of experimental group (the vertical jump, shuttle briskness, medicine ball throw, and the 30-meter speed run).

Discussion and Conclusion

The findings of the study revealed that plyometric circuit exercises had an effect on the vertical jump of male handball players and had increased the participants' jump. The results of the current research are consistent with Robinson et al. (2004), Faigenbaum, et al. (2007), Thomas, French, and Hayes (2009), Potach et al. (2009), Sedano et al. (2009), Meylen and Malatesta (2009), Martin and Lue-Chin (2010), Chelly et al. (2010), Santos and Janeira (2011), Sedano et al. (2011), Rubley et al. (2001), Shahdadi (1999), Mohsenzade (2000), Behdari (2004), Haghighi Najafabadi (2007), Eslami (2008), and Zahediasl (2009). The probable reason for the increase in the amount of the vertical jump is that in plyometric circuit exercises, the muscles first encounter outward contractions, followed immediately by inward contractions, which result in developing explosive movement (Gaeini, and Rajabi, 2003). When the muscles are stretched during plyometric exercise, they cause elastic potential energy which is similar to the contracted energy stored in a compressed spring or a drawn arc. Therefore, when this energy is released, the amount of created contraction by the muscle cords increases (Boumpa, 2005) and causes an increase in the vertical jump. Whenever special kinds of sensory messages pass from several consecutive synapses, the next time the synapses can direct that messages more properly, and this process is called facilitation (Guyton, and Hall, 2006). It seems that it develops during the vertical jump, because in these exercises these jumps are done repeatedly. However, these results are not consistent with Conroy (1998) and Jensen and Ebben (2003). One of the probable reasons for this inconsistency can be the duration of the exercise, because Conroy (1998) used four-week exercises in her study, which should last longer, according to Robinson et al. (2004). On the other hand, Conroy's exercises were done twice a week, which seems that three sessions per week bring better results (Salehi Golsefidi, 2000). Jensen and Ebben (2003) also performed plyometric exercises immediately after squat exercises, and it is most likely that the muscles did not have enough time to return to their initial state. When the rest interval is short (1 to 2 minutes), the athlete experiences both the local tiredness and central nervous exhaustion. Due to the fact that doing plyometric exercise is the result of nerve impulses that the central nervous system sends to the active muscles, and these impulses have definite speed, power, and frequency, and the speed, power, and frequency of muscle contraction during exercise should be at the highest possible level so that the desired results are created (Boumpa, 2005), it seems that this matter has not been studied properly. Thus, perhaps the participants performed plyometric exercises with poor quality or without any effect on the stretch rate, because squat exercises put more emphasis on the stretching, while plyometric exercises emphasize the speed of the stretch more (Gaeini, and Rajabi, 2003). Therefore, this issue can be one of the other reasons for the inconsistency between the mentioned study and the current research.

The second finding of the study demonstrates that plyometric circuit exercises had an effect on the amount of shuttle briskness amount and have reduced its time. This finding of the study is in accordance with the findings of Faigenbaum et al. (2007), Thomas, French, and Hayes (2009), Meylen and Malatesta (2009), Martin and Lue-Chin (2010), Shahdadi (1999), Mohsenzade (2000), Behdari (2004), and Eslami (2008). It seems that learning the proper manner of using the muscles and ankle joints while doing skips as a part of plyometric circuit exercises is one of the reasons for this improvement (Zahediasl, 2009), since these muscles have fundamental roles in the shuttle test. On the other hand, plyometric exercises enhance nerve and muscle coordination and increase the briskness of physical abilities which have a significant impact on performing sports skills (Khorrami, 1997). Accordingly, this increase in briskness is probably due to the created changes in the muscular and nervous system. However, these results are not in accordance with the findings of Salehi Golsefidi (2000). Salehi Golsefidi used 21 to 25-year-old university amateur athletes, but in the current study, the researchers included 17 to 19-year-old elite athletes, and based on the fact that skill and age variables are important in obtaining results (Alijani, 2008), it is most likely that this inconsistency is probably due to these aforementioned reasons.

The third finding of the current research revealed that plyometric circuit exercises have had a significant effect on the amount of throwing a medicine ball and have increase the distance of the throw. This finding is consistent with research findings of Schult-Edelmann et al. (2005), Faigenbaum et al. (2007), Marques et al. (2008), Sedano Campo et al. (2009), Santos and Janeira (2011), Sedano Campo et al. (2011). Since triceps brachial muscles involved in this performance are among the fastest muscles in the body, have fast twitch muscle fibers (Fox, and Mathews, 2007) and reach their peak tension in 40 milliseconds (Run Mogan et al., 2009), it is likely that the speed of movement of this part of body genetically predetermined. However, no study was found to have been carried out in and outside Iran which would be inconsistent with this finding. Moreover, in the hand muscles position and elbow joint, and following the principle of leverage, speed levers (the first kind) have been mostly utilized (Thompson, and Floid, 2010) and not power levers (the third kind), so it seems that this is one of the other reasons for the increase in the distance of throwing the medicine ball in plyometric exercises.

The forth finding of the study showed that plyometric circuit exercises have an effect on the 30-meter speed run and reduce its time. This result is in accordance with the findings of Faigenbaum et al. (2007), Meylen and Malatesta (2009), Sedano Campo et al. (2011), Behdari (2004), and Haghighi Najafabadi (2007). It appears that because in plyometric circuit exercise, the speed of converting outward contractions into inward contractions increases, and the created tension in the muscle increases as does the production power of the muscle, therefore reducing the duration of the speed run. Improvements in doing other sports have been partly attributed to outward-oriented training programs and the use of the elasticity feature of muscles (Radcliffe, and Farentionos, 1999). On the other hand, since in plyometric circuit exercise the muscles first encounter outward contractions and then immediately inward contractions, and with the shortening of this phase, stronger inward contractions can be created (Radcliffe, and Farentionos, 1999). The potential energy stored in the fibers, in the inward contraction, is released and a greater number of muscle cords are called into action. However, these findings are not consistent with Conroy (1998), Robinson et al. (2004), Thomas, French, and Hayes (2009), and Zahediasl (2009). It seems that the participants involved in Conroy (1998) and Thomas, French, and Hayes (2009) were amateur or semi-professional athletes, both male and female, but the participants in the current research were selected from a population of elite male players, since skill and gender are two important factors in improving running speed (Alijani, 2008). Moreover, Conroy (1998), Thomas, French, and Hayes (2009), and Zahediasl (2009) included exercises performed twice a week, which would make it seem that three sessions a week will have better results, and places the optimum pressure upon the athlete (28). Nevertheless, Zahediasl (2009) points out that due to the fact that plyometric exercises can be done quite similarly in water and on solid ground, low pressure plyometric exercises have been used, so it is likely that the reason for this inconsistency is the unequal pressure of training in the research. Due to the fact that the activities involve weight bearing on the ground, this places more outward pressure on the lower extremities. Thus, outward pressure will be reduced considerably under floating conditions (Sanders, 2000), and the inward pressure will be increased, since plyometric exercises have a greater effect on outward, not inward contractions (Gaeini, and Rajabi, 2003). Therefore it seems that these factors are the probable reasons for the inconsistency between the findings of the current research and those of studies conducted in aquatic environments. Furthermore, Conroy (1998) has used four weeks of exercises in her study, while according to Robinson et al. (2004), in order to be effective, the exercises need to be longer than four weeks. Since a longer training period and change in the intensity and volume of training can lead to significant improvement in the speed of running, Robinson quotes Brown and his colleagues in saying that the proper time for a greater effect of plyometric exercises is 10 to 16 weeks.

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UTICAJ PLIOMETRIJSKIH VEŽBI NA FIZIČKU SPREMNOST ELITNIH RUKOMETAŠA

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Cilj ovog istraživanja bio je da se utvrdi uticaj pliometrijskih vežbi na fizičku spremnost elitnih rukometaša iz grada Behbahan. 20 elitnih rukometaša (starosti 17-19 godina) je učestvovalo u ovom istraživanju. Ispitanici su odabrani iz grupe srednjoškolaca i učestvovali su u četiri testa (skok u vis – promena pravca – bacanje medicinke – sprint na 30 metara). Nakon što je uzorak ujednačen, učesnici su metodom slučajnog uzorka podeljeni u dve podgrupe, na eksperimentalnu grupu (pliometrijske vežbe) i kontrolnu grupu (samo rukomet). Učestvovali su u programu u trajanju od 6 nedelja, sa tri treninga nedeljno, od kojih je svaki trajao 90 minuta. Nakon završetka tretmana, obe grupe su učestvovale u post testu. Rezultati su im beleženi tokom 4 pre- i post testa a zatim poređeni. Ishod istraživanja bio je da 6 nedelja pliometrijskog vežbanja ima značajni uticaj na učinak učesnika na četiri testa (skok u vis – promena pravca – bacanje medicinke – sprint na 30 metara) i doveo je do poboljšanja u pogledu rezultata postignutih na ova četiri testa. Samim tim, može se zaključiti da su pliometrijske vežbe imale uticaj na fizičku spremnost rukometaša i da mogu doprineti poboljšanju učinka ovih sportista.

Ključne reči: *pliometrijska vežbanja, rukomet*