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The Effects of Plyometric Training on Balance, Anaerobic Power and Physical Fitness Parameters in Handball

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ABSTRACT The aim of this paper was to investigate the effects of a 10-week plyometric training (PT) on static balance (SB-unipedal), dynamic balance (DB-bipedal slalom), anaerobic power (AP) and some physical fitness parameters (PFP). Female handball players (aged: 15.13±0.87 years) were randomly selected into an experimental group (EG; n= 14), and a control group (CG; n= 12). At the begining of the examination, SB-unipedal, DB-bipedal slalom and PFP were measured. Wilcoxon test was used for comparison within groups and Mann-Whitney U test was used for comparison of between groups. Research findings show that the EG made significantly greater improvements than the CG in the SB-unipedal (left), AP, 30-meter sprint, agility, vertical jump (VJ), and horizontal jump (HJ) performances ($p<0.05$). Finally, 10-week PT positively affects SB-unipedal (left), AP, 30-meter sprint, agility, VJ and HJ performances. In order to gain positive results for these parameters, the PT program should be added and applied regularly in handball practice by coaches.

INTRODUCTION

Team handball consists of both, physical fitness parameters (PFP) (that is, strength, speed, endurance, jumping ability) and techical skills (that is, throwing, passing). This sport is known with a large number of explosive movements such as change of direction speed (CODS), therefore, the emphasis should be on the anaerobic capacity of the players, however, the significiance of the aerobic capacity should not be disregarded (Sporis et al. 2010; Zapartidis et al. 2011). Handball players should have excellent physiological characteristics to reach the highest performance level (Ingebritsen et al. 2013; Ingebritsen and Jeffreys 2012; Marques and Gonzales-Badillo 2006; van den Tillaar et al. 2015).

The high performance in various CODS tests in handball players, compared with both general population and higher standarts of handball, indicates that CODS and agility attributes are adventageous for elite handball players. Agility it is often recognized as the ability to change direction and start and stop quickly (Hermassi et al. 2014; Thomas et al. 2009). Sprinting speed is also one of the basic and important characteristics of handball particularly for short distances. Handball players are required to cover distances from 20 to 30 meters with maximal speed in the transition from defense to offense or, after a ball loss, to prevent a fast break (Granados et al. 2007; Hermassi et al. 2014; Ingebritsen et al. 2013; Zapartidis et al. 2011). In addition, it is proved that if maximal speed increases, the ball throwing velocity also increases (Zapartidis et al. 2011). Flexibility is another important factor in PFP for handball players, although it was stated that lower back and hamstring flexibility, did not affect throwing velocity in a previous study (Zapartidis et al. 2011). It is known that flexibility is widths of range of motion. Generally, it is applied as ballistic, static stretching and proprioceptive neuromuscular facilitation exercises because of sports injury prevention (Demirel et al. 2004; Demirel et al. 2005).

Even if balance is not included among the most crucial characteristics in athletic success, balance drills should also be included into a sports training program because of sports injury prevention, too. For this reason, it is mostly and importantly known as a cofactor that contributes to reducing the risk of injuries. In addition, balance exercises improve athlete performances and emergence of productivity in movement development (Cankaya et al. 2015; Ramirez-Campillo et al. 2015; Salahzadeh et al. 2011). Providing the balance, players are required to support stability of the center of mass when performing static and dynamic sports movements (Atilgan 2013; Karadenizli et al. 2014). Dynamic balance (DB) is necessary and effective in the fundamental technical movements of the handball sports such as dribbling, throwing, and faking. The DB on one leg is also very important for performing the basic movements on handball (Rannou et al. 2001). Myer et al. (2006) also stated that the incorporate unilateral and bilateral plyometric training (PT), improve the balance in young athletes. Salahzadeh et al. (2011) also indicate that using a combinational plan (plyometric, technical, balance, and strength) can improve antrerior-posterior balance. It is stated that balance ability is affected by explosive power (Atilgan 2013).

PT is widely known as a potential tool for improving functional sports performance. During PT, the muscles switch rapidly from an eccentric to a concentric phase of contraction. The decreased duration of the amortization phase exploits stored elastic energy and the stretch reflex, allowing a greater than normal release of power during the concentric phase of movement (Ramirez-Campillo et al. 2015; Saez de Villarreal et al. 2015). PT programs are often implemented during the pre-season to bring young players to an appropriate initial level of fitness. In addition, it is strongly recommended that handball coaches implement in-season PT to enhance the performance of their players. Biweekly PT inculcated into the standard training improved parts, which are important to handball performance, particularly, the explosive actions, such as sprinting, jumping and ball throwing velocity (Chelly et al. 2014). Hermassi et al. (2014) indicated that in-season 8-week biweekly PT including lower limbs can positively affect jump ability and absolute leg power in elite adolescent male handball. Van den Tillaar et al. (2015) also suggest that a short in-season 6-week squat or PT program can improve the physical performance of the lower body in young handball players.

On the other hand, recent reviews on the topic suggest that PT should include vertical and horizontal movements to enhance vertical and horizontal power (Randel et al. 2010; Ricotti 2011). Most previous papers of PT have also observed increased velocities, VJ and HJ height performances (Adibpour et al. 2012; Agilonu and Kiratli 2015; Andrejic 2012; Arazi and Asadi 2012; Asadi 2013; Lohindren and Adorable 2013; Michailidis 2015; Ozbar 2015). It is recommended to conduct PT on stable rather than unstable surfaces if the goal is to enhance VJ and sprint performances in young sub-elite handball players (Büsch et al. 2015). Another previous paper shows that PT can be considered an effective alternative stimulus to improve pre-planned agility outcomes in young players (Miller et al. 2006; Thomas et al. 2009). In addition, it is also stated that speed and CODS ability were extensively correlated with VJ and HJ performances (Cross et al. 2015; Loturco et al. 2015). For these reasons, tests of PFP mentioned should be used for determing successful players.

However, when it was carefully searched in literature, it was seen that different and opposite results were found (Herrero et al. 2006; Markovic et al. 2007). It is understood that although there are a lot of papers about PT program applied with vary methods, there are limited investigations (Carvalho et al. 2014; Chelly et al. 2014; Ramirez-Campillo et al. 2015) about the effect of PT on the balance and PFP performances in young athletes.

Objective of the Study

The objective of the current paper was to investigate the effects of a 10-week plyometric training on the static, dynamic balance, anaerobic power and physical fitness parameters of young female handball players.

MATERIAL AND METHODS

Participants

Twenty-six young female handball players (EG aged= 15.64±0.82 years; CG aged= 15.38±0.92 years) volunteered to participate in this paper. The participants were randomly assigned to an experimental group (EG; n= 14; bi-weekly PT and handball training), and control group (CG; n= 12; handball training only). While both groups participated in the handball training regularly for three times a week, EG performed extra PT twice a week. The participants were homogeneous in terms of their sports experince, ages and anthropometric characteristics such as body height, weight and body mass index (BMI). Descriptive data of anthropometric characteristics in both groups is presented in Table 2. The participants have no sports injuries in the last year and visual-sensory disorders were recorded in the examination. This investigation was approved by the local Ethical Committee of the University. The research was conducted in agreement with the Declaration of Helsinki. All the players and their coaches were informed about the purpose of the recent paper, benefits and risks of the participation.

Procedures

The players were given information about the 10-week PT program, static balance (SB-unipedal), dynamic balance (DB-bipedal slalom) and physical fitness parameters (PFP). PFP were organized with 30-meter sprint, Illinois CODS test (ICODT), vertical jump (VJ), horizontal jump (HJ) and flexibility sit-and-reach test (SAR). Anaerobic power (AP) was calculated by Lewis formula, that is, $\sqrt{4.9}$ x (body weight) x $\sqrt{D}$ (D= jumping height). Measurements were taken one week before and one week after the intervention. Testing periods were scheduled at minumum of 48 hours after a match to minimize the effect of fatique. All the PFP tests were conducted twice and the best scores were recorded as the test results. Between the repetitions, 1-2 minutes and between the PFP tests, 2-3 minutes' rest intervals were given. All PFP tests and PT program were completed during the in-season period.

Firstly, anthropometric measurements were taken. A portable stadiometer (SECA, Hamburg, UK) was employed for body height, and an electronic weight scale (Tanita, Illinois, USA) was employed for body weight (to the nearest 0.1 kg). Based on anthropometric characteristics, the participants from EG and CG did not show significant difference at baseline. These results are presented in Table 2.

Secondly, after the 15-minutes of warming up activity, which included moderate-intensity dynamic drills, the PFP tests were applied on the synthetic taraflex floor by the participants.

30-meter Sprint Test: A distance of 30 meters was selected for evaluation of running sprint time using the Sport Expert MPS 501 (Ankara, Turkey) infrared photocell. The participants performed two maximal 30-meter sprints from a standing position. This test protocol has been previously decscribed (Hermassi et al. 2014; Ingebritsen et al. 2013; Zapartidis et al. 2011).

Illinois-Agility Test: The ICODT is well accepted as a standard test of CODS in team sports. ICODT was used to observe the ability to accelerate, decelarate, turn in different directions, and run at differences angles. This test was selected based upon established criteria data for females and males, and because of their reported validity and reproducibility of the test (Wilkinson et al. 2009). Test was used with the photocelled doors at the starting and finishing points. ICODT was selected for evaluation of agility time (Sport Expert MPS 501, Ankara, Turkey). The participants performed two runs to finish as quickly as possible.

Counter Movement Jump Test: CMJ involves a stretch-shortening cycle that is very similar to the plyometric exercises. For this reason, CMJ with arm-swing (CMJarm) test was selected in the recent paper. The participants could use their arms during the CMJ arm. The participants performed two bilateral jumps to reach maximum height on an Ergojump (Bosco System, Globus, Italy), to determine lower body explosive strength. The best score was recorded. For HJ test, the participants were instructed to jump forward as far as possible and land with their feet together. The participants performed two bilateral jumps to reach maximum length. The best score was accepted and was expressed in centimeters. Distance of HJ was measured with a tape measured to the nearest centimeter. All jumping protocols have been previously described (Chelly et al. 2014; Ramirez-Campillo et al. 2015).

Sit-and-reach Flexilibity Test: For measuring flexibility of the hamstring muscles and the lower back, the modified sit-and-reach (SAR) test was used (Hoeger et al. 1990) (ICC=0.97, TE=2.8%). The participants were instructed to flex forward as far as possible, and stop with the two hands together. The participants performed two flexes to reach maximum length. This test protocol has been previously decscribed (Demirel et al. 2004; Demirel et al. 2005; Zapartidis et al. 2011).

Thirdly, following a 2 hour-resting time, the SB-unipedal and DB-bipedal slalom tests were measured on the same day. Both SB-unipedal and DB-bipedal slalom tests were measured by Prokin System 5.0 (Bergamo, Italy). After explaining these tests to the participants, data (that is, height, weight, age) was entered and the device was calibrated.

Static Balance-unipedal Tests: The participant was placed on the balance platform naked, and on one leg. He was asked to look at the screen in front of him, while the participant's arms were at his sides. The participant tries to stand up motionless and on one leg (left and right) for 30 seconds without leaning anywhere. After completion of each test, when the device was being recalibrated, the participants were asked to rest. During the time of the measurements, no verbal feedback was given to the participants except what was necessary. The data obtained was evaluated in terms of left foot elipse area (LFEA) and right foot ellipse area (RFEA).

Dynamic Balance-bipedal Slalom Test: This was used as a monoaxial dynamic-time test Medio-Lateral (ML) to one axis at a time, and in order to assess the participant's skill while completing the exercise. In this test, the participant tries to see some balls (objectives) that he has to come against. The participant's scope is to hit objectives and follow the ideal line within a 60-second duration hold with two hands. The degree of loading was selected at 5 hard degrees (according to soft (0) to hard (10) degree system). At the end of the test, the software provides two results, that is, caught up objectives (CUO) and the perimeter error (PE). The CUO show the objectives hit by the participant regarding the total objectives of the test. The PE, which is calculated automatically by the computer program, shows the participant's ability to stay on the blue ideal line. All balance protocols have been previously described in a manual book of device. All balance protocols have been previously described (Cankaya et al. 2015; Karadenizli et al. 2014).

Plyometric Training Protocols

The PT program used in the paper was designed by the researcher and it is based on the findings from previous publications (Adibpour et al. 2012; Andrejic 2012; Arazi and Asadi 2012; Asadi 2013; Myer et al. 2006). Following the 10-week PT program, all tests were repeated, and pre-test and post-test scores were compared. The protocol of 10-week PT program was applied twice in a week (Tuesday, Thursday). PT program was completed during the in-season period. PT drills were prepared to develop an upper and lower extremity and PT program consisted of three levels. These drills were performed by EG before the handball trainings.

The PT protocol was planned as 2-4 sets, 3-15 repeats and 5-6 drills, minumum 120 amd maximum 140 foot/hand contacts. Between the repetitions, 1-minute and between the sets 3-minute active resting times were given. PT drills (that is, skipping, hopping, jumping, running, throwing, passing) were applied after 10-15 minutes of the warming up period, which consisted of moderate-intensity dynamic drills (that is, the walking lunge, high knee skip, high knee run). Intensity of PT drills was set with hurdle height (40cm), medicine ball (3kg), handball weighted ball (800gm), handball ball (325gm/2 number), distance of sprint (5m) and number of foot and hand contact (120-140). Technical or tactical trainings started after PT drills, and these lasted 20-25 minutes. The PT program is presented in Table 1.

Statistical Analysis

Descriptive statistics (mean±SD) were calculated for all of the variables. For statistical analysis, Wilcoxon test was used for comparison of intra-group and Mann-Whitney U-test was used for comparison of inter-group. All of the data was analysed using SPSS, version 15.0 (SPSS, INC. Chicago, USA). The significance level was set at 0.05.

RESULTS

All the participants completed the tests of investigation without any injuries. The participants were randomly assigned to an EG (n= 14) and CG (n= 12). There are no significant differences (p>0.05) between EG and CG in term of sports experience averages (3.82±0.57 and 3.57±0.59 years respectively), age averages (15.64±0.82 and 15.38±0.92 years respectively), height averages (161.32±34.22 and 160.07±49.08 cm respectively), weight averages (56.41±3.68 and 55.86±4.59 kg respectively) and BMI averages (22.3±2.6 and 21.6±2.8 kg/m² respectively) (p>0.05). These descriptive data are presented in Table 2.

The Shapiro-Wilk test suggested that all anthropometric variables were distributed normally (p>0.05). The participants were homogeneous in terms of their sports experience, ages and anthropometric characteristics such as body height, weight and BMI. The Shapiro-Wilk test results are presented in Table 2.

After the 10-week PT program, according to the results of balance tests within group, the EG made significant improvements on both DB and SB tests between pre-test and post-test in terms of DB-bipedal slalom-CUO averages (0.69±0.14 and 64.28±28.72% respectively), DB-bipedal slalom-PE averages (0.44±0.17 and 0.12±0.11% respectively), SB- LFEA averages (1574.53±586.92 and 1089.00±516.88 mm² respectively) and SB-RFEA averages (1581.84±581.69 and 1483.21± 418.32 mm² respectively) (p<0.05). Whereas, the CG made significant improvements on only the

Table 1: Plyometric training program protocol

Week	*Foot/hand contact*	*Plyometric drills*	*Sets-Reps*	*Training intensity*
1, 2	120	Forward-skipping over cone	2x10	Low
		Side to side skiping over cone	2x10	Low
		Side to side ankle hops	2x10	Low
		Forward-skiping over cone with medicine ball*	2x10	Low
		Side-skiping over cone with medicine ball*	2x10	Low
		Slalom running and sprint**	2x10	Low
3	120-130	Side to side ankle hops	2x15	Low
		Double leg front jump over hurdle***	3x6	Low
		Over head passing with medicine ball* and sprint**	2x10	Low
		Forward-skipping over 15 cones with medicine ball*	2x15	Low
		Side-skipping over cone with medicine ball*	2x15	Low
4	120-130	Side to side skipping and sprint**	3x10	Average
		Standing vertical-jump and reach	3x10	Average
		Sit-up with medicine ball* and sprint**	3x10	Average
		Double leg forward-jump over hurdle***	3x5	Average
		Over head passing with handball weighted ball-800gm and sprint**	2x10	Average
5	130	Horizontal jump and sprint**	2x4	Average
		Double leg forward-jump over hurdle with medicine ball*	3x7	Average
		Forward skipping over 15 cones with change of direction sprint**	3x10	Average
		Double leg lateral-jump over hurdle***	3x15	Average
		Over head passing with handball weighted ball-800gm and sprint**	2x10	Average
6	130	Double leg forward-jump over hurdle with medicine ball*	3x6	Average
		Sit-up with medicine ball* and sprint**	3x10	Average
		Double leg lateral-jump over hurdle*** and sprint**	3x15	Average
		Over head throwing with handball ball-325gm and sprint**	2x10	Average
		Standing vertical-jump	3x6	Average
7	140	Horizontal jump and diagonal sprint**	3x4	Average
		Double leg forward-jump over hurdle***	4x8	Average
		Double leg lateral-jump over hurdle***	4x8	Average
		Single leg forward-jump over hurdle*** and sprint**	4x8	Average
		Single leg lateral-jump over hurdle*** and sprint**	4x8	Average
8	140	Double leg forward-jump over hurdle***	4x8	High
		Double leg lateral-jump over hurdle***	4x8	High
		Single leg forward-jump over hurdle*** and sprint**	4x8	High
		Single leg lateral-jump over hurdle*** and sprint**	4x8	High
		Standing vertical-jump and sprint**	3x4	High
9,10	140	Forward hoping over 15 cones and change of direction sprint**	4x8	High
		Slalom running and sprint**	4x3	High
		Single leg forward-jump over hurdle***	4x8	High
		Single leg lateral-jump over hurdle***	4x8	High
		Single leg diagonal-jump	4x8	High

*3kg., **5m., ***40cm.

DB tests between pre-test and post-test and in terms of DB-bipedal slalom-CUO averages (0.67±0.12 and 63.91±30.35 % respectively) and DB-bipedal slalom-PE averages (0.43±0.24 and 0.13±0.17 % respectively) ($p<0.05$). These values are presented in Table 3.

After the 10-week PT program, according to the results of PFP tests within group, the EG made significant improvements on all tests between pre-test and post-test in terms of AP averages (596.60±73.80 and 634.87±77.69 W respectively), SAR averages (26.61±6.32 and 30.21±8.15 cm respectively), CMJ arm averages (37.5±5.6 and 41.6±7.3 cm respectively), HJ averages (176.63±13.35 and 189.22±14.95 cm respectively), sprint 30-meter averages (5.38±0.23 and 4.93±0.20 sec respectively) and ICODT averages (16.02±0.23 and 16.02±0.38 sec respectively) ($p<0.05$). Whereas, the CG made significant improvements only the SAR test between pre-test and post-test in terms of SAR averages (25.77±5.30 and 29.55±6.18 cm respectively) ($p<0.05$). These values are presented in Table 4.

According to the results of both balance and PFP tests between group, the EG made significantly ($p<0.05$) greater improvements than the

Table 2: Data of descriptive and homogeneity test (Shapiro-Wilk) of anthropometric characteristics

	N	*Groups*	*Mean±SD*	*(Range)*	*P*
Sports experience (year)	14	EG	3.82± 0.57	(3- 5)	0.681
	12	CG	3.57± 0.59	(3- 5)	
Age (year)	14	EG	15.64± 0.82	(14-15)	0.534
	12	CG	15.38± 0.92	(14-15)	
Height (cm)	14	EG	161.32± 34.22	(1.57- 1.70)	0.587
	12	CG	160.07± 49.08	(1.58- 1.67)	
Weight (kg)	14	EG	56.41± 3.68	(50.08-62.85)	0.679
	12	CG	55.86± 4.59	(46.06-64.76)	
BMI (kg/cm²)	14	EG	22.3± 2.6	(19.6-28.4)	0.852
	12	CG	21.6± 2.8	(17.7-25.9)	

EG: experimental group, CG: control group

Table 3: The pre-test and post-test values and comparisons (Wilcoxon test-within group; Mann-Whitney U-test-between group) for static and dynamic balance measurements of the participants

EG (n=14) *CG (n=12)* *Parameters*	*Group*	*Pre-test*	*Post-test*	*Difference*	*P Within group*	*P Between group*
DB-bipedal slalom-CUO(%)	EG	0.6± 0.1	64.2± 28.7	63.5± 0.6	.000*	.527
	CG	0.6± 0.1	63.9± 30.3	63.2± 0.4	.000*	
DB-bipedal slalom-PE (%)	EG	0.4± 0.1	0.1± 0.1	-0.3± 0.4	.006*	0.324
	CG	0.4± 0.2	0.1± 0.1	-0.3± 0.3	.006*	
SB-LFEA (mm²)	EG	1574.53± 586.92	1089.00± 516.88	-485.53± 0.6	.000*	0.000*
	CG	1588.62± 487.84	1570.84± 502.14	-17.78± 0.5	.311	
SB-RFEA (mm²)	EG	1581.84± 581.69	1483.21± 418.32	-98.63± 0.6	.002*	0.281
	CG	1558.62± 487.83	1510.19± 396.21	-48.43± 0.4	.481	

EG: experimental group, CG: control group.
*Significant ($p < 0.05$

CG in the SB-LFEA, 30-meter sprint, ICODT, CMJ arm, HJ and AP performances following the 10-week PT program. Wilcoxon test was used for comparison within groups and Mann-Whitney U-test was used for comparison of between groups. For balance, pre-test, post-test scores and results of the statistics evaluations are presented in Table 3. For PFP, pre-test, post-test scores and results of the statistics evaluations are presented in Table 4.

DISCUSSION

The aim of this paper was to investigate the effects of 10-week PT on SB-unipedal, DB-bipedal slalom, AP and PFPs (30-m sprint, ICODT, VJ, HJ, SAR) performances. The results indicate that 10 weeks of PT within handball training positively affect performances on some balance and PFPs tests in young female handball players.

In the current paper, it is seen that the EG made significantly ($p<0.05$) greater improvements than the CG in the 30-meter sprint (-0.45 sec vs. -0.03 sec), ICODT (-1.61 sec vs. -0.12 sec), CM-Jarm (4.1 cm vs. 1.1 cm), HJ (12.59 cm vs. 0.62 cm) and AP (38.27 W vs. 1.51 W) performances following the 10-week PT program in female handball players. These results are presented in Table 4. When papers in literature were searched carefully, it was seen that there are a lot of results supporting the findings of this recent paper. Agilonu and Kiratli (2015) stated that significant differences were found for the 30-meter sprint, CMJ and HJ scores of female handball players aged 12-16 years old, after 8 weeks of PT. Hermassi et al. (2014) stated that CMJ improvement was significantly higher for PT group than CG in elite male handball players. Ozbar (2015) stated that PT group has improved their 30-meter sprint, CMJ, HJ and peak power performances of female soccer players aged 18-22 years old, after a 10-weeks PT. Michailidis (2015) also proved that PT could improve HJ and running performance for the 30-meter sprint in preadolescent

Table 4: The pre-test and post-test values and comparisons (Wilcoxon test-within group; Mann-Whitney U-test-between group) for physical fitness parameters of the participants

EG (n=14) CG (n=12) Parameters	*Group*	*Pre-test*	*Post-test*	*Difference*	*P Within group*	*P Between group*
AP (W)	EG	596.60± 73.80	634.87± 77.69	38.27± 4.2	.005*	0.002*
	CG	584.70± 68.14	586.21± 62.58	1.51± 0.9	.286	
SAR (cm)	EG	26.61± 6.32	30.21± 8.15	3.60± 0.8	.000*	0.379
	CG	25.77± 5.30	29.55± 6.18	3.78± 0.7	.002*	
CMJarm (cm)	EG	37.5± 5.6	41.6± 7.3	4.1± 0.6	.000*	0.000*
	CG	36.2± 5.3	37.3± 8.9	1.1± 0.7	.484	
HJ (cm)	EG	176.63± 13.35	189.22± 14.95	12.59± 3.4	.000*	0.000*
	CG	175.92± 11.24	176.54± 10.92	0.62± 0.9	.395	
30m-sprint (sec)	EG	5.38± 0.23	4.93± 0.20	-0.45± 0.2	.001*	0.001*
	CG	5.44± 0.25	5.41± 0.47	-0.03± 0.4	.234	
ICODT (sec)	EG	16.02± 0.23	16.02± 0.38	-1.61± 0.4	.003*	0.001*
	CG	16.88± 0.86	16.76± 0.49	-0.12± 0.3	.376	

EG: experimental group, CG: control group.
*Significant ($p < 0.05$)

male soccer players. Arazi and Asadi (2012) proved that compared to pre-intervention measures, the PT group made significantly greater improvements than CG in the CMJ and HJ performances. Adibpour et al. (2012) stated that significant difference was found between CMJ performances of basketball players, after 8 weeks' PT. In addition, Lohindren and Adorable (2013) stated that PT positively affects CMJ performances in the university basketball team players. Similarity, Andrejic (2012) also stated that significant difference was found between CMJ performances of basketball players after 6 weeks' PT.

Ramirez-Campillo et al. (2015) stated that all PT groups show a significant increases in 30-meter sprint times, agility and CMJarm performances in young soccer players. In addition, researchers suggest that compared with bilateral and unilateral, PT may cause greater adaptations in agility performances. Loturco et al. (2015) also suggest HJs are able to increase the acceleration/velocity over short distances in U-20 soccer players. It is indicated that PT done throughout the season can positively affect sprint and agility performances (Arazi and Asadi 2012; Asadi 2013). In addition, Saez de Villarreal et al. (2015) observed after PT and sprint training program, CMJ and agility values were significantly enhanced in the EG in adolescent soccer players. Michailidis et al. (2015) stated there is a significant increase in agility performance of pre-adolescent soccer players only in EG, whereas, the CG did not change. Thomas et al. (2009) also observed that there is a significant increase in agility performance in EG after the effect of two PT techniques in youth soccer players.

Another finding of the current paper shows that the EG made significant ($p<0.05$) greater improvements than the CG in the AP (38.27 W vs. 1.51 W) performances following the 10-week PT program in female handball players. This result is presented in Table 4. It is stated that balance ability is affected by explosive power (Atilgan 2013). On the other hand, it was indicated that horizontal force production and HJ drills should be considered to achieve in sprint values improvement. In addition, it was also stated that speed and CODS ability are related as VJ and HJ (Cross et al. 2015; Loturco et al. 2015).

These results mentioned above are in agreement with the results of the current paper. It can be said that 10-week PT program included VJ, HJ jump and sprint drills, which positively affected VJ, HJ, 30-meter sprint, agility and AP performances of participants. On the contrary, Hermassi et al. (2014) stated that no interaction effect was found between the groups (EG and CG) for the relative peak power in elite male handball players (aged: 20 years). In addition, some previous researchers found no significant gains of CMJ height and 20-meter sprint time with their PT program (Herrero et al. 2006; Markovic et al. 2007). It was seen that Herrero et al. (2006) continued to drop HJs for about 4 weeks, whereas PT program used in the current paper was planned for 10 weeks. This program is presented in Table 1.

It is estimated that the differences in PT protocol may also be an important factor.

Another finding of current paper shows that the EG made significant ($p<0.05$) greater improvements than the CG in the SB-unipedal (left) values. It can be understood that PT positively affects LFEA at SB-unipedal performances. This result is presented in Table 3. In the current paper, participants' dominant legs were right but their jumping legs were left. Because handball players, who use right hands, usually jump with their non-dominant (left) leg, so, they usually have strong non-dominant legs. For this reason, it is estimated that the findings mentioned in the recent paper may be affected by this situation apart from the effect of 10 weeks' PT. Barone et al. (2001) also stated that soccer players have a better standing balance on the non-dominant leg because of soccer activities, and soccer players have to stabilize their stance leg in different positions for kicking the ball. In addition, it was stated that the soccer group showed better standing balance on the left leg than the sedentary group. Cankaya et al. (2015) also proved that the improvements for the SB measurements were taken from the left foot, and were better than when they were taken from the right in the specific balance training program applied. Ramirez-Campillo et al. (2015) observed that all PT group's successes are significantly increased in all measures of medial-lateral and anterior-posterior balance. Similar results were indicated in other papers (Arazi and Asadi 2011; Asadi 2013). The results are in agreement with current paper.

On the contrary, in another finding of this current paper, it was seen that no difference was found among SB-unipedal (right) and DB-bipedal performances between EG and CG ($p<0.05$). This result is presented in Table 3. It is seen that 10-weeks of PT within the handball training positively affects this SB performances in young female handball players. Cankaya et al. (2015) also stated that specific balance training programme is efficient on SB development rather than DB development. Arazi and Asadi (2012) also stated that PG has improved their DB, but this change was not statistically significant. These results are in agreement with current paper. On the other hand, in the current paper, CG made significant ($p<0.05$) improvements on DB within the group. It is estimated that the positive results in CG can be related with regular handball trainings and learning effects.

On the other hand, it is known that the balance performance for dominant foot of the athletes is better than the other foot, because of its widespread and intensive usage in training and competitions (Cankaya et al. 2015). However, a certain tendency to balance better in the non-preferred leg was observed, a few different results were found from the recent paper. Atilgan (2013) proved that no significant difference was found between the pre-test and post-test results in terms of unipedal static balance among 9 to 10-year-old boys. In addition, Seiler et al. (2008) stated that unipedal balance was not significantly improved after the intervention training. Besides these results, Karadenizli et al. (2014) stated that significant difference was found in DB-unipedal (forward-backward) test performances when compared with right and left foot in soccer players. As a result, researchers indicated that right foot is better than left for DB performance in their paper. In addition, it was proved that there is no significant difference found in DB in young male handball players, too. In another paper, it is indicated that 8 weeks of combinational training (strenght and plyometric) is important in DB of teenage handball players. The highest effects were found in three directions of posterior-internal, internal and posterior balance of three groups (strenght, plyometric and combinational). It is also expressed that it was necesary for hamstring muscle activity during achievement action concerning these directions (Salahzadeh et al. 2011).

The results of previous papers are different from each other particulary in balance performances, but it is obvious that the 10 weeks PT program organized in the recent paper was more efficent in SB performances rather than DB in young female handball players.

The last finding of the current paper shows that EG made significant ($p<0.05$) improvements on all of the tests within the group. Although no difference was found among SAR performances between EG and CG, CG made significant ($p<0.05$) improvements within the group. These results are presented in Table 4. When papers in literature are searched, it can be seen that there are limited and different results. Hewett et al. (1996) indicated that after PT program, there was no significant difference in flexibility performance in female athletes. It was also proved that no significant difference was found between the SAR performances of young male tennis players after PT program (Aktas et al. 2011). These results are in agreement with current paper. On the contrary, Andrejic (2012) stated that a significant difference was found between SAR performances of basketball players who were between the ages of 12-13 years old, and after a 6-week power training (including PT). It is estimated that SAR performances found in the recent paper may be influenced by somatometrics characteristics of participants.

CONCLUSION

According to the researcher's knowledge, the recent paper is the first to be examined about effects of a10-week plyometric training on both balance and physical fitness parameters in young handball players. For this reason, results are important for sports sciences. It is seen in the current paper that 10-weeks plyometric training program positively affect vertical jump, horizontal jump, anaerobic power, 30-meter sprint, agility and static balance-unipedal (left) performances in young female handball players. On the contrary, it is seen that there are no significant differences about flexibility, static balance-unipedal (right), and dynamic balance-bipedal performances. It is believed that there is a significant relation between the given PT program, balance abilities and somatometrics characteristics. Results of previous papers are different from each other, particularly in balance performances. It is estimated that the differences in PT protocol may also be a factor. On the other hand, core and leg strength of participants were not measured in the current paper. If outcomes from these measurements are observed, results mentioned about balance and flexibility values would have to be clearly explained. It can be said that biweekly 10-weeks of plyometric training program (including handball training) can improve some important parameters of sports performance relative to in-season handball training.

RECOMMENDATIONS

It can be said that if the PT drills are added to handball training program and if this program is regularly applied, positive results can be found in physical fitness parameters and balance performances. The results, which are found in the current paper, may make great contributions to the development of psyhcomotor abilities and fitness level of young players. It is recommended that some other researches, coaches and psychical education teachers should consider the findings of this study, so that they can benefit from these results.

FOR FUTURE STUDIES

Although there are a lot of papers on plyometric training and its relations to soccer and basketball, there are limited investigations in handball. In addition, it is also seen that a limited paper was examined about effects of plyometric training on balance and physical fitness performances in female players. For this reason, young female handball players in particular should be examined by researchers, and new investigations should be planned concerning these subjects.

LIMITATIONS

This investigation has some limitations. First limitation is correlated to the absence of measurements of core and leg muscles strength. Second limitation is that, only female players were included as participants in the recent paper.

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