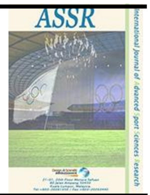

Impact of Plyometric Training Program on Physical Performance in Girls Age 12 to 15 Years

Article Info

Received: January 17, 2014
Accepted: February 15, 2014
Published online: March 01, 2014

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ABSTRACT

The purpose of this study was to determine the effects of a 6-week plyometric training program on physical performance (leg muscle power, explosive leg power, 20 m sprint and agility). With ethical approval, twenty-four girls (mean ±SD: age 13.4 ± 1.4 yr; body mass: 55.2 ± 3.1 kg; stature: 1.54 ± 0.06 m; BMI 21.5 ± 2.3 kg.m^2) from a local school. Participants were randomly assigned to either an experimental (EXP, n = 12) or a control (CON, n = 12) group. The training program duration per session for both groups was 60 min. After a familiarisation session, participants performed the following tests, before and after a 6 week intervention: 1) vertical jump height (VJH, to measure leg muscle power); 2) standing long jump (SLJ, to measure explosive leg power); 3) 20 metre sprint (to measure speed) and 4) the Illinois agility test (to measure specific agility). The EXP group made significantly ($p < 0.05$) greater improvements than CON in vertical jump height (9.30 vs. 2.56), standing long jump (13.70 vs. 0.92), speed over 10 m (-5.41 vs. 2.10) and agility time (-2.75 vs. -0.25) following training. Thus 6-weeks performing the plyometric training program can enhance physical performance in experimental group, while generally no effect was observed on a series of performance tests in a control group of adolescent female using the usual training program.

Keywords: **physical performance, plyometric training, leg power, speed, agility.**

1. Introduction

The Plyometrics are training techniques used by athletes in all types of sports to increase strength and explosiveness (Chu, 1998). Plyometrics consists of a rapid stretching of a muscle (eccentric action) immediately followed by a concentric or shortening action of the same muscle and connective tissue. The stored elastic energy within the muscle is used to produce more force than can be provided by a concentric action alone (Marginson, et al., 2005).

Plyometric training conditions the body through dynamic, resistance exercises. This type of training typically includes hops and jumps that exploit the muscles' cycle of lengthening and shortening to increase muscle power. Plyometric exercises start with a rapid stretch of a muscle (eccentric phase) and are followed by a rapid shortening of the same muscle (concentric phase) (Fletcher and Jones, 2004). With plyometric training, the nervous system is conditioned to react more quickly to the stretch-shortening cycle. This type of training enhances a child's ability to increase speed of movement and improve power production. Regular participation in a plyometric training program may also help to strengthen bone and facilitate weight control (Fukunaga et al., 2002). Further, plyometric training performed during the preseason may decrease the risk of sports-related injuries. This may be of particular benefit to young female athletes who appear to be at increased risk for knee injuries as compared to young male athletes.

In children and adolescents, it is well-established that training-induced gains in strength and power are indeed possible following participation in a resistance training program (Faigenbaum et al., 1996). More recent observations suggest that plyometric training may also be safe and effective for children and adolescents provided that age appropriate training guidelines are followed (Chu et al., 2006; Marginson et al., 2005). For example, Matavulj et al. (2001) found that plyometric training improved jumping performance in teenage basketball players and Kotzamanidis (2006) reported that plyometric training enhanced jumping performance and running velocity in prepubertal boys. However, plyometric training is not intended to be a stand-alone exercise program (Bompa, 2000).

As previously observed in adults, significantly greater gains in performance may be observed when using plyometric training (Adams et al., 1992; Fatouros et al., 2000). Given the growing popularity of youth strength and conditioning programs, and the perception among most youth coaches that pre-event static stretching is beneficial (Shehab et al., 2006), it is important to ascertain the most efficacious method for enhancing fitness performance in children and adolescents. This information would be useful to physical educators, sport coaches and health care providers. Thus, the purpose of the present investigation was to determine the effects of a 6-week plyometric training program on physical performance in young girls.

2. Methodology

2.1 Subjects

The study was conducted during the first half of the 2014 school season. Before the start of the investigation, the 26 girls available received written and oral information about the study, and it was emphasized that participation in the plyometric training program ''PTP'' program was voluntary. Written consent was obtained. The participants were screened for injuries using a questionnaire at the start of the study, and they had to be uninjured to be included. Two participants had to be excluded because of injury. With ethical approval, twenty-four girls (mean ±SD: age 13.4 ± 1.4 yr; body mass: 55.2 ± 3.1 kg; stature: 1.54 ± 0.06 m; BMI 21.5 ± 2.3 kg.m2) from a local school. Participants were randomly assigned to either an experimental (EXP, n = 12) or a control (CON, n = 12) group (Table 1).

Table 1.
Descriptive characteristics of the subjects. Data are means (±SD)

Groups	EXP, n = 12	CON, n = 12
Age (years)	13.3 (1.2)	13.5 (0.8)
Height (m)	1.56 (0.8)	1.52 (1.10)
Body Mass (kg)	56.1 (12.6)	54.3 (23.2)
BMI (kg·m2)	20.9 (4.9)	22.1 (3.8)

2.2 Physical performance tests

Four standard specific tests were performed at the same time of the day. All tests were carried out between 8 am and 11 am. Participants performed the following tests, before and after a 6 week intervention: 1) vertical jump height (VJH, to measure leg muscle power); 2) standing long jump (SLJ, to measure explosive leg power); 3) 10 metre sprint (to measure speed) and 4) the Illinois agility test (to measure specific agility). Performance tests were conducted by a different member of the research team. The tester was blinded to the type of intervention the players participated in. A standardized 10-min warm-up, including running, calisthenics and dynamic stretching was performed before the tests. The pre-testing was conducted one week prior to the first day of training, while the post-test was recorded three days after the final training session. All tests were conducted in the same order for each player during the pre and post-tests.

2.2.1 Vertical jump height test (VJHT)

The vertical jump test has been shown to be a reliable test in measuring the jump performance of athletes (ICC = 0.97), (Christou et al., 2006). Each subject performed two practice jumps prior to testing to ensure proper jumping techniques. They were instructed to jump vertically (initiated from a knee flexion of 90°), and execute a maximum vertical jump while swinging their arms actively. Jump height was determined using a measuring tape fastened to a dark paper on which each subject's pretest and post-test jump chalk prints would be clearly recorded. Each subject performed 2 practice jumps and the best score was used for analysis (Vanderford et al., 2004) Figure 1.

2.2.2 Standing long jump test (SLJT)

The ability to produce explosive leg power may help in the production of a maximum sprinting and jumping. In this study, the SLJT was used to measure the explosive leg power and followed the procedure as described by Castro-Pinero et al. (2010). Stand with feet parallel approximately shoulder width apart, toes at starting line. Squat and jump horizontally as far as possible. Measure from starting line to back of heels. Score best of three trials Figure

Figure 1. Vertical jump height test

Figure 2. Standing long jump test (SLJT)

2.2.3 Illinois agility test (IAT)

The Illinois agility test is commonly used in measuring agility in soccer (Amiri-Khorasani et al., 2010). The reliability of this test has been reported to be high (ICC = 0.85) (Katis and Kellis 2009).

The length of the zone is 10m, while the width (distance between the start and finish points) is 5m. Four cones were placed in the center of the testing area at a distance of 3.3m from one another. Four cones were used to mark the start, finish and two turning points. The subjects started the test lying face down, with their hands at shoulder level. The trial started on the "go" command, and the subjects began to run as fast as possible. The trial was completed when the players crossed the finish line without having knocked any cones over. Three trials were performed by every subject with the best score (time) used for analysis.

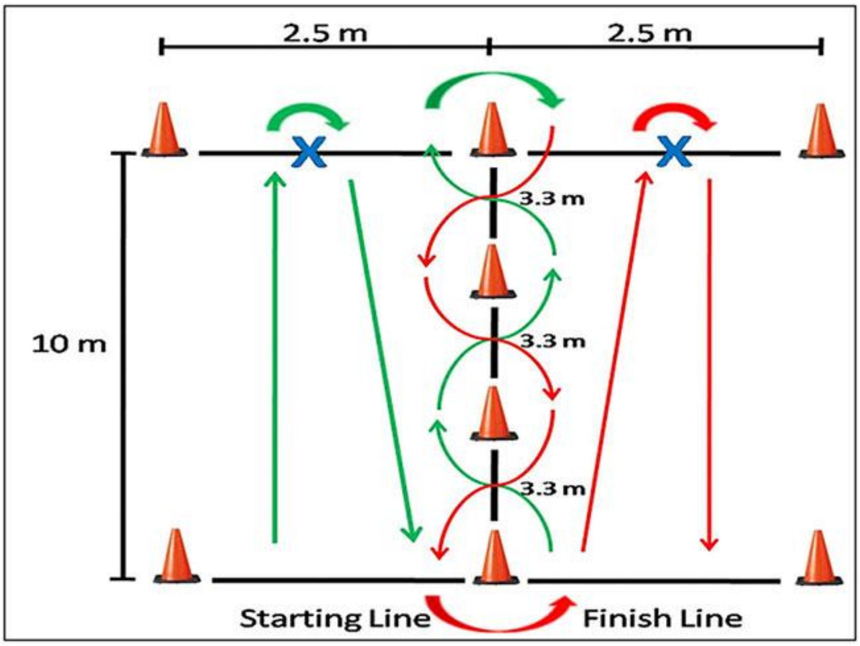

Figure 3. Illinois agility test

2.2.4 20m Sprint test (ST)

The ability to run at a high speed is necessary when trying to score goal or to stop a ball from being scored. Bangsbo (1993) suggested that by increasing the force of appropriate muscles and training speed, may improve skills for turning, sprinting, and changing pace during soccer. In this study, the running speed was tested based on time for running a single maximum sprint over 20 meters (ST). The test started from a stationary position, with one foot in front of the other and held for at least 2 seconds prior to running. The researcher assistant provided motivation for the subject to continue running hard till the finishing line. The average of two trials was recorded as the score for this test, in which an adequate recovery time (approximately 3 to 5 min) was allowed between the trials.

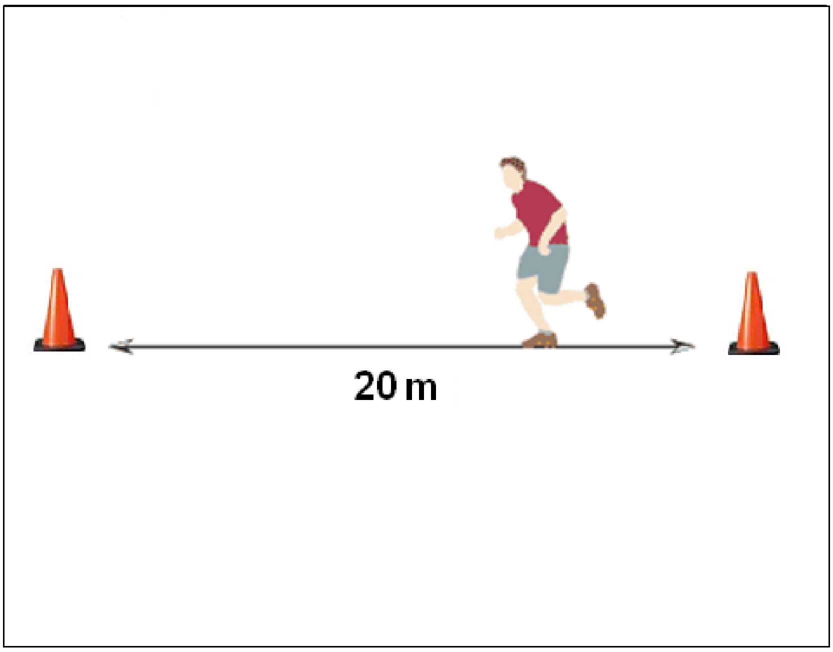

Figure 4. 20m sprint test (ST)

2.3 Plyometric training program (PTP)

The plyometric training group participated in a 6-week training program performing a variety of plyometric exercises designed for the lower extremity (Table 2), while the control group did not participate in any plyometric exercises. All subjects were instructed not to start any lower extremity strengthening programs during the 6-week period and to only perform activities of normal daily living. Prior to the study, procedures and guidelines were presented orally and in written form. Subjects agreeing to participate signed an institutionally approved consent form. A 6-week plyometric training program was developed using two training sessions per week. The training program was based on recommendations of intensity and volume from Piper and Erdmann (1998). The plyometric training group trained at the same time of day, two days a week, throughout the study. During the training, all subjects were under direct supervision and were instructed on how to perform each exercise.

2.4 Control group

The control group was asked to continue with their regular training and warm-up sessions throughout the study period. In addition, prior to the commencement of the study, the control group was assured that they would receive the plyometric training program in the subsequent season.

Table 2.
Plyometric 6-week training protocol

Training Week	Plyometric Drill	Sets X Reps	Training Intensity
Week 1	Side to side ankle hops	1-2 X 6	Low
	Standing jump and reach	1-2 X 6	Low
	Front cone hops	1-2 X 6	Low
Week 2	Side to side ankle hops	1-2 X 8	Low
	Standing long jump	1-2 X 6	Low
	Lateral jump over barrier	1-2 X 6	Medium
	Double leg hops	1-2 X 6	Medium
Week 3	Side to side ankle hops	1-2 X 8	Low
	Standing long jump	1-2 X 6	Low
	Lateral jump over barrier	1-2 X 6	Medium
	Double leg hops	1-2 X 8	Medium
	Lateral cone hops	1-2 X 6	Medium
Week 4	Diagonal cone hops	1-2 X 6	Low
	Standing long jump with lateral sprint	1-2 X 6	Medium
	Lateral cone hops	1-2 X 8	Medium
	Single leg bounding	1-2 X 6	Medium
	Lateral jump single leg	1-2 X 6	Medium
Week 5	Diagonal cone hops	1-2 X 6	Low
	Standing long jump with lateral sprint	1-2 X 6	Medium
	Lateral cone hops	1-2 X 6	Medium
	Cone hops with 180 degree turn	1-2 X 6	Medium
	Single leg bounding	1-2 X 6	Medium
Week 6	Diagonal cone hops	1-2 X 8	Low
	Hexagon drill	1-2 X 6	Low
	Cone hops with change of direction sprint	1-2 X 6	Medium
	Double leg hops	1-2 X 8	Medium
	Lateral jump single leg	1-2 X 6	Medium

2.5 Statistical analysis

Descriptive data were calculated for all variables. Group differences at baseline were evaluated using independent sample t-tests. One way repeated measures ANOVA were performed to assess group differences for the variables of interest including vertical jump height, standing long jump, 20 m sprint and agility. When significant main effects and interactions were observed, post-hoc paired t-tests corrected for alpha inflation (Bonferroni correction) were utilized for identifying the specific differences. All analyses were carried out using SPSS version 19.0, and statistical significance was set at $p < 0.05$.

3. Results & Discussion

There were no changes to body mass or stature during the study in either the EXP or CON group (Table 2). Training diaries revealed that participants completed the training, on average, 1.8 ± 0.4 times per week, resulting in an adherence rate of 90%. The pre- and post-intervention results for both groups are presented in Table 3.). The EXP group made significantly ($p < 0.05$) greater improvements than CON in vertical jump height (9.30 vs. 2.56), standing long jump (13.70 vs. 0.92), speed over 20 m (-5.41 vs. 2.10) and agility time (-2.75 vs. -0.25), this was not significant when compared to changes in the CON group, Table 3.

Table 3.
Pre- and post-intervention data, and percent changes, for all measures in both the experimental and control group. Values are mean (± SD)

Variable	EXP (n = 12)			CON (n = 12)			P value
	Pre	Post	Δ%	Pre	Post	Δ%	
Vertical Jump Height (m)	.39 (.16)	.43 (.18)	9.30	.38 (.19)	.39 (.07)	2.56	.002
Standing Long Jump (m)	2.14 (.15)	2.48 (.18)	13.70	2.15 (.13)	2.17 (.16)	0.92	.000
20 m Sprint (sec)	3.70 (.45)	3.51 (.38)	-5.41	3.72 (.09)	3.80 (.91)	2.10	.016
Agility (sec)	14.92(.72)	14.52 (.63)	-2.75	15.51 (.93)	15.47 (.76)	-0.25	.027

Δ = change. P value reflects differences between the change scores for each group

Performance of plyometric training program (PTP) resulted in significant changes in all of the physical performance abilities assessed. The largest improvement was observed for standing long jump (EXP = 13.70%; CON = 0.92 %, $p < 0.05$, Table 3). In sports, leg power would likely be associated with improved jumping and sprinting ability on the field.

However, it may also serve to reduce the risk of ankle, knee and other lower limb injuries (Chandy and Grana, 1985). Chandy and Grana (1985) showed that jump training programmes, incorporating plyometric exercises and weight lifting, both increased performance and decreased injury risk in competitive high school athletes (age: 15 ± 0.6 years). Also, positive effects of a six week training programme incorporating strength, power and agility training, alongside the development of correct and maximal jumping technique, are apparent in volleyball (Hewett et al., 1996).

Hewett et al. (1996) found that such a programme improved technique and decreased peak impact forces by 22% when landing and reduced medial and lateral directed forces by 50%. The performance benefit was a 10% increase in vertical jump height, which was consistent that observed in the present study (9.30%, Table 3). In the present study, the PTP resulted in improved speed (EXP = -5.41%; CON = 2.10%, $p < 0.05$, Table 2) and agility (EXP = -2.75%; CON = -0.25%, $p < 0.05$, Table 2) which are both desirable changes regardless of a players age or playing level.

As previously observed in adult populations (Sale and MacDougall, 1981), it appears that training programs that include movements which are biomechanically and metabolically specific to the performance test may be more likely to induce improvements in selected performance measures. Although few if any training activities have 100% carryover to a sport or activity in terms of specificity, our findings suggest that a conditioning program which includes different types of exercises that are specific to the test (i.e., plyometric training) and different loading schemes (i.e., high velocity jumps and heavy squatting) may be most effective for enhancing power performance in youth.

High velocity plyometrics which consist of a rapid eccentric muscle action followed by a powerful concentric muscle action are important for enhancing the rate of force development during jumping and sprinting whereas heavy resistance training is needed to enhance muscular strength and acceleration (Fleck and Kraemer, 2004). While some evidence suggests that plyometric training and resistance training can increase speed in adults (Delecluse et al, 1995), data on the effects of resistance training or combined plyometric training and resistance training on speed enhancement in youth is limited.

Myer et al. (2005) demonstrated that a 6-week multi-component training program that included resistance training, plyometric training and speed training enhanced 9.1 m sprint performance in adolescent female athletes. Kotzamanidis (2006) reported that running velocity improved in prepubertal boys following 10 weeks of plyometric training. However, Kotzamanidis (2006) observed improvements in velocity for the running distances of 0 to 30 m, 10 to 20 m, and 20 to 30 m, but not for the distance of 0 to 10 m. In the present study, the daily training duration for both groups was 60 minutes, the group that performed plyometric training more physical conditioning than the group that performed usual training program.

4. Conclusions

It can be concluded that the PTP showed a significant increases in physical performance on vertical jump height, standing long jump, speed and Illinois agility test performance, while there was no significant showed on all tests among control group.

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