Effects of 4-week Plyometric Training on Speed, Agility, and Leg Muscle Power in Male University Basketball Players: A Pilot Study

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ABSTRACT

This pilot study investigated the effects of 4-week plyometric training on the speed, agility, and leg muscle power in male university basketball players. Ten male basketball players from the University of Phayao whose ages ranged from 18 to 23 years were included in the study. The subjects were randomly divided into 2 groups of 5 subjects each: 1) a training group and 2) a control group. The training group performed plyometric training 2 days a week for 4 consecutive weeks. Speed and agility were assessed using a 20-meter sprint test and t-test agility, respectively. Leg muscle power was measured using a vertical jump test. All of the subjects performed the tests before and after the training program. Data were analyzed using a dependent *t*-test and an independent *t*-test. A confidence level of .05 was considered significant. The results presented that speed, agility, and leg muscle power significantly improved in the training group (p = .018, .001, and .003, respectively). Significant differences were not found in the control group. There were also statistically significant differences between the 2 groups after the training program. The training group had higher speed and agility compared to the control group (p = .003 and .011, respectively). This study provides support that 4-week plyometric training can be an effective training program to improve agility, speed, and leg muscle power in basketball players.

Keywords: plyometric, basketball, speed, agility, leg muscle power

บทคัดย่อ

งานวิจัยนำร่องนี้มีวัตถุประสงค์เพื่อศึกษาผลของการฝึกแบบพลัยโอเมตริกระยะเวลา 4 สัปดาห์ต่อความเร็ว ความคล่องแคล่ว และพลังกล้ามเนื้อขาในนักกีฬาบาสเกตบอลชายระดับมหาวิทยาลัย อาสาสมัครทั้งหมดเป็นนักกีฬาบาสเกตบอลของมหาวิทยาลัยพะเยา มีอายุระหว่าง 18-23 ปี จำนวน 10 คน อาสาสมัครถูกสุ่มแบ่งออกเป็น 2 กลุ่ม ได้แก่ กลุ่มที่ได้รับการฝึกแบบพลัยโอเมตริกและกลุ่มควบคุม กลุ่มละ 5 คน กลุ่มฝึกได้รับการฝึก 2 ครั้งต่อสัปดาห์ เป็นระยะเวลา 4 สัปดาห์ติดต่อกัน ทดสอบความเร็ว ความคล่องแคล่ว และพลังกล้ามเนื้อขาด้วยแบบทดสอบ 20-meter sprint test แบบทดสอบ T-test agility และแบบทดสอบ Vertical jump test ตามลำดับทั้งก่อนและหลังการฝึกแบบพลัยโอเมตริก นำข้อมูลที่ได้มาวิเคราะห์ด้วยสถิติ Dependent t–test ในการเปรียบเทียบความแตกต่างของความเร็ว ความ

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คล่องแคล่ว และพลังกล้ามเนื้อขาภายในกลุ่มก่อนและหลังการฝึกด้วยโปรแกรมพลัยโอเมตริก และใช้สถิติ Independent t-test ในการเปรียบเทียบความแตกต่างหลังสิ้นสุดโปรแกรมการฝึกระหว่างกลุ่มฝึกแบบพลัยโอเมติกและกลุ่มควบคุม โดยกำหนดนัยสำคัญทางสถิติที่ .05 จากผลการศึกษาพบว่ากลุ่มฝึกมีความเร็ว ความคล่องแคล่ว และพลังกล้ามเนื้อขาเพิ่มขึ้นอย่างมีนัยสำคัญทางสถิติ (p = .018, .001 และ .003 ตามลำดับ) แต่ไม่พบความแตกต่างดังกล่าวในกลุ่มควบคุม เมื่อเปรียบเทียบความแตกต่างหลังสิ้นสุดการฝึกระหว่างกลุ่มฝึกและกลุ่มควบคุมพบว่ากลุ่มฝึกมีความเร็วและความคล่องแคล่วมากกว่ากลุ่มควบคุมอย่างมีนัยสำคัญทางสถิติ (p = .003 และ .011 ตามลำดับ) สรุปว่าการฝึกแบบพลัยโอเมตริกระยะเวลา 4 สัปดาห์ สามารถเพิ่มความเร็ว ความคล่องแคล่วและพลังกล้ามเนื้อขาในนักกีฬาบาสเกตบอลชายได้
คำสำคัญ: พลัยโอเมตริก บาสเกตบอล ความเร็ว ความคล่องแคล่ว พลังกล้ามเนื้อขา

INTRODUCTION

Basketball is one of the most popular team sports widely played and watched all over the world. Through time, basketball has improved to involve common techniques of shooting, passing, and dribbling, including player positioning as well as offensive and defensive structures (Shaji & Isha, 2009). Seemingly, basketball players require abilities to rapidly move, to change direction quickly, and to jump high (Bal, Kaur, & Singh, 2011; Shaji & Isha, 2009). In order to achieve success in this sport, all the abilities should be subjected to training in specific ways (Balciunas, Stonkus, Abrantes, & Sampaio, 2006). Plyometrics is a training method used by athletes in many types of sports. This type of training which involves repeated rapid stretching and contracting of muscles to increase power is referred to as "explosive-reactive" power training (Bal et al., 2011). This is accomplished by optimizing the stretch-shortening cycle, which occurs when the active muscle switches from rapid eccentric muscle action to rapid concentric muscle action. The rapid eccentric movement creates a stretch reflex that produces a more forceful concentric muscle action than could otherwise be generated from a resting position. The faster the muscle is stretched, the greater the force produced and the more powerful the muscle movement (Rahimi & Behpur, 2005). Plyometric training can contribute to improvements in speed, agility, and vertical jump (leg muscle power) performance, which are important skills in basketball (Ratamess, 2012; Shaji & Isha, 2009). Kotzamanidis (2006) presented that a 10-week plyometric training program could improve running speed and vertical jumping in prepubertal boys. Moreover, Bal et al. (2011) demonstrated that plyometrics also enhanced agility in young basketball players after 6-weeks training. Although plyometric training has been shown to increase performance variables, little scientific information is available to determine if short-term plyometric training actually enhances speed, agility, and leg muscle power in basketball players. Therefore, the purpose of this study was to assess the effects of 4-week plyometric training specifically designed for basketball movements involving speed, agility, and leg muscle power in male university basketball players.

MATERIALS AND METHODS

Participants

Ten male basketball players from the University of Phayao were included in the study and were randomly assigned into two groups: 1) a training group and 2) a control group (Table 1). All the players had at least 3 years of competitive basketball experience at high school or college level. The subjects were also free of lower extremity injuries and were not involved in any type of plyometric training or strength training at the time of the study (Asadi & Arazi, 2012; Miller, Herniman, Ricard, Cheatham, & Michael, 2006). They were informed about the nature, benefit, and potential risks of this study, and signed a written informed consent before beginning the study. Ethical permission was approved by the committee on Human Rights Related to Human Experimentation, University of Phayao.

Measurements

Three tests conducted both pre-training and post-training were used to determine speed, agility, and leg muscle power outcomes. A 20-meter sprint test was used to determine speed. T-test agility was used to determine agility. A vertical jump test was used to determine leg muscle power (Asadi & Arazi, 2012).

Twenty-meter sprint test: The test was performed on an outdoor basketball court. The subjects started to sprint from a standing position start behind the start line when they were ready. Sprint time was recorded using a hand-held stopwatch. On command, the individuals were instructed to run 20 meters as fast as possible over the distance. When they crossed the finish line, the time was stopped on the hand-held stopwatch (Asadi, 2011; Asadi & Arazi, 2012; Markovic, Jukic, Milanovic, & Metikos, 2007).

T-test agility: Four cones were set as illustrated in Figure 1. Each player started at cone A. On the command of the timer, the player sprinted 10 meters to cone B and touched the base of the cone with his right hand. He then side stepped 5 meters to cone C on the left and touched its base with his left hand. After that, the player side stepped 10 meters to cone D on the right and touched the base with his right hand. He side stepped back 5 meters to cone B, touched the base with his left hand and ran backwards to cone A. The stopwatch was stopped as the player passed cone A (Asadi & Arazi, 2012; Miller et al., 2006; Shaji & Isha, 2009).

Vertical jump test: Each subject took a standing position facing sideways to a wall, to which a measuring tape was attached. Standing erect with the feet flat on the floor, each player reached as high as possible on the tape with his arms and fingers fully extended and the palms placed towards the wall. This was recorded as the beginning height. Standing about a foot away from the wall, the players brought the arms downwards and backwards while bending the knees to a balanced semisquat position, and then jumped as high as possible with the arms moving forwards and upwards. The tape was touched at the peak height of the jump with the fingers of the arms facing the wall. The highest jump from three attempts was recorded with a rest period of 10–15 seconds between attempts. The beginning height was subtracted from the peak height to determine the height jump in centimeters (Kumar & Kumar, 2005; Nieman, 2011).

Table 1 Baseline characteristics of the subjects

	Training group (n = 5)	Control group (n = 5)	*p*-value
Age (yr)	19.60±1.34	19.20±0.84	0.587
Weight (kg)	65.20±5.50	66.30±8.39	0.812
Height (cm)	173.00±9.11	174.30±6.08	0.797
Body mass index (kg/m^2)	21.81±1.64	21.98±2.11	0.891
Pre-test of speed (s)	3.41±0.14	3.53±0.23	0.325
Pre-test of agility (s)	12.35±0.75	12.22±0.22	0.706
Pre-test of leg muscle power (cm)	59.00±4.58	60.00±5.10	0.753

Procedures

The plyometric training program was designed to suit basketball movements and was based on recommendations of intensity and volume from ACSM's Foundations of Strength Training and Conditioning (Piper & Erdmann, 1998; Ratamess, 2012) (Table 2).

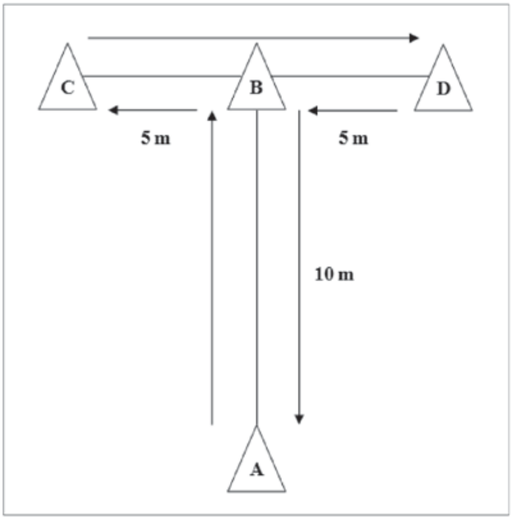

Figure 1 T-test agility layout.

The training group performed the plyometric training program on the outdoor basketball court twice a week for 4 weeks with 2 days recovery between training sessions. The plyometric program lasted approximately 35 minutes including 10 minutes of warm-up (jogging and stretching), 20 minutes of the plyometric training, and 5 minutes of cool-down (jogging and stretching) (Asadi, 2011). The subjects in the training group performed exercises in each training session with maximal effort. A work-to-rest ratio of 1:5 was recommended for front cone hops, lateral cone hops, lateral jump over barriers, alternate bounding, diagonal cone hops, cone hops with 180º turn, and cone hops with change of direction sprint. For noncontinuous jumps (standing jump and reach and single-leg vertical jump), 5 seconds of intraset rest interval and 2 minutes of interest rest interval were required

Table 2 Plyometric training program

Training week	Training volume (Foot contacts)	Plyometric drill	Sets × Repetitions	Training intensity
1	100	- Front cone hops	3 × 12	Low
		- Lateral cone hops	3 × 12	Low
		- Standing jump and reach	4 × 7	Low
2	120	- Lateral cone hops	3 × 10	Low
		- Standing jump and reach	5 × 6	Low
		- Lateral jump over barriers	3 × 10	Moderate
		- Alternate bounding	3 × 10	Moderate
3	140	- Diagonal cone hops	3 × 8	Low
		- Lateral jump over barriers	3 × 8	Moderate
		- Cone hops with 180 degree turn	4 × 8	Moderate
		- Cone hops with change of direction sprint	4 × 8	Moderate
		- Single-leg vertical jump	4 × 7	High
4	120	- Diagonal cone hops	3 × 10	Low
		- Cone hops with 180 degree turn	3 × 10	Moderate
		- Cone hops with change of direction sprint	3 × 12	Moderate
		- Single-leg vertical jump	4 × 6	High

(Ratamess, 2012). During the training, the players were under direct supervision and were instructed to perform each exercise. Both groups continued their routine basketball activities during the experimental period and were not allowed to perform any other training that would impact the results (Asadi, 2011; Asadi & Arazi, 2012; Hossein & Monireh, 2012). Training volume ranged from 100 to 140 foot contacts per session while the intensity of the exercises increased for 3 weeks before tapering off during week 4 (Bal et al, 2011; Hossein & Monireh, 2012; Miller et al., 2006).

Statistical analysis

Speed, agility, and leg muscle power were expressed as mean ± SD. The normal distribution of all data was investigated using the Shapiro-Wilk test. Differences of the variables (pre-test and post-test) within the groups were analyzed by a dependent *t*-test. An independent *t*-test was used to determine differences of the variables (post-test) between the two groups. An Alpha level of $p \leq .05$ was used to test statistical significance.

RESULTS

After 4 weeks of training, the training group showed significant improvements in all the variables while those in the control group remained unchanged (Table 3).

When comparing post-test results between the training group and the control group, it was found that speed and agility in the training group were significantly greater than those in the control group. However, there was no statistically significant difference of leg muscle power between both groups (Table 4).

DISCUSSION

The purpose of this study was to demonstrate the effects of short-term plyometric training on the speed, agility, and leg muscle power in male university basketball players. The results in this study showed that 4-weeks of plyometric training could significantly improve speed performance in the basketball players. These

Table 3 Mean differences of speed, agility, and leg muscle power within the 2 groups

	Training group			Control group		
	Pre-test	Post-test	*p*-value	Pre-test	Post-test	*p*-value
Speed (s)	3.41±0.14	2.98±0.25	0.018*	3.53±0.23	3.54±0.18	0.848
Agility (s)	12.35±0.75	11.13±0.72	0.001*	12.22±0.22	12.32±0.38	0.516
Leg muscle power (cm)	59.00±4.58	64.20±5.45	0.003*	60.00±5.10	60.00±5.57	1.000

* $p \leq .05$

Table 4 Mean differences of speed, agility, and leg muscle power between the two groups

	Training group (Post-test)	Control group (Post-test)	*p*-value
Speed (s)	2.98±0.25	3.54±0.18	0.003**
Agility (s)	11.13±0.72	12.32±0.38	0.011*
Leg muscle power (cm)	64.20±5.45	60.00±5.57	0.262

* $p \leq .05$; ** $p < .01$

findings support several previous studies which have suggested that plyometric training can enhance sprinting ability because of the stretch-shortening cycle (Chelly et al., 2010). Asadi (2011) found that plyometrics improved the results of a 20-meter sprint time after 6 weeks of training on sand. These findings are in line with Kotzamanidis (2006) who found a significant improvement in sprinting (30 meters) following 20 sessions (10 weeks × 2 sessions per week) of plyometric training. Asadi & Arazi (2012) also presented that a high-intensity plyometric program positively affected sprint performance in young male basketball players after training for 6 weeks. Similarly, Chelly and others (2010) investigated that running velocities (40 meters) of soccer players significantly increased after 8 weeks of lower limb plyometric training program. The factor that probably affects the obtained results for the 20-meter sprint test in the present study after training only 4 weeks is the quality of the modified training program which was designed to suit basketball movements. In relation to the transfer of plyometric training to sprinting, it is likely that the greatest improvements in sprinting will occur at the velocity of muscle action that most closely approximates the velocity of muscle action of plyometric exercises employed in training (Rimmer & Sleivert, 2000). It is also possible that a training program that incorporates greater horizontal acceleration such as cone hops with a change of direction sprint would result in the most beneficial effects (De Villarreal, Gonzalez-Badillo & Izquierdo, 2008). Other mechanisms that improved sprint performance in this study could be changes in stride length and stride frequency. However, these variables were not evaluated, but previous studies reported a high relationship between stride length and frequency with sprint performance (Rimmer & Sleivert, 2000). In contrast, Balciunas et al. (2006) did not find any significant improvement in the 20-meter speed running of young male basketball players after 4 months of plyometric training. Markovic et al. (2007) examined the effects of 10-weeks of plyometric training on the 20-meter sprint time and found no significant changes. Similarly, Thomas, French, and Hayes (2009) compared the effects of depth jump and countermovement jump training on 5, 10, 15 and 20-meter sprints, and found no statistically significant improvements. It can be seen that the differences in intensity of training, training volume, and sample size may be reasons for the discrepancy in results (Markovic et al., 2007).

The findings of this study also indicated that 4-weeks of plyometric training increased agility (t-test). This supports previous research. Asadi & Arazi (2012) investigated a significant improvement in agility (4 x 9-meter shuttle run, t-test, and Illinois agility test) of young male basketball players after 6-weeks of high intensity plyometric training. Renfro (1999) measured agility using a t-test with plyometric training, while Robinson and Owens (2004) used vertical, lateral, and horizontal plyometric jumps and presented improvements in agility. Miller et al. (2006) demonstrated that 6-weeks of plyometric training could improve an athlete's agility (t-test and Illinois agility test) as well. Similarly, Bal et al. (2011) demonstrated the benefits of a short-term plyometric training program on agility (t-test and Illinois agility test) in young basketball players. These findings demonstrate the necessity of plyometric training for enhancing performance in activities that involve acceleration, deceleration, and a change of direction. It is also well documented that agility requires the development of muscle factors (for example, strength and power) to improve change of direction speed and it appears that agility has a high relationship with strength and power (Sheffard & Young, 2006). Perhaps an increase in the power performance becomes one of the important variables for the enhancement of agility. In addition, neural adaptations and the enhancement of motor unit recruitment are other mechanisms that can lead to increases in the agility tests (Miller et al., 2006). However, neural adaptations were not examined in this study to determine if they occurred via synchronous firing of motor neurons or the better facilitation of neural impulses to the spinal cord. Therefore, further studies are required to determine neural adaptations as a result of plyometric training and how they affect agility.

The current study presented that 4 weeks of plyometric training improved leg muscle power (vertical jump test) in the training group. However, there was no significant difference between the training group and the control group though the training group tended to jump higher after the program. This result might have been due to the limited number of subjects. In the training group, this result was in agreement with Asadi (2011) who reported a significant improvement in vertical jumping in male collegiate students following depth jump and countermovement jump training for 6 weeks. Asadi & Arazi (2012) also found that there was a statistically significant difference in vertical jumping in basketball players between the training group and the control group after 6-weeks of high intensity plyometric training. Shallaby (2010) investigated vertical jumping of basketball players and reported it was better after 12 weeks of plyometric training. Furthermore, Faigenbaun et al. (2007) reported that boys in a plyometric resistance training group had a higher vertical jump than those in the resistance training group after 6 weeks. A possible explanation for the jumping enhancement in the present study is that plyometric training improves explosive power performance (Ratamess, 2012). Several researchers suggested that muscular performance gains after plyometric training are attributable to a neural adaptation located in the nervous system (Asadi & Arazi, 2012). Plyometric drills included in the recent study may have in part increased motor unit function (McClenton, Brown, Coburn, & Kersey, 2008). Bosco and Komi (1979) found that increases in vertical jump ability following countermovement jump and depth jump could be attributed to a combination of the utilization of elastic energy and the stretch reflex potentiation of muscle activation. However, countermovement jumps and depth jumps were not included in the present study, so standing jumps and reach and single-leg vertical jumps might play important roles in this study.

CONCLUSIONS

The results of this study highlight the potential of plyometric training designed for basketball movements. Not only can basketball players use plyometrics to break the monotony of training, but they can also improve their speed, agility, and leg muscle power. In addition, these positive results can occur after only 4 weeks of training which will be useful during the last preparatory phase before in-season competition for basketball players.

SUGGESTIONS

1. The proposed plyometric training program should be a part of the physical preparation for basketball players because of its significant effectiveness in improving the skills of the players.
2. The present study was a pilot study so significant differences in leg muscle power were not found. Future research should include more volunteers which may result in a better sample and possibly a significant difference in leg muscle power between the training group and the control group.
3. Future study should be conducted in the same area on different samples in terms of age and gender to see if the plyometric training program will be effective in these groups as well.

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