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Original

EFFCTOS DEL ENTRENAMIENTO PLIOMETRICO DE ALTA INTENSIDAD EN EL EQUILIBRIO DINAMICO, LA AGILIDAD, EL SALTO VERTICAL Y EL SPRINT EN JOVENES JUGADORES SE BALONCESTO

EFFECTS OF HIGH-INTENSITY PLYOMETRIC TRAINING ON DYNAMIC BALANCE, AGILITY, VERTICAL JUMP AND SPRINT PERFORMANCE IN YOUNG MALE BASKETBALL PLAYERS

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RESUMEN

Objetivos: El objetivo de este estudio era evaluar los efectos de un programa de entrenamiento pliométrico de alta intensidad en el equilibrio dinámico, la agilidad, el salto vertical y el sprint en jóvenes jugadores de baloncesto.

Material y métodos: 16 jugadores semiprofesionales de baloncesto participaron en este estudio. Los sujetos se distribuyeron en 2 grupos: un grupo de entrenamiento pliométrico (PL; n = 8) y un grupo de control (GC; n = 8). Se realizó el entrenamiento pliométrico 2 días por semana durante 6 semanas incluyendo salto en profundidad, squat jump y salto en profundidad con salto en longitud. Los siguientes tests fueron utilizados antes y después del entrenamiento: Star Excursion Balance Test (SEBT), Salto Vertical (SV), Salto en Longitud (SL), Shuttle Run 4 x 9m., Prueba t de Student, Test de Agilidad Illinois y sprint de 20m.

Resultados: PL mostró mejoras significativas ($P < 0.05$) en SV (~23%), SL (~10%), Shuttle Run 4 x 9m. (~7%), Prueba t de Student (~9%), Test de Agilidad de Illinois (~7%) y sprint de 20m. (~9%) tras 6 semanas de entrenamiento y en comparación con GC. No se encontraron cambios significativos ($P > 0.05$) en SEBT, aunque PL mostró un ~4% de mejora.

Discusión y conclusiones: Se puede concluir que un programa pliométrico de alta intensidad de 6 semanas de duración puede mejorar la potencia, la agilidad, la carrera corta y el equilibrio en jóvenes jugadores de baloncesto. Además, este estudio proporciona apoyo teórico a los entrenadores y jugadores que usan este método de entrenamiento durante la fase de preparación (acondicionamiento).

Palabras clave: alto impacto, rendimiento, pliometría, control postural.

ABSTRACT

Objetives; The purpose of this study was to evaluate the effects of high-intensity plyometric training program on dynamic balance, agility, vertical jump, and sprint performance in young male basketball players.

Methods; Sixteen semi-professional basketball players participated in this study. Subjects were divided into two groups: plyometric training (PL; n = 8) and control group (CG; n = 8). Plyometric training took place 2 days a week for 6 weeks including depth jump, squat depth jump, and depth jump to standing long jump. Star Excursion Balance Test (SEBT), vertical jump (VJ), standing long jump (SLJ), 4 × 9-m shuttle run, T-test, Illinois Agility Test, and 20-m sprint were measured at pre- and post-training.

Results; The PL demonstrated significant improvement ($P < 0.05$) in VJ (~23%), SLJ (~10%), 4 × 9-m shuttle run (~7%), T-test (~9%), Illinois Agility test (~7%), and 20-m sprint (~9%) after a 6-week of training and compared to CG. There were not significant changes ($P > 0.05$) in SEBT, but PL showed ~4% improvement.

Disscusion and Conclusions; It could be concluded that a 6-week high-intensity plyometric program can improve power, agility, sprint and balance in young male basketball players. Also, this study provides support for coaches and basketball players who use this training method at the preparation (conditioning) phase.

Keywords: high-impact, performance, plyometrics, postural control

INTRODUCTION

In basketball, the ability to generate maximal strength levels in the shortest period of time (muscular power) has been considered as essential to obtain high sport performance levels [Jose Almeida Martino de Santos & Janeira, 2008; Klinzing, 1991]. Moreover, dynamic balance and agility are vital components for the success in basketball players. Two methods, plyometric and resistance training, are usually referred to in the literature as improving the most powerful strength characteristics (explosive strength) in basketball players. Several studies have demonstrated the positive effects of plyometric and resistance training for higher increases in the explosive strength indicators [Brown et al, 1986; Fulton, 1992; Matavulj et al, 2001; Wagner & Kocak, 1997].

Plyometrics are training techniques used by athletes in all types of sports to increase strength and explosiveness (Chu, 1998; Saez-Saez de Villarreal et al, 2010). 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 (Chu, 1998). The stored elastic energy within the muscle is used to produce more force than can be provided by a concentric action alone (Asmussen & Bonde-Peterson, 1974). Several investigations reported that, plyometric training can contribute to improvements in vertical jump performance, acceleration, leg strength, muscular power, increased joint awareness, and overall proprioception [Harrison & Gaffney, 2001; Hewett et al, 1996; Holcomb et al, 1996; Rimmer & Sleivert, 2000; Chimera et al, 2004; Stemm & Jacobson, 2007; Myer et al, 2006; Saez-Saez de Villarreal et al, 2010; Arazi & Asadi, 2011]. This type of exercise causes higher muscle tension compared to conventional resistance training [Asmussen & Bonde-Peterson, 1974]. For this reason, plyometric exercises are widely recommended for power enhancement in jumping [Verkhoshanski, 1973].

Intensity in plyometric training is defined as the amount of stress placed in the involved muscles, joints, and connective tissues involved in the movement [Potach & Chu, 2008]. Many plyometric training sessions for inexperienced participates are administered at volumes well in excess of the recommended maximum of between 80 (novice) and 140 (advanced) ground contacts per session [Potach & Chu, 2008; Twist et al, 2008]. The effects of high-volume plyometric programs on strength, sprint, voluntary and evoked contractile properties such as rate of force development and muscle activation are known by previous researchers in trained and recreationally trained athletes [Drinkwater et al, 2009; Saez-Saez de Villarreal et al, 2008; Saez-Saez de Villarreal et al, 2010]. Furthermore, the bulk of research investigating plyometric training efficacy has looked at high-impact plyometric exercises such as depth jumps [Adams et al, 1992; Brown et al, 1986; Holcomb et al, 1996; Saez-Saez de Villarreal et al, 2008], but no study examined the effects of high-intensity and high-volume of plyometric training in basketball players. This is especially the case in young male basketball players, for whom there are, to our knowledge, related studies available in literature. But, in young male basketball players, the effects of plyometric training especially on dynamic balance, agility, power, and speed performance are unknown. Therefore, the aim of the present study was to determine how dynamic balance, agility, power, and speed are affected by a 6-week plyometric training program in young male basketball players.

METHODS

Participants

Sixteen semi-professional male basketball players volunteered to participate in this study. Subjects were randomly assigned either plyometric group (PL = 8) or control group (CG = 8) (Table 1). Subjects were informed about the nature, benefit, and potential risks of this study, and signed a written informed consent form before beginning the study and the University Human Subjects Institutional Review Board approved all testing and training protocols. Subjects were screened for any medical or orthopedic concern that would limit participation. No subject performed strength training or plyometric exercises for the lower body during the study period.

Table 1. Initial characteristics of the experimental groups (mean ± SD).

	Plyometric (n = 8)	Control (n = 8)
Age (yr)	19.12 ± 0.83	20 ± 0.75
Height (cm)	182.12 ± 9.99	178.38 ± 3.24
Body mass (kg)	75.78 ± 7.54	68.50 ± 12.10
Experience of player in basketball (yr)	5.62 ± 2.13	4.75 ± 1.03

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Procedure

Plyometric training was undertaken twice a week for 6 weeks (on Monday and Friday). The training program was based on recommendations of intensity and volume from Chu (1998) and Stemm & Jacobson (2007) (Table 2). Training sessions in PL group lasted 55 min; and began with a standard 10 min warm-up, 5 min of jogging, 5 min ballistic exercises and stretching; 40 min training, and 5 min cool-down. Subjects in PL group were instructed to perform exercises in each training session with maximal effort. During the training, all subjects were under direct supervision and were instructed on how to perform each exercise. During the intervention of 6 weeks, PL and CG continued their normal basketball training, and were not allowed to perform any other training (such as: resistance training and or plyometric training) that would impact the results.

Table 2. Plyometric training program.

	Set	Repetitions	Rest	Box height
Depth jump	3	20	2-min	45-cm
Squat depth jump	3	20	2-min	45-cm
Depth jump to standing long jump	3	20	2-min	45-cm

Measurements

In order to evaluate the effects of plyomeric training on dynamic balance, agility, and power, we applied seven tests; Star Excursion Balance Test (SEBT), vertical jump (VJ), standing long jump (SLJ), 20-m sprint, 4 × 9-m shuttle run, T-test, and Illinois Agility Test. Before the initial testing, each player was familiarized with the testing protocol. To standardize testing procedures, the same trained test leaders carried out the entire test procedure using identical order and protocol. Before testing, Subjects performed 10-min warm-up protocol consisting of submaximal running, and active stretching.

Star Excursion Balance Test (SEBT): This is a test that incorporates a single-leg stance on one leg with maximum reach of the opposite leg. The test is consisted of 8 lines that make a 45° angle to one another. The 45° increments are from the center of the grid. The 8 lines positioned on the grid are labeled according to the direction of excursion relative to the stance leg (anterior, anterolateral, anteromedial, medial, lateral, posterior, posterolateral, posteromedial) [Kinzey & Armstrong, 1998]. The diameter of the circle is 182/9 cm and it is placed on a firm surface. The width of each line is 7/62 cm. In order to reduce the learning effect each subject chooses 6 directions out of the 8 to practice [Blackburn et al, 2000]. The subject stood in the middle of the circle with the dominant leg; then with the opposite leg he reached for the furthest marked distance. Each subject was asked to touch the furthest part of the line with the most distal part of his reach foot. This was done with control and in a slow manner to ensure adequate neuromuscular control of the stance leg. The subject then returned to the original stance and the touch points that were marked during examination were recorded. Three second rest was allocated between each reach. The direction of the revolution based on the right or left reach legs was clock wise and counter clock wise, respectively [Blackburn et al, 2000]. The reach was not accepted if the leg could not touch the target line, if the subject's weight was shifted to the reach leg, if the support leg was lifted from the center, or if balance was disturbed during the reach [Blackburn et al, 2000]. Participant's legs were measured from the anterior superior iliac spine to the distal tip of the medial malleolus using a standard tape measure while participants lay supine. Leg length was used to normalise excursion distances by dividing the distance reached by leg length then multiplying by 100 [Gribble & Hertel, 2003].

Vertical jump (VJ): Each subject performed three trials with 1 min of rest in between each jump and the highest jump was used in the data analysis. The following procedure was used for each subject during data collection. The Vertec was adjusted to match the height of the individual subject by having them stand with the dominant side to the base of the testing devise. Their dominant hand was raised and the Vertec was adjusted so that their hand was the appropriate distance away from the marker based on markings on the device itself. At that point, subjects performed a countermovement jump. Arm swings were allowed but no preparatory step was performed [Maffiuletti et al, 2002].

Standing long jump (SLJ): Standing long jump was measured via a tape measure. Subjects were required to stand with their toes behind the zone point of the tape measure prior to jumping. Subjects were not allowed a preparatory step of kind but arm swings were allowed at the discretion of the subject. Distance was determined measuring the point at which the heel of the trail leg touched the ground.

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Each subject performed three trials with 1 min of rest in between each trial. The best jump of the three was used for analysis.

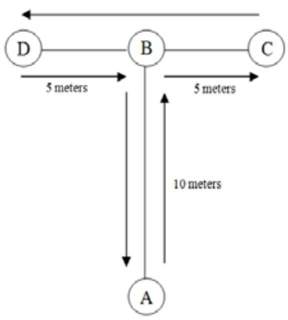
20-m sprint: The sprint running tests were performed on an outdoor track. The sprint running test consisted of 3 maximal sprints of 20-m, with a 2-min resting period between each sprint. Sprint time was recorded using hand-held stopwatch (Joerex, ST4610-2). The subjects started the sprint when ready from a standing position start, behind the start line. On commend, subjects were instructed to sprint as fast as possible through the distance. The timer stood at the finish line [Markovic et al, 2007].

4 × 9-m shuttle run: The shuttle run test was included as a measure of the ability to sprint and change direction. With the 4 × 9-m shuttle run, subjects stood behind a starting line, on command, they started the 9-m run. At the end of the 9-m section, subjects were asked to stop with 1 food beyond a marker while reversing running direction and sprinting back to the start where the same reversing of movement direction was required. After the fourth 9-m section, when the subjects passed a finish line time stopped by hand-held stopwatch (Joerex, ST4610-2). The better of 2 consecutive trials was used for the statistical analysis. Three minutes rest between attempts was provided for each subject.

The T-test (Figure 1) was used to determine speed with directional changes such as forward sprinting, left and right side shuffling, and backpedaling. *The Illinois agility test* (Figure 2) was used to determine the ability to accelerate, decelerate, turn in different directions, and run at different angles [Miller et al, 2006]. These tests were selected based upon established criteria data for males and females and because of their reported validity and reproducibility of the tests [Paoule et al, 2000; Roozen, 2004]. Three attempts were carried out for the each test. The best result was used for the statistical analysis. The rest in between trials was 3-min.

Statistical analysis

Test of normal distribution (Kolmogorov-Smirnov) was conducted on all data before analysis. All data were normally distributed ($P > 0.05$). Change scores (post – pre) were computed for each of the dependent variables. Single factor ANOVAs were used to test for differences between groups (Plyometric Training, Control) for the dependent variable change scores using the pretest values as a covariate.



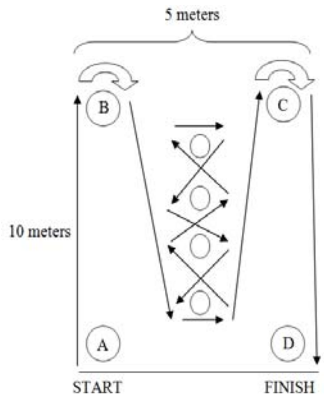


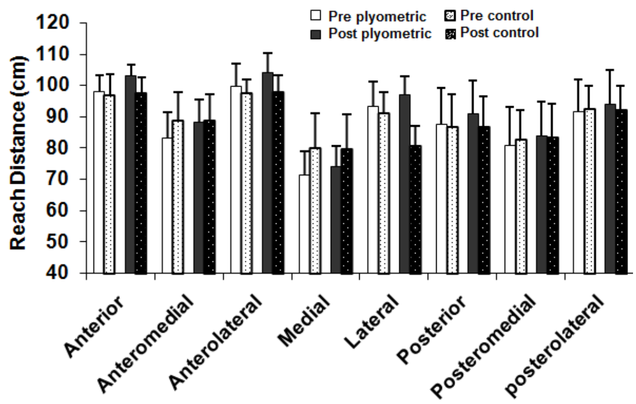
Figure 1. T-test **Figure 2**. Illinois agility test

All data are presented as mean ± SD. A criterion α level of $P < 0.05$ was used to determine statistical significance.

RESULTS

No injuries occurred throughout the study period, and the testing and training procedures were well tolerated by the subjects.

After 6 weeks of training, the PL group made significantly ($P < 0.05$) greater improvements than CG in all variables (except dynamic balance). The PL group improved their dynamic balance ~4%, but this change was not statistically significant ($P > 0.05$) (Figure 3). Compared to pre-intervention measures, PL group significantly ($P < 0.05$) improved their VJ from 43.75 ± 3.65 to 53.5 ± 3.81 cm (~23%), SLJ from 216.75 ± 13.62 to 238 ± 11.12 cm (~10%), 20-m sprint from 3.71 ± 0.12 to 3.40 ± 0.14 sec (~9%) (Figure 4; A, B, C), 4 × 9-m shuttle run from 9.69 ± 0.37 to 9.07 ± 0.18 sec (~7%), T-test from 11.99 ± 0.53 to 10.93 ± 0.62 sec (~9%), and Illinois agility test from 17.49 ± 0.53 to 16.25 ± 0.56 sec (~7%) (Figure 5; A, B, C).



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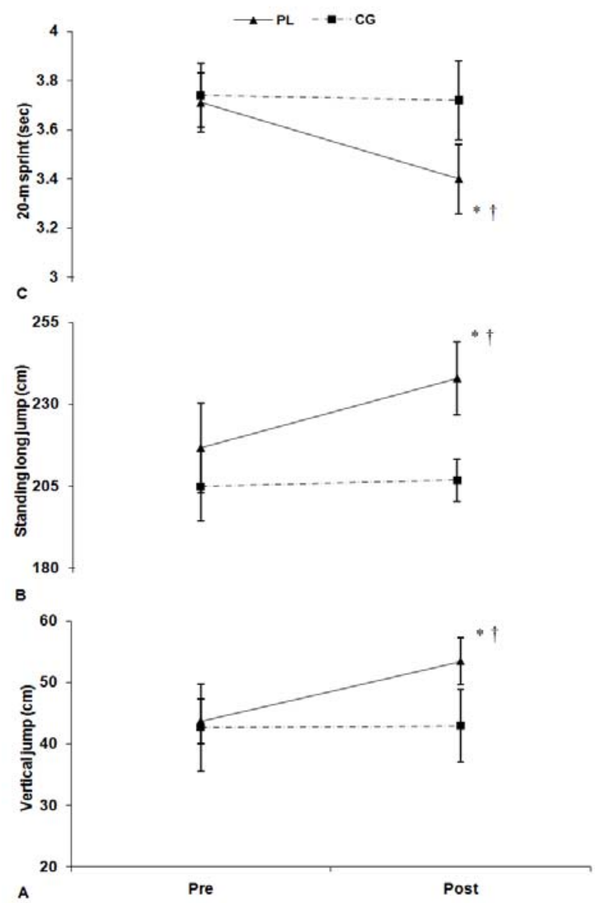


Figure 3. Changes in the 8 direction of the dynamic balance for plyometric and control groups.

Figure 4. A; Vertical jump (cm), B; Standing long jump (cm), C; A 20-m sprint test (sec) separated by group pre and post-training. Values are mean ± SD.

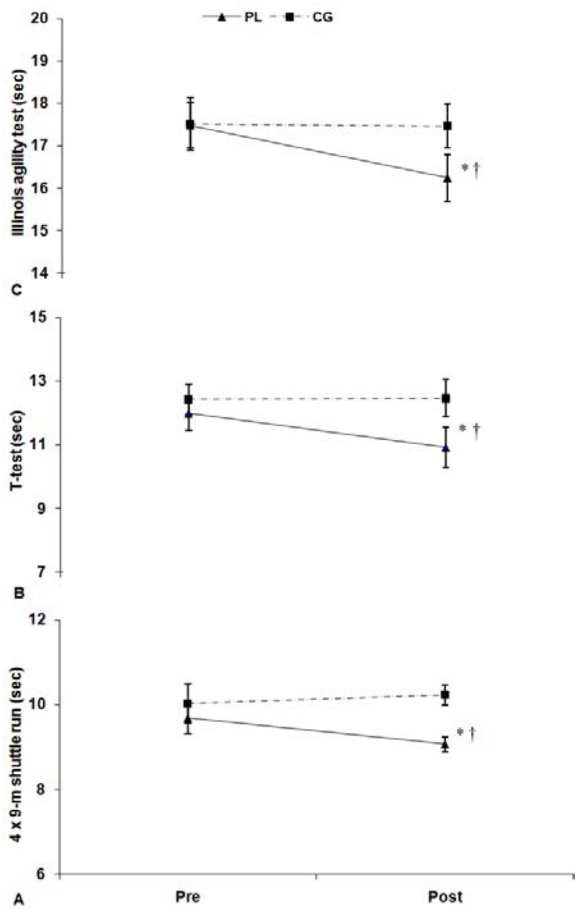
* Significantly different ($p < 0.05$) from the corresponding baseline.

† Significantly different ($p < 0.05$) from the corresponding CG.

PL = plyometric group; CG = control group.

DISCUSSION

A novel approach in this investigation was to examine the effects of high-intensity plyometric training on dynamic balance, agility, power and sprint in young male basketball players. Information regarding the effects of plyometric training on dynamic balance is generally lacking. The results of the present study are in line with Myer et al (2006) and Twist et al (2008) who reported plyometric training can improve balance



performance in adults and female. Paterno et al (2004) who used a combine dynamic balance and plyometric protocol and found that improvements in body sway measures occurred in the anterior/posterior plane. Recently, Arazi &

Figure 5. A; 4 × 9-m shuttle run (sec), B; T- test (sec), C; Illinois agility test (sec) separated by group pre and post-training. Values are mean ± SD.

* Significantly different ($p < 0.05$) from the corresponding baseline.

† Significantly different ($p < 0.05$) from the corresponding CG.

PL = plyometric group; CG = control group.

Asadi (2011) reported changes in dynamic balance following 8 weeks plyometric training, but these changes were not statistically significant. In this study we found that PL group improved their dynamic balance ~4% (not significant). Subjects were tested at 8 plans, and the highest improvement was observed in the anteromedial plan. These suggest that peripheral and central neural adaptations and enhancement of neuromuscular factors were induced by plyometric training, resulting in improved joint position sense and detection of joint motion. Peripheral adaptations that may have occurred because of plyometric training likely resulted from the repetitive stimulation of the articular mechanoreceptors near the end range of motion [Grigg, 1994]. Central adaptation resulting from plyometric training may also improve proprioception. The novelty of this task required preparatory muscle activation [Chimera et al, 2004].

In the present study, the plyometric training group increased VJ and SLJ (~23% and ~10%, respectively), whereas control group showed no improvement. Many studies have shown a significant increase in VJ following a structured plyometric training regimen [Adams et al, 1996; Brown et al, 1986; Fulton, 1992; Holcomb et al, 1996; Matavulj et al, 2001; Saez-Saez de Villarreal et al, 2008, Saez-Saez de Villarreal et al, 2009; Stemm & Jacobson, 2007; Markovic, 2007] however, the overwhelming majority of studies have been conducted using high-impact plyometric training, such as depth jumps. In basketball player subjects, two studies examined the effect of plyometric training program on VJ performance. Brown et al (1986) found that moderate amounts of plyometric training substantially improved jumping ability. The plyometric training included three sets of 10 drop jumps, performed three times a week for 6 weeks. They indicated 11.1% increases. Also, Matavulj et al (2001) compared two groups using different plyometric programs to a control group. One group used drop jumps from a height of 50-cm and another group used drop jumps from a height of 100-cm. Both groups demonstrated a significant increase in VJ height (12.4%), while the control group showed no gain in VJ height. We found that high-intensity plyometric exercise (such as depth jump, squat depth jump, and depth jump to standing long jump) at 2 times a week for 6 weeks, can increases ~23% of VJ and ~10% of SLJ. The difference in frequency of training could be the reason of the discrepancy in results (2160 reps vs. 540 reps) [Markovic et al, 2007]. The improvement in jump height indicates that adaptations relating to increases in leg power have occurred. The adaptations of training are likely to be neural because these predominate in the early stages of strength and power training [Sale, 1988] and have been shown to be the main adaptation to plyometric exercise [Hakkinen et al, 1985]. Many authors suggested that muscular performance gains after plyometric training are attributed to a neural adaptation located in the nervous system [Maffiuletti et al, 2002; Potteiger et al, 1999]. According to these authors, neuromuscular factors such as increasing the degree of muscle coordination and maximizing the ability to use the muscles' stretch-shortening cycle appear to be more important for the improvement in jump performance (VJ and SLJ) following high intence plyometric training [Maffiuletti et al, 2002; Potteiger et al, 1999].

The unique findings of the present study showed that high-intensity plyometric training can positively affect agility performance (4 × 9-m shuttle run ~7%, T-test ~9%, and Illinois agility test ~7%) in basketball players. This result is agreement with previous researchers. In a study of tennis players, the authors used a T-test and dot drill test to determine speed and agility [Parsons & Jones, 1998]. They found that the players became quicker and more agile; enabling them to get to more balls and be more effective tennis players. Renfro (1999) measured agility using the T-test with plyometric training, while Robinson & Owens (2004) used vertical, lateral and horizontal plyometric jumps and showed improvements in agility. Miller et al (2006) who examined the effects of a 6-week plyometrics on agility. They used PL and CON groups, and found significant difference in PL after training, but no significant from corresponding control group in the agility tests (T-test and Illinois Agility test). They reported 4.86% and 2.93 % improvement in T-test and Illinois Agility test, respectively, but we found higher than 7% improvement. These findings demonstrate the necessity of plyometric training program for enhancing performance in activities which involve acceleration, deceleration and a change of direction. In addition, the plyometric training program may have improved the eccentric strength of the lower limb, a prevalent component in changes of direction during the deceleration phase [Sheffard & Young, 2006]. It is well document that agility requires development of muscle factors (e.g., strength and power) to improve change of direction speed and it appears that, agility has high relationship with strength and power [Sheffard & Young, 2006]. Perhaps increases in the power performance become one of the important variables for the enhancement of agility. Also, neural adaptations and enhancement of motor unit recruitment are other mechanisms can lead to increase for the agility tests [Miller et al, 2006]. However, we could not exactly determine that neural adaptations occurred or better facilitation of neural impulse to spinal cord; therefore, further studies are needed to determine mechanisms of agility improvement by plyometric training.

The results of this study show that high-intensity plyometric training can positively affect sprint performance (~9%). These findings support studies showing improvements in sprint speed after a plyometric program [Rimmer & Sleivert, 2000; Markovic et al, 2007; Saez-Saez de Villarreal et al, 2008; Arazi & Asadi, 2011]. The factor that probably affected the obtained results for the 20-m distance was the quality of the applied training program (intensity and volume). In relation to the transfer of plyometrics 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 the plyometric exercises employed in training [Rimmer & Sleivert, 2000]. It is also possible that a training program that incorporates greater horizontal acceleration would result in the most beneficial effects [Saez-Saez de Villarreal et al, 2008]. Other mechanisms that improved sprint performance could be changes in stride length and stride frequency. However, we did not evaluate these variables, but previous studies reported high relationship between stride length and frequency with sprint performance [Rimmer & Sleivert, 2000].

CONCLUSIONS

The results of this study highlights the potential of using high-intensity plyometric training to improve power, agility, sprint and dynamic balance, especially in young male basketball players (19-20 years old). It is recommended that, coaches sometimes design high-intensity plyometrics for young athletes, because this type of training can be effective for improving performance. Also, basketball players who use plyometrics to train dynamic balance should create programs that progress train intensity of the exercises based on the results of this study. Since coaches and athletes are often restricted to a short preseason, this is beneficial for coaches or athletes before competition such as collegiate or logical competitions.

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