Original Article

The effect of aquatic and land plyometric training on strength, sprint, and balance in young basketball players

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ABSTRACT

Arazi H, Asadi A. The effect of aquatic and land plyometric training on strength, sprint, and balance in young basketball players. *J. Hum. Sport Exerc.* Vol. 6, No. 1, pp. 101-111, 2011. The purpose of this study was to compare the effect of eight weeks of aquatic and land plyometric training on leg muscle strength, 36.5 and 60 meters sprint times, and dynamic balance test in young male basketball players. Eighteen young male basketball players (age=18.81±1.46 years, height=179.34±6.11 cm, body mass=67.80±9.52 kg, sport experience=4.8±2.47 years) volunteered in this study and divided to three groups; aquatic plyometric training (APT), land plyometric training (LPT) and control group (CON). Experimental groups trained; ankle jumps, speed marching, squat jumps, and skipping drills for eight weeks and 3 times a week for 40 min. The data were analyzed by one way analysis of variance with repeated measures, a Tukey post hoc testing and independent-sample *t*-test. The results showed there were not any significant differences between the APT and LPT groups in any of the variables tested ($P>0.05$). Significant increases were observed in posttraining both APT and LPT groups in 36.5-m and 60-m sprint times record compare to pretraining ($P<0.05$). There was a significant difference in relative improvement between the APT and CON in 36.5-m, 60-m, and one repetition maximum leg press ($P<0.05$). We conclude that plyometric training in water can be an effective technique to improve sprint and strength in young athletes. **Key words**: WATER, LAND, PLYOMETRIC EXERCISE, PERFORMANCE.

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INTRODUCTION

Plyometric training – jumping, bounding, and hopping exercises that exploit the stretch-shortening cycle have been shown to enhance the performance of the concentric phase of movement (Gehri et al., 1998) and increase power output (Adams et al., 1992; Paul et al., 2003). Plyometric exercises evoke the elastic properties of the muscle fibers and connective tissue in a way that allows the muscle to store energy during the deceleration phase and release that energy during the acceleration period (Asmussen, 1974; Bosco et al., 1982; Kaneko et al., 1983; Stone & O'Bryant, 1986). Benefits from the plyometric training include improved measures of muscular strength and power explosive (Bobbert, 1990; Matavulj et al., 2001; Wilson et al., 1996), joint function and stability (Hewett et al., 1996), reduced incidence of serious knee injuries (Hewett et al., 1996), and running economy (Turner et al., 2003). Several studies have shown that when combined with resistance and anaerobic training, plyometric training can improve muscular strength, vertical jump, and speed (Harrison & Gaffney, 2001; Hennessy & Kilty, 2001). Saez Saez de Villareal et al. (2010) addressed that various training methods, including weight training (Wilson et al., 1993), electrostimulation training (Maffiuletti et al., 2002), plyometric and weight training (Adams et al., 1992) can enhance of strength performance. Rimmer & Sleivert (2000) demonstrated that a plyometric intervention program resulted in improvements in 40-m sprint times and a 4.4% decrease in ground contact time. Plyometric exercises can be done with or without external load, and both modalities have been shown to increase power, jumping height, and sprint performance (McBride et al., 2002; Wilson et al., 1993). Effective neuromuscular training protocols have used plyometric, biomechanics and technique, strength, balance, and core stability training to induce neuromuscular changes and possible injury prevention (Hewett et al., 1996; Myklebustet et al., 2003). Maximum strength and sprint are vital components to success in many sports, may be increased using plyometrics. However, this type of training can cause injury in various limbs like vertebrae and osteoarticular (Grantham, 2006), acute muscle soreness, muscle damage, or even musculoskeletal injuries (Almeida et al., 1999; Jamurtas et al., 2000). This is guide researchers to choose optimum training surface plyometric exercise, with minimum injuries and improve performance. Some authors investigated the effects of different surfaces like sand, grass and wood on performance with reducing injuries (Miyama & Nosaka, 2004; Impellizzeri et al., 2007). Others have recommended that plyometric training would be to perform in water, swimming pool or aquatic plyometric training (APT). Water may reduce the pressure put on the musculoskeletal system because aquatic environment provides buoyancy that reduces weight bearing stress on the limbs. The viscosity and resistance to movement within the water requires additional muscle activation to overcome the resistance and produce the similarly movement that is more easily produced land or other surfaces. Different studies compared the effects of aquatic and land plyometric training on power, vertical jump (VJ), speed, strength, agility and muscle soreness (Robinson et al., 2004; Martel et al., 2005; Stemm & Jacobson, 2007; Shiran et al., 2008). Miller et al. (2002) compared the effects of 8-week of APT vs. LPT on VJ, muscle power and torque, muscle soreness, and range of motion in college-aged men and women. The results showed an increase in muscle power only in ATP group. Both groups had improved in knee peak torque during knee flexion. In addition, none of the experimental groups showed significant improves in vertical jump. Martel et al. (2005) reported that, both groups (APT and CON) indicated significant improvements in concentric peak torque during knee extension and flexion at 60 and180°·s^{-1} after 6-week training. Robinson et al. (2004) compared the effects of 8-week of APT vs. LPT on VJ, muscle strength, sprint velocity, and muscle soreness in healthy college-aged women. Both groups made significant increases in VJ, isokinetic torque production, and sprint velocity. But, aquatic plyometrics provided significantly less muscle soreness. Shiran et al. (2008) compared the effects of 5-week of APT vs. LPT on physical performance and muscular enzymes in professional male wrestlers. The results indicated, APT provided the similar enhancement as LPT in physical performance with less muscle soreness. To our knowledge, no researches have addressed

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the effects of plyometric training on male participation and especially young basketball players or in aquatic setting. Also, with attention to the vague and controversial results from the effects of plyometric training on different surfaces like water, grass, mat, and land, this question existing that: Does plyometric in water can be effective to improve performance? Therefore, the purpose of this study was to determine the effect of aquatic and land plyometrics on strength, sprint and dynamic balance in young male basketball players. We hypothesized that aquatic plyometrics would lead to greater improvements in muscular strength, 36.5-m, 60-m sprint times and dynamic balance as compared with the land plyometrics.

MATERIAL AND METHODS

Experimental approach to the problem

This study was designed to examine the effect of aquatic and land plyometrics in young male basketball players. Using a randomized, between groups design, 18 basketball players were assessed for leg muscle strength, sprint, and dynamic balance pre and post 8 weeks of aquatic or land plyometric training.

Subjects

Eighteen young semi-professional male basketball players from a Rasht area participated in this study. Subjects were informed about the aims, nature, benefits and potential risks the study and provided written informed consent to take apart prior to the investigation. The study protocol was approved by the Ethics Committee of the Department of Sport Sciences, University of Guilan. The subjects were healthy, free of lower extremity injuries, and they had no medical or orthopedic that comprehensive their participation in this study.

Subjects were matched and randomly assigned to three groups; aquatic plyometric training group (n=6), land plyometric training group (n=6), and control group (n=6). The subjects' characteristics are given in Table 1.

Table 1. *Baseline physical characteristics. Data are means (±SD).*

	APT (n=6)	**LPT (n=6)**	**CON (n=6)**
Age (y)	18±0.60	18.03±1.38	20.4±0.64
Body Mass (kg)	75.66 ±3.93	67.5±1	60.25±7.03
Height (cm)	180.28±4.58	182.41±7.24	175.33±4.67
Sport experience (y)	4.75±2.23	4±2.7	5.66±2.58

APT= aquatic plyometric training group. LPT= land plyometric training group. CON= control group.

Experimental design

All study procedures took place at gymnasium in University of Guilan, IRAN. Both groups trained for 8 weeks, three days per week. They performed a plyometric exercises designed in mat and water for the lower extremity, while the control group no participated in any type of plyometric exercises. Subjects continued their routine basketball training, during experimental period. Subjects no participated in any type of plyometric training at the last six months and not permitted to use weight training along the plyometric training protocol. Both groups trained three a week (Saturday, Monday, and Wednesday) with 48-hours-recovery, for 8 weeks (Robinson et al., 2004). The subjects in the plyometric groups performed four plyometric drills - the ankle jumps, speed marching, squat jumps, and skipping drills. The training protocol of this study was step loading that comprised; fatigue, adaptation, jump, peak adaptation and reduction load (Table 2). The plyometric exercise lasted from 03.30 PM to 05.30 PM for APT group. In contrast, plyometric exercise lasted from 05.30 PM to 07 00 PM for LPT group. Aquatic plyometric group trained in a swimming pool, while approximately 70 % of their body was floating down the water. The temperature of the swimming pool was kept consistent at 27˚C or 28˚C (Martel et al., 2005). Land plyometric group trained on mat of 3 cm at gymnastic club. Each exercise session lasted 40 min. Every session started with a 5-min Jogging, a 5-min stretching and ballistic movements to warm-up and a 5-min of stretch movements to cool-down. The sufficient recovery was 60 sec rest between the sets and 3 min between each jump on per session. Subjects performed the plyometric exercises with a maximum ability and capacity in per session.

***Table 2**. Plyometric training protocol.*

	Plyometric drills and reps					
Training Week	**Ankle jump**	**Speed marching**	**Squat jump**	**Skipping drill**	**Sets**	**Total**
Wk 1	15	8	8	8	3	117
Wk 2	17	9	9	9	3	132
Wk 3	19	10	10	10	3	147
Wk 4	22	11	11	11	3	165
Wk 5	17	9	9	9	3	132
Wk 6	19	10	10	10	3	147
Wk 7	22	11	11	11	3	165
Wk 8	25	12	12	12	3	183

Testing procedures

Maximum leg muscle strength, sprint and balance were measured by 1RM leg press, 36.5-m, 60-m sprint times and dynamic balance test. Subjects were tested pre and post the 8-week training. All tests were explained before performance by tester.

Maximum strength: The 1-RM leg press assesses the maximum muscular strength of the major muscles of the lower extremity. Warm-up consisted of a set of five repetitions at the loads of 40-50 % of the perceived maximum. Leg press test was completed using standard leg press machine (NIROO, KING BODY). Subjects assuming a sitting position with back on padded supported and about 180̊ hips flexion, 80˚ knees flexion and 10̊ dorsiflexion at the ankles. The weight action line was obliquely at 45˚. On command, the subject performed a concentric extension (as fast as possible) of the leg muscles starting from the flexed position to reach the full extension of 180º against the resistance. Tester alerted the subjects when the

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starting and finishing positions were attained. Each subject was performed 2 maximal trails. Three minutes of rest was permitted between trials. Maximum weight was measured at pre and post 8-week training.

Sprint: Sprinting speed and endurance are most commonly measured using the 36.5-m and 60-m runs. The 36.5-m and 60-m has been used in many different sports like basketball, handball and soccer. Subjects performed a standardized warm-up prior to the sprint test which was concluded by 2 60-m submaximal runs. Sprints were performed on outdoor track for 60 m, with the timing device situated in 2 locations to determine 36.5-m and 60-m sprint times. Subjects assuming a standing (static) position in the start line. On commend, subjects were instructed to sprint as fast as possible through the distance. The timer stood at the finish of 36.5-m and 60-m, and recorded the time from the start of movement until the subject crossed the 36.5-m and 60-m finish line. Times were recorded by hand-held stopwatch (Joerex, ST4610-2). Subjects were allowed 3 trials, of which the fastest time for each distance was using as the comparison measure for pre and post test. Each of the 3 sprints was separated by a 3 minutes rest period to ensure full recovery between sprints.

Dynamic balance: Dynamic balance is very important at sports which need to many joint awareness, and overall proprioception. Balance test investigated by 5 m-timed-up-and-go-test (5m-TUG). Subjects performed 5-TUG with time taken to rise from a chair, walk a set distance 5 m, turn around, walk back and sit down. Each subject was given 2 practice trials performed to familiarize. All subjects completed three trials with 1 min recovery between trials. The least time for each trial was recorded.

Statistical analyses

All data are presented as mean ± SD. Statistical analysis was performed using SPSS version 16.0 software. One-way analyses of variance (ANOVA) with repeated measures by Tukey post hoc testing were used to determine significant differences among the APT, LPT, and control groups. The independent sample *t*-tests were used to identify any significant differences between the groups at the pre and post tests for the dependent variables. The level of significance was set at $P \leq 0.05$.

RESULTS

There were no significant differences between APT, LPT and CON groups at pre test. No significant changes were observed in the control group in any of the variables tested either. No significant differences were observed in the magnitude of the increase in 1 RM leg press at 8 weeks between the APT group and the LPT group (18.33 kg vs. 16.00 kg) ($P>0.05$). The APT group displayed significantly larger increases then the CON group for 1RM leg press ($P<0.05$) (Figure 1). Both groups demonstrated significant improvements in 36.5-m and 60-m sprint times at posttraining ($P<0.05$). However, no significant differences were observed between APT and LPT (-0.7 sec vs. -0.67 sec in 36.5-m and -0.93 sec vs. -0.8 sec in 60-m, respectively). There were significant differences between the APT group and CON group in 36.5-m and 60-m sprint times ($P<0.05$) (Figure 2, A and B). In dynamic balance test, APT and LPT showed improvements at posttraining. However, the improvement in LPT was greater than APT, But no significant was difference (-1.87 sec vs. -1.06 sec, respectively) ($P>0.05$) (Figure 3). Subjects were no injuries resulting from the training program in lower extremities.

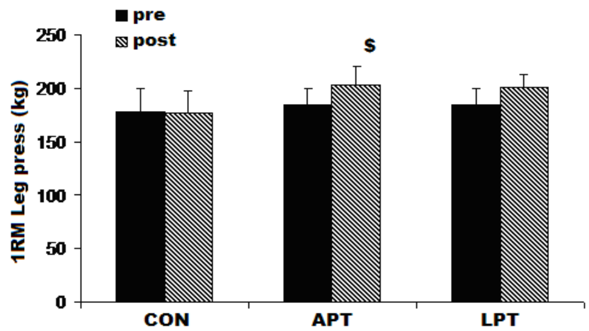

Figure 1. *Maximal strength (1 repetition maximum) for aquatic plyometric training (APT), land plyometric training (LPT) and control (CON) groups before and after 8 weeks training.*
$ Significant difference with control group

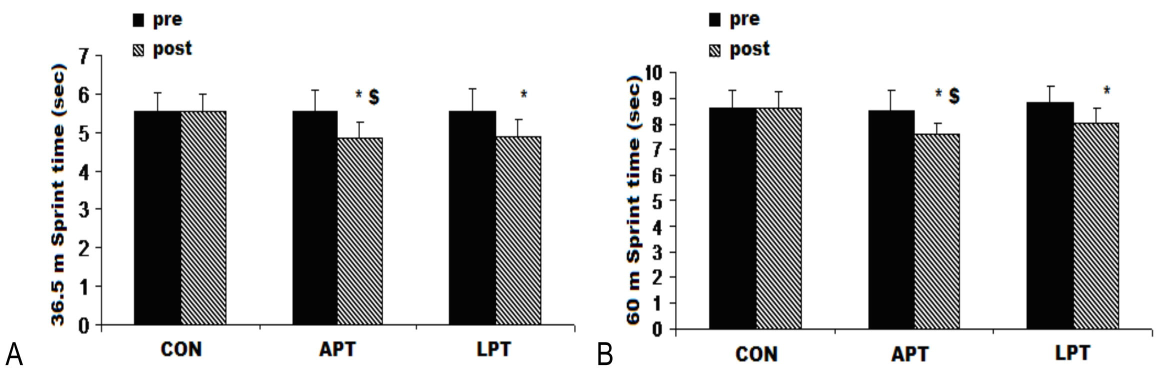

Figure 2. A** and **B. *36.5-m and 60-m sprint times for aquatic plyometric training (APT), land plyometric training (LPT) and control (CON) groups before and after 8 weeks training.*
** Significant difference from the pretraining*
$ Significant difference with control group

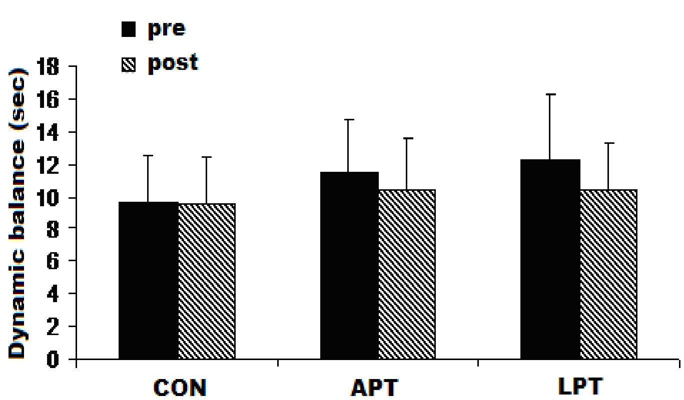

Figure 3. *Dynamic balance performance for aquatic plyometric training (APT), land plyometric training (LPT) and control (CON) groups before and after 8 weeks training.*

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DISCUSSION

The present study examined the effect of 8 weeks of aquatic and land plyometric training on strength, sprint, and balance performance. The results observed that APT improved better than LPT in strength and sprint. Whereas, the LPT group indicated better improvement than APT group in dynamic balance. In this study, maximal strength as measured by 1RM leg press was improved more by APT than by LPT; however, there was no significant difference between APT and LPT groups. A numerous studies reported that plyometric training, weight training and complex training can improve of strength performance (Wilson et al., 1993; Bobbert, 1990; Adams et al., 1992). The reasons of increase strength performance by weight training and complex training can be the type of plyometric and weight training exercises used and or the training stimulus. To our knowledge, a little study has addressed the effects of APT on strength performance. Robinson et al. (2004) examined the effects of 8-week of aquatic and land plyometric training on peak torque production by isokinetic strength testing. Subjects were thirty one collage age women with 20.5 years age and 5.5 years sport experience. Subjects performed in a swimming pool at the depth of 4 to 4.5 feet of water; 3 times per week for 8 weeks and 50 min with the minimum 360 reps and maximum 630 reps. They reported that both groups improved peak torque production. This finding is in line with our study. However, there were difference testing procedures, but the results of increase strength were similar. The reasons for this similarity can be depth of water, volume, frequency, training period and total workload was equated between studies. Also, sex difference cannot cause gains different results; therefore, we can say that no difference existed between male and female to increase strength by plyometric training. The reasons for this similarity are not clear. Martel et al. (2005) compared the combination of APT and volleyball training with traditional volleyball training. Subjects were nineteen female volleyball players with 15 years age and ≥ 2 yr sport experience. Both the APT and CON groups demonstrated significant improvements after the 6-wk study; however, the APT group had a significantly larger increase than the CON group for torque production in the during maximal knee-extension exercise. Our study is in line with above study. With attention to, differences strength tests, sex, age, and training period, the results was similar. The reason of similarity finding can be volleyball training and very young subjects to response the training stimulus because, volleyball training can cause SSC stimulus and accordingly, increase in maximum muscular strength. Shiran et al. (2008) reported that 5-week of APT and LPT improved leg muscle strength in male wrestlers. Our finding is similar to this study, but in our study was no significant difference in leg muscle strength. There was different testing procedure, leg press as compared with squat. Electromyographic analysis demonstrates that during the leg press hamstring co-activation is significantly reduced compared to the squat exercise (Wilk et al., 1996). Therefore, different tests are important to measure the muscular strength. It seems aquatic and land plyometrics cause a tangible increase in the recruitment of motor units of agonist muscles and hence, improve the strength. Also, one may speculate that the muscle force stimulus experienced by previously physically active or moderately trained individuals during plyometric training can be effective for maximal strength development. This suggests that plyometric training with additional loads might increase strength. Aquatic setting can provide resistance to movement, stimulus and additional muscle activation to overcome the resistance, and consequently, muscular strength improvement.

The results of this investigation suggested that plyometric training in water and land can improve sprint performance. Several studies have suggested that plyometric training may enhance sprint ability, because the use of stretch-shortening cycles during plyometrics performance has been shown to have a significant relationship to 30-m and 40-m sprint times (Hennessy & Kilty, 2001; Nesser et al., 1996). These findings are in line with demonstrated that a plyometric intervention program resulted in improvements in 40-m sprint times (Rimmer & Sleivert, 2000). In addition, the results are in line with those studies, which found significant changes after 7 weeks (twice a week) plyometric and weight training in professional soccer players (Ronnestad et al., 2008). Saez Saez de Villarreal et al. (2008) reported that 7 weeks plyometric training with difference frequency (420 DJs, 840 DJs, and 1680 DJs) in male students subjects can significantly improve in sprint ability. Although our plyometric training protocol was horizontal and vertical drills, whereas above studies using depth jumps, it did not result in sprint performance difference. In contrast to the results of the present study Reyment et al. (2007) found that plyometric training cannot induce significant reduce in 40-yard dash times. The reasons of this difference can be very low frequency, volume and training period. To the authors' knowledge, a limited number of studies have attempted to an effective of APT on sprint performance. In agreement with our results Robinson et al. (2004) and Shiran et al. (2008) reported a little improvement in sprint times by using the APT and LPT in participants. Also, this finding is in accordance with Ratamess et al. (2007) demonstrated that 10 weeks of combined resistance and sprint/plyometric training with the Meridian Elyte shoe in women causes an effective of enhancing 60-m sprint. The combined resistance and sprint/plyometric training can be the reason of sprint improvement, by facilitates the neuromuscular system into making a more rapid transition from eccentric to concentric contraction. Biomechanical analyses of sprinting have shown that sprints greater than 50 m may depend upon elasticity of the plantar flexor muscles to a greater extent than do shorter sprints, which consist mostly of acceleration. Sprints of at least 100 m consist of 3 phases: acceleration, constant velocity (or maximum speed), and deceleration. The acceleration phase is highly dependent upon reaction time and the athlete's ability to generate force and power during propulsion. During the constant-velocity phase, explosive power and efficiency of movement are critical up to the point of the deceleration phase, in which the attainment of maximal speed may rely greatly upon elasticity of the plantar flexor muscles (Mero et al., 1992). The results of this study observed that LPT made greater improvements than APT on dynamic balance test. There is a little information about the effect of plyometric training on balance. The results of the present study are in line with Myer et al. (2006) and Twist et al. (2008) reported plyometric training can improve balance performance in adults and female. In this study APT cannot improve dynamic balance better than LPT, because an aquatic setting can provide a safer environment and reduce weight bearing stress on the legs in which reduce impact on the joints and consequently, proprioceptors cannot be used property.

We recommend that future studies consider to different sport disciplines and increase training period in male and female athletes.

CONCLUSIONS

The results of the present study indicate that the 8-week of aquatic and land plyometric training in young basketball players can enhance the strength, sprint and balance performance. However, plyometric exercise could have a major disadvantage: particularly, an enhanced risk of injuries caused by external forces acting upon a joint that every moment exceed the structural integrity of the bones, muscles, ligament and tendon**.** The APT can provide a proper environment for improve performance with lower risk of injuries in muscles, bones and joints.

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