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COMPARATIVE EFFECT OF LAND- AND AQUATIC-BASED PLYOMETRIC TRAINING ON JUMPING ABILITY AND AGILITY OF YOUNG BASKETBALL PLAYERS

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ABSTRACT

The effect of land- and aquatic-based plyometric training on jumping ability and agility of young basketball players was investigated. Eighteen young male, semi-professional basketball players (age: 18.81±1.46 years) were randomly assigned to aquatic plyometric training (AP), land plyometric training (LP) or a control group (CON). The plyometric training groups were subjected to an 8-week long plyometric training program that consisted of three plyometric training sessions per week of 40 minutes per session. The players performed jumping ability and agility tests before and after the training or non-training period. The 2×3 analysis of variance and Tukey post hoc test revealed no significant differences (p>0.05) between the AP and LP for any of the jumping ability and agility test values. A significant training effect (p<0.05) was seen in the experimental groups (AP and LP) for all the test variables from pre- to post-training. Significantly greater gains were observed with regard to all measurements in the AP compared to the CON. The LP only achieved significant greater gains in the Vertical Jump Test compared to the CON. The 8-week aquatic-based plyometric training program provided the same or more benefits for jumping and agility ability of young basketball players than the land-based plyometric training program of the same duration.

Key words: Power; Agility; Aquatic plyometrics; Land plyometrics; Basketball.

INTRODUCTION

Plyometrics as it is known and used today received a great deal of attention in the early 1970s when athletes from the Eastern European countries began to dominate power dependant events (Stemm & Jacobson, 2007). Plyometrics is a specialised, high-intensity training technique that enables an athlete’s muscles to deliver as much strength as possible in the shortest period of time so that power development results (Radcliffe & Farentinos, 1999; Chimera *et al*., 2004). Plyometrics make use of the stretch-shortening cycle, which utilises the energy stored during the eccentric loading phase and stimulation of the muscle spindles to facilitate maximum power production during the concentric phase of movement (Potach, 2004; Potach & Chu, 2008). The afore-mentioned descriptions, together with several research findings, show that land-based plyometric programs can be used to significantly improve: explosive power (Fatouros *et al*., 2000; Luebbers *et al*., 2003); flight time (Fatouros *et al*., 2000); maximal isotonic (Fatouros *et al*., 2000; Toumi *et al*., 2004) and isometric leg muscle strength (Toumi *et al*., 2004); isokinetic peak torque of the legs (Miller *et al*., 2002) and shoulders (Schulte-Edelmann *et al*., 2005); range of ankle motion (Miller *et al*., 2002); speed (Rimmer & Sleivert, 2000); and the electrical muscle activity (Toumi *et al*., 2004) of males. Furthermore, land-based plyometric programs seem to significantly decrease ground contact time during sprinting activities (Rimmer & Sleivert, 2000) and the amortisation time during the execution of plyometric exercises (Toumi *et al*., 2004), which may have a positive effect on sport performance (Wilkerson *et al*., 2004).

Based on these benefits, it is apparent that land-based plyometric training is regarded as a useful training tool for athletes who participate in sport, which require dynamic, explosive types of movement such as basketball. In this regard, a period of 8 weeks of land-based plyometric training has been shown to be effective in eliciting significant positive changes with regard to maximum jump velocity, maximum force, absolute and relative power, as well as average power during 10 maximum counter-movement jumps among university-level male basketball players (Boraczyñski & Urniaz, 2008). Khlifa *et al*. (2010) reported similar significant positive results for squat jumps, counter-movement jumps and the 5-jump test among elite male basketball players after a 10-week plyometric program. The research findings of Santos and Janeira (2011) support the results of the latter studies. They concluded that a 10-week in-season land-based plyometric training program significantly improved squat jump, counter-movement jump, the Abalakov test, depth jump and the medicine ball throw test results for a group of male basketball players.

Despite the widespread acceptance, benefits and use of land-based plyometric training programs in the conditioning of basketball players, several researchers have questioned the efficacy and highlighted the potential risks of land-based plyometric training programs as a conditioning technique. Marginson *et al*. (2005), reported muscle soreness and a decrease in squat jump and counter-movement jump height in a group of men for 72 hours after a bout of plyometric jumps. According to Jamurtas *et al*. (2000), damage to muscle fibres or possible damage to musculotendinous junctions could be the sources of higher muscle soreness and the decrease in muscle function after the performance of land-based plyometric exercises. Moreover, the potential for injury exists, especially for athletes that are not used to land-based plyometric training. This is due to the high intensities and impacts or high volumes that are normally associated with plyometric training (Miller *et al*., 2002; Miyama & Nosaka, 2004; Ploeg *et al*., 2010).

In light of possible injury risk, the occurrence of muscle soreness and a possible decrease in muscle function due to land-based plyometric training programs, research findings suggest that aquatic-based plyometric training programs may provide a safer and more effective alternative for athletes, who need to develop their muscle power optimally (Miller *et al*., 2002; Miller *et al*., 2007; Stemm & Jacobson, 2007; Ploeg *et al*., 2010; Donoghue *et al*., 2011). Research offers several explanations for the preferred use of aquatic- above land-based plyometric training programs. The buoyancy provided by the water due to the increased density of water compared to air, reduces the impact forces and weight-bearing stress on the joints and limbs, thereby decreasing the risk of injuries (Miller *et al*., 2007; Ebben *et al*., 2010; Donoghue *et al*., 2011). Furthermore, the dynamic properties of water, such as surface, profile and wave drag, as well as the high viscosity of this medium, increases the resistance to movement (Miller *et al*., 2002; Robinson *et al*., 2004; Miller *et al*., 2007). Additional muscle activation is therefore required to overcome the water resistance and execute the same movement through water (Robinson *et al*., 2004).

Despite the possible benefits of aquatic-based plyometric training programs, to date only one study (Martel *et al*., 2005) has explored the relevance of these programs for team sport participants and no studies compared the benefits of these types of programs to those of land-based plyometric training programs for basketball players. The majority of studies that exist focused on sedentary and recreationally active participants of both genders. Studies by Miller *et al*. (2002), Robinson *et al*. (2004), Stemm and Jacobson (2007) and Ploeg *et al*. (2010) collectively reported that aquatic- and land-based plyometric training programs of between six and eight weeks had similar effects with regard to changes in jumping height (Vertical Jump Test), muscle power (Vertical Jump and Margaria-Kalamen Test), speed (40-m Sprint Test), isokinetic peak torque (knee-flexion and-extension, as well as ankle dorsi- and plantar-flexion) and active range of motion (dorsi- and plantar-flexion and knee-flexion) among groups of sedentary and recreationally active men and women. Only Robinson *et al*. (2004) found a significantly greater perception of muscle soreness at 48 and 96 hours after the plyometric exercise bout for the land-based plyometrics group when compared to the aquatic-based plyometrics group.

Merely one study could be found that compared the effects of aquatic- and land-based plyometric training programs on the performance and muscular injury of sport participants (club wrestlers) (Shiran *et al*., 2008). Consistent with the results of these studies, no significant differences were found pertaining to the changes in strength, speed, agility, fatigue index, peak and mean power or the risk of muscle injury between the aquatic- and land-based plyometric training programs. The wrestlers who participated in the aquatic-based plyometric training program did, however, experience less muscle soreness than the group that participated in the land-based plyometric training program.

It is clear from the findings of these studies that aquatic-based plyometric training programs could reduce the impact forces and the potential trauma to joints while providing resistance to movement well beyond that of land-based plyometric training programs. Unfortunately, studies to date have not addressed the effectiveness and benefits of aquatic-based plyometric training on team sport participants, such as basketball players. Therefore, the purpose of this study was to compare the effects of an 8-week land- and aquatic-based plyometric training program on the jumping ability and agility of young male basketball players. The findings of this study may possibly provide coaches and other sport professionals, who are involved with team sport participants, with information and guidelines that would enable them to plan and set-up safer and more effective plyometric training programs.

METHODS

Experimental design

A quasi-experimental pre-post-test design with convenient sampling was used for this study and participants were subjected to a series of jumping ability and agility tests after which the experimental groups completed an 8-week plyometric training program in addition to their regular basketball conditioning program. The control group continued with their regular conditioning program for basketball and did not participate in a plyometric program. After completion of the 8-week plyometric or non-plyometric training programs, the jumping ability and agility tests were repeated.

Participants

Eighteen (n=18) young, semi-professional male basketball players participated in this study. Participants volunteered for the study and were healthy and free of lower extremity injuries during the time of testing. Participants were informed of the aims, nature, benefits and potential risks of the study, after which they all completed an informed consent form. The Ethics Committee of the institution where the study was conducted approved the study. Participants were matched and randomly assigned to three equal groups: an aquatic-based plyometric training group (AP: n=6); a land-based plyometric training group (LP: n=6); and a control group (CON: n=6). The descriptive statistics of the different groups of basketball players are presented in Table 1.

TABLE 1: **BIOGRAPHIC STATISTICS OF THE DIFFERENT GROUPS OF BASKETBALL PLAYERS**

	AP (n=6)		**LP (n=6)**		**CON (n=6)**	
Variables	Mean	SD	Mean	SD	Mean	SD
Age (years)	18.00	0.60	18.03	1.38	20.40	0.64
Body mass (kg)	75.66	3.93	67.50	1.00	60.25	7.03
Stature (cm)	180.28	4.58	182.41	7.24	175.33	4.67
Sport experience (yrs)	4.75	2.23	4.00	2.70	5.66	2.58

AP = Aquatic plyometric group; LP = Land plyometric group; CON = Control group
SD = Standard deviation

Testing procedures

The players underwent two days of testing, namely one pre- and one post-test day respectively. A week before the official testing week, each player was familiarised with the testing procedures and plyometric training programs, and the demographic data were gathered and anthropometric measurements (body mass & stature) taken. The baseline testing of agility (t-test and Illinois Agility Run Test) and jumping ability (Vertical Jump Test and Standing Long Jump Test) was completed one week before the onset of the different plyometric training protocols. Post-testing was performed a week after the training period. For the post-test, players were tested at the exact same time of day and same day of the week as the pre-test day to minimise the effect of circadian variations on the test results. All participants had to continue with the normal basketball, conditioning program through the duration of the study. Participants had not participated in any type of plyometric training programs for at least six months prior to the start of the study and were not permitted to participate in any resistance training programs during the time period of the study.

The following laboratory tests were conducted:

Vertical Jump Test [VJT] (Explosive leg power)

The VJT is regarded as an objective (r=0.90) and valid (r=0.93) test to determine the peak anaerobic power output of participants (Safrit, 1990; Maud *et al*., 2006). The VJT was executed according to the method of Harman and Garhammer (2008). The VJT was performed using the Vertec device (Power Systems, Knoxville, Tennessee). The participants performed a minimum of three trials with a 30-second rest period between each trial. The best of the three trials was recorded.

Standing Broad Jump [SLJT] (Explosive leg power)

The SLJT is considered a reliable (r=0.89-0.90) and valid test to determine the peak anaerobic power output of participants (Maulder & Cronin, 2005). The test was performed on a flat even mat that was fixed to the floor. A measuring tape was laid out on this surface. The participants stood with both feet so that the toes were behind the zero line. When the subject was ready, he would take off from both feet and jump forward as far as possible from a still-standing position. The jumping distance was recorded as the distance from the heel closest to the zero line. The participants performed a minimum of three trials with a 30-second rest period between each trial. The best of the three trials was recorded.

Agility T-Test [ATT] and Illinois Agility Run Test [IART] (Agility tests)

The ATT and the IART were conducted according to the method of Bloomfield *et al*. (1994) and Van Heest *et al*. (2002), respectively. Both tests were performed on the basketball court. A hand-held stopwatch was used to take the participants' time to the nearest 0.01seconds. The fastest time of the three trials was noted as the final agility time. A 5-minute rest period was allowed between each trial. According to Gabbett (2002), the intraclass correlation coefficient for the test-retest reliability and technical error of measurement for the IART are 0.86 and 2.02% respectively.

Training

The 8-week training regimen was adopted from a previous study by Robinson *et al*. (2004). Both the LP and AP trained three times per week (Saturdays, Mondays and Wednesdays) with a 48 hour recovery period between each training session. Each training session lasted for approximately 40 minutes and consisted of a warm-up, main set and cool-down. The aquatic-based plyometric training program was performed in a swimming pool with a depth of 130 cm (chest-deep). The participants were submerged during the performance of the aquatic-based plyometric training program. The warm-up of 10 minutes consisted of jogging for five minutes after which static stretches and a specific warm-up period of shorter, high intensity, dynamic stretches for more or less 5 minutes followed.

The plyometric exercises consisted of ankle jumps, speed marching, squat jumps and skipping drills. The participants were encouraged to perform all exercises in an explosive manner by performing each movement at a maximal effort. Each subject was allowed a 1-minute rest between sets and 3 minutes rest between exercises. The cool-down period consisted of static stretches of the major leg muscle groups for a period of 5 minutes. The swimming pool was regulated at a temperature of 27±1°C, according to the guidelines set by Martel *et al*. (2005).

The LP performed the plyometric exercises on a mat with a thickness of 3cm. The training procedures were similar to those of the AP. The training program was based on the recommendations of intensity and volume from Chu (1998) and Milic *et al*. (2008). The list of plyometric exercises as well as the progression that was followed over the 8-week period is presented in Table 2. All CON participants were requested to refrain from any plyometric training.

TABLE 2: **PLYOMETRIC EXERCISE PROGRESSION FOR 8-WEEK PERIOD**

Training week	**Plyometric training exercises and repetitions**				
	Ankle jump	Speed marching	Squat jump	Skipping drill	Sets
1	15	8	8	8	3
2	17	9	9	9	3
3	19	10	10	10	3
4	22	11	11	11	3
5	17	9	9	9	3
6	19	10	10	10	3
7	22	11	11	11	3
8	25	12	12	12	3

Statistical analysis

Data analysis was performed using the Statistical Package for the Social Sciences (SPSS) for Windows (SPSS version 16.0, SPSS Inc., Chicago, IL). The descriptive statistics of each test variable for each group were calculated first. A 2×3 analysis of variance (ANOVA) followed by a Tukey post-hoc test was used to examine the significance between independent variables of groups (AP, LP and CON) on the dependent variables of jumping ability and agility. Dependent paired *t*-tests were done to reveal the significant changes between the pre- and post-training results. In all analyses the level of significance was set at $p<0.05$.

RESULTS

The results for the jumping ability and agility measurements of each of the groups are presented in Figure 1. Table 3 presents the percentage differences between all of the pre- and post-training values for the ATT, IART, VJT and SLJT, as well as the significance of these differences. None of the last-mentioned measurements displayed any significant differences in terms of the pre-training values between the different groups. There were no significant differences between the post-training values of the AP and LP. A significant training effect ($p<0.05$) was found in the experimental groups (AP and LP) for all the test variables from pre- to post-training. The post-hoc analysis revealed significantly greater gains with regard to all measurements in the AP compared to the CON. However, the LP only succeeded in achieving significant greater gains (pre- to post-training) in the VJT compared to the CON (Figure 1A).

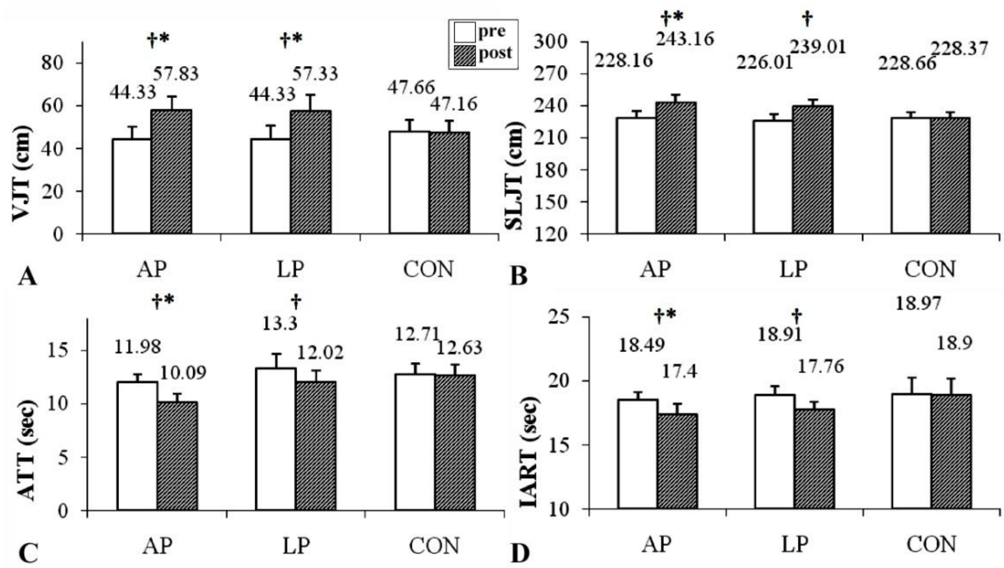

FIGURE 1: **MEANS, RANGE AND WITHIN GROUP CHANGES AND BETWEEN GROUP DIFFERENCES**

TABLE 3: **PERCENTAGE DIFFERENCE BASED ON PRE- AND POST-TEST VALUES OF GROUPS FOR EACH TEST**

Test values	**AP (n=6)**	**LP (n=6)**	**CON (n=6)**
VJT (cm)	30.45*	29.33*	-1.05
SLJT (cm)	6.57*	5.75	0.13
ATT (secs)	-15.78*	-9.62	-0.63
IART (secs)	- 5.90*	-6.08	-0.37

* Changes in pre- to post-training values are significantly different ($p<0.05$)

DISCUSSION

The study succeeded in showing that aquatic- and land-based plyometric training programs of an eight-week duration had a significant training effect with regard to all the measured jumping ability and agility values from pre- to post-training in a group of young, male basketball players. The control group's jumping ability and agility values showed no significant improvements from the pre- to post-training period. In spite of the favourable results with regard to the training affect that each of the experimental groups (AP and LP) experienced, the AP was the only group that had achieved significantly better pre- and post-training differences in all the measured variables compared to the CON. VJT was the only test in which the LP displayed significantly better pre- and post-training improvements compared to the CON.

No other studies have been conducted to compare the effects of an aquatic- and land-based plyometric training program on jumping ability and agility test scores of young, male basketball players, which made it difficult to compare the results of this study to similar studies. However, several studies have compared the benefits of aquatic-based programs to those of land-based plyometric training programs in sedentary and recreationally active men and women. Overall, these studies seem to suggest that aquatic- and land-based plyometric training programs of between six and eight weeks have similar effects with regard to changes in jumping height and muscle power in the VJT (Miller *et al*., 2002; Robinson *et al*., 2004; Stemm & Jacobson, 2007; Ploeg *et al*., 2010), which is consistent with the findings of this study.

Similar to the results of this study, the majority of research reported a significant training effect for VJT height from pre- to post-training in AP (Miller *et al*., 2002; Robinson *et al*., 2004; Stemm & Jacobson, 2007), whereas only two of the identified studies found a significant pre- to post-training effect in the LP for VJT height (Robinson *et al*., 2004; Stemm & Jacobson, 2007). In contrast to the results of the present study that the AP achieved significantly better pre- and post-training differences in VJT height when compared to the CON, the majority of research in this area that included a CON in the study design, reported no significant differences between AP and CON (Miller *et al*., 2002; Ploeg *et al*., 2010). Stemm and Jacobson (2007) are the only researchers to find that AP and LP significantly outperformed the CON in the VJT height after a period of training.

Although no studies could be found that have simultaneously investigated the possible effects of aquatic- and land-based plyometric training programs on the agility of participants, the results of this study suggest that participants' agility values could be significantly improved by making use of a period of aquatic-based plyometric training when compared to non-plyometric training. However, the land-based plyometric training program failed to produce significant improvements in the agility of participants when compared to the non-plyometric program. Dissimilarly, one research study in which the efficacy of a 6-week land-based plyometric training program on athletes' agility was investigated, provided proof that the mentioned program may lead to significant decreases in agility times for the ATT and IART compared to a non-plyometric program (Miller *et al*., 2006).

Although the design of this study did not allow the researchers to determine the reasons underlying the improvements in jumping ability and agility from pre- to post-training due to the plyometric training programs, several authors have proposed some credible explanations. Plyometric-related programs may promote changes within the neuromuscular system that enhances neuromuscular efficiency. In this regard research evidence suggests that more motor units are stimulated and activated or the neural firing frequency is enhanced due to plyometric training (McLaughlin, 2001). The activation of more motor units would enable the muscle to generate more power, compared to what was previously possible.

Furthermore, Swanik *et al*. (2002) concluded that the sensitivity of the muscle spindle system may increase because of a plyometric training program and that this adaptation may lead to the enhancement of participants' joint proprioception. Plyometric training appears to enhance kinaesthesia, which together with an enhanced joint proprioception may increase functional stability (Swanik *et al*., 2002). Kubo *et al*. (2007) demonstrated that jump performance gains after plyometric training can be attributed to changes in the mechanical properties of the muscle-tendon complex. Notably, the authors observed that plyometric training significantly increased the maximal Achilles tendon elongation and the amount of stored elastic energy together with an increase in the stretch-shortening cycle jumping performance. It can be postulated that a more compliant muscle-tendon unit would improve the stretch-shortening cycle jumping performance by allowing the muscle fibres to operate at a more optimal length over the first part of the shortening phase (Markovic & Mikulic, 2010).

Despite inconsistent findings, researchers are of the opinion that plyometric training may possibly lead to significant increases in the proportion of type IIa fibres and the peak force of these muscle fibres (Malisoux *et al*., 2006). A transition in the muscle fibre type, as well as an increase in the contractile ability of the changed muscle fibres, would allow the exercising muscles as a whole to produce more power and higher jumping heights. Another possible neuromuscular adaptation that plyometric training appears to induce is the reduction in the time required for voluntary muscle activation, which may facilitate faster changes in movement direction and an accompanied decrease in the IART and ATT times (Wilkerson *et al*., 2004). According to Hutchinson *et al*. (1998), it is also possible that a cognitive, learned effect, rather than a purely motor strengthening effort, is the reason for an increase in the selected jumping ability and agility components due to plyometric training programs.

An unexpected result of the study was that the aquatic- and land-based plyometric training programs led to more-or-less similar gains in jumping ability and agility for the study participants. It is, therefore, conceivable that both training regimens led to the same physical and physiological adaptations over the period of eight weeks. According to Miller *et al*. (2002), the landing force during aquatic-based plyometric exercises is decreased because of the buoyant force of water, which facilitates a more rapid transition from eccentric to concentric muscle contractions (amortisation phase) and ultimately an increased power output. On the other hand, during land-based plyometric exercises, participants experience a higher amount of force during the landing phase (no buoyancy effect), which facilitates a longer amortisation phase and ultimately an increase in muscle strength (Miller *et al*., 2002). Both these adaptations could ultimately be transferred to the tests of jumping ability and agility, which would improve the scores of these tests.

A somewhat unexpected outcome of the study was that AP achieved significantly better pre- and post-training differences in all the measured variables compared to the CON, whereas VJT was the only test in which the LP displayed significantly better pre- and post-training improvements compared to the CON. This can possibly be attributed to the fact that participants in this study have been participating in basketball in which land-based plyometric type explosive movements (mimicking the VJT) are constantly being performed during practices, training and matches. Research also suggests that jump performance is a major factor of success in basketball, and a key fitness component for development during training sessions (Delextrat & Cohen, 2008). Activities such as blocking and scoring need a large amount of explosive power to be performed successfully.

Furthermore, research indicates that players move at an average velocity of 1.86 m/sec during the active phase of a game (Erčulj *et al*., 2008). For players to be able to maintain high velocities during the game, leg power (jumping performance measures) must be developed as these values act as predictors of sprint performance (Cronin & Hansen, 2005). Players' muscles were therefore already accustomed to land-based plyometric type, explosive movements before the start of the intervention period. As a result, they would probably not be so sensitive and reactive to land-based compared to aquatic-based plyometric conditioning programs. This statement is confirmed by the findings of Turner *et al*. (2003), who attributed the positive results due to a land-based plyometric training period to the fact that the participants were untrained and not accustomed to this type of training. In view of this, it is important to consider participants' experience in plyometric type of movements and training when planning a study of this kind. Participants, who are not accustomed to land- and aquatic-based plyometric type explosive movements, would probably be more sensitive and reactive to these plyometric conditioning programs than participants who are accustomed to these types of movements.

The finding that the AP was the only group that achieved significantly better pre- and post-training differences in the agility values compared to the CON, could be attributed to the fact that the AP trained with lower loads (buoyancy effect), which facilitated a faster transition time from eccentric to concentric muscle contractions (amortisation phase), whereas the LP trained with heavier loads (no buoyancy effect) and experienced a longer amortisation phase (Miller *et al*., 2002). These statements suggest that aquatic-based plyometric training programs may reduce ground contact times when players are changing direction during agility tests and drills, which is a major component of agility (Miller *et al*., 2006). However, agility can be described as a relatively complex task, which makes power transfer from plyometric exercises to the agility tests very difficult (Tricoli *et al*., 2005). This notion is highlighted by the non-significant pre- and post-training differences in the agility values of the LP when compared to the CON. Tricoli *et al*. (2005) failed to demonstrate that land-based plyometric training programs would lead to improved agility performances when compared to a group that underwent Olympic weightlifting training. It is, therefore, possible that agility tasks are more influenced by motor control factors than by muscle strength or power capacity (Young *et al*., 2002).

CONCLUSION

A comparison between the effects of an 8-week land- and aquatic-based plyometric training program on the jumping ability and agility of young, male basketball players revealed that both plyometric training programs had a significant training effect whereas the control group's values showed no significant improvements from pre- to post-training. However, the AP was the only group that achieved significantly better pre- and post-training differences in all the measured variables compared to the CON. Overall, the results of the study suggest that an 8-week aquatic-based plyometric training program provides the same or even more benefits with regard to the jumping ability and agility of young team sport participants than a land-based plyometric training program of the same duration. The fact that literature shows that aquatic-based plyometric training programs are associated with less muscle soreness and a lower risk of injury compared to land-based plyometric training programs, make it a viable alternative for athletes who participate in explosive-types of sports, such as basketball. A reduction in training-related injuries while attaining the highest possible level of adaptation remains a priority for athletes who wish to perform consistently for long periods of time.

However, the results of the present study must be interpreted with caution since the participants were a selected group of young, male basketball players from one geographic area in Iran. Hence generalisation of the results to other basketball players would not be accurate. Another possible limiting factor is the small number of participants available for each of the subgroups tested. Small group sizes in this study could have caused outliers to influence the mean values of the respective jumping ability and agility test scores more than would have been the case with larger group sizes. Finally, the study design did not allow the researchers to explain the reasons underlying the improvements in the different jumping ability and agility test scores.

Further studies in the area of aquatic-based plyometric training programs are needed to test the benefits of these types of programs with a much larger sample size of athletes from different sport disciplines and from various geographic areas in the world. These studies also need to conduct biochemical and biomechanical analyses to identify the precise neural and musculoskeletal mechanisms that underlie the changes in the various physical and motor performance components after a period of plyometric training.

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