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Effects of Aquatic and Land Plyometrics on Athletic Performance: A Systematic Review

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Abstract

The purpose of this study was to systematically review literature to determine whether aquatic plyometric training (APT) increases athletic performance compared to land-based plyometric training (LPT). We identified 6 articles from *PubMed, CINAHL, MEDLINE*, and single-citation matching from January, 1995 through January, 2017 using search words *"aquatic plyometric training OR aquatic plyometric OR aquatic plyometrics."* After screening (title, abstract), 6 articles were reviewed for inclusion criteria: (1) full-report/abstract, (2) peer-reviewed RCTs/clinical trials, (3) English language, (4) focused on healthy individuals (free of current, lower-extremity, musculoskeletal injuries) ages 16-30 years, and (6) included strength, power, and/or vertical jump [VJ] dependent variables. Six (of 6) studies met inclusion criteria (LOE, 1b = 6; PEDro score = 6.3±0.3). Reported pooled sample size was 182, mean age 22.46±3.67 (range 17-27). Studies found significant ($p>.05$) performance increases in the LPT and APT groups, with no significant ($p>.05$) differences in the amount of performance increase between experimental groups. Results demonstrated both LPT and APT can improve measures of athletic performance; however, neither appears to produce significantly better performance than the other.

Keywords: plyometric training, water, athletic performance, aquatic exercise

Introduction

Plyometric training can be an effective way to increase athletic performance which in this review, was defined by 3 variables: (1) strength, (2) power, and/or (3) vertical jump (VJ) (Arazi & Asadi, 2011; Gulick, O'Melia, Libert & Taylor, 2007; Miller, Berry, Bullard, & Gilders, 2002; Robinson, Devor, Merrick, & Buckworth, 2004; Stemm & Jacobsen, 2004). Miller, Berry, Bullard, and Gilders (2002) defined *plyometrics* "as a rapid pre-stretching of a muscle during an eccentric action, followed immediately by a concentric action of the same muscle." The stored elastic energy from this rapid transition enables the muscle to create a greater contraction (Gulick et al., 2007) as compared to starting from a static position (Miller et al., 2002). By utilizing various plyometric exercises, with multiple sets and repetitions, physically active individuals can increase athletic performance measures (Arazi & Asadi, 2011; Gulick, O'Melia, Libert & Taylor, 2007; Miller, Berry, Bullard, & Gilders, 2002; Robinson, Devor, Merrick, & Buckworth, 2004; Stemm & Jacobsen, 2004).

Traditionally, plyometric training has been practiced in land-based settings only. Land plyometric training (LPT) has demonstrated significant athletic performance benefits, but the potential for injury exists during training (Arazi & Asadi, 2011; Gulick et al., 2007; Miller et al., 2002; Robinson et al., 2004; Stemm & Jacobsen, 2004). The repetitive ballistic movements of plyometrics can cause injuries such as "meniscal damage, patellar tendonitis, Achilles tendon strains, and heel bruises" (Robinson et al., 2004). Recent studies have begun to examine the potential benefits of aquatic plyometric training (APT) to improve athletic performance measures and decrease injury rates as compared to LPT. Researchers agree the aquatic environment can be beneficial in injury risk reduction while providing sufficient resistance for training (Arazi & Asadi, 2011; Gulick, O'Melia, Libert & Taylor, 2007; Miller, Berry, Bullard, & Gilders, 2002; Robinson, Devor, Merrick, & Buckworth, 2004; Stemm & Jacobsen, 2004). Water's buoyancy reduces joint compression forces (which are significantly increased on land) and can reduce weight-bearing status (Gulick et al., 2007; Miller et al., 2002). Additionally, the density of the aquatic environment provides 12 times the resistance of air, making it very comparable to land-based training, despite the decreased weight bearing status seen in the water (Gulick et al., 2007). Athletic trainers (ATs) can use this information to tailor a training program for their athletes, whether it be an aquatic- or land-based training program.

With 94% of college strength and conditioning coaches incorporating plyometric training (Gulick et al., 2007) in their programs and with the high risk of injury during traditional land-based plyometric training programs, it is important to explore alternatives to reduce injury rates while still increasing athletic performance measures. To our knowledge, a systematic review has not been conducted comparing and combining studies of APT and LPT. We set out to systematically review the recent literature to determine whether, in healthy individuals ages 16-30 years, APT may increase athletic performance measures (i.e., VJ, power, and strength) and how APT results compared to LPT.

Method

Data Sources

The electronic database *The Cumulative Index to Nursing and Allied Health Literature* (*CINAHL)* was searched for relevant articles published between January 1995 to January 2017 using the search phrase "*aquatic plyometric training OR aquatic plyometric OR aquatic plyometrics*" and the following filters: abstract, January 1995 to January 2017, English language only, human, clinical trial, randomized controlled trial, and peer-reviewed. The search yielded 2 *CINAHL* results. The *Medical Literature Analysis and Retrieval System Online* (*MEDLINE)* database was also searched using the string *"*aquatic plyometric training OR aquatic plyometric OR aquatic plyometrics" and the following filters: abstract, January 1995 to January 2017, English language only, human, clinical trial, and randomized controlled trial. This search yielded 3 results. The *PubMed* database was searched using the same search phrase with the following filters: clinical trial, randomized controlled trial, English language only, human, abstract available, and January 1995 to January 2017. This search revealed 3 additional articles. Three more articles were found via single-citation search. Amongst all searches, 6 articles were found in more than 1 database. Excluding doubles, the total article count was 6. The 6 articles were screened per the inclusion criteria below.

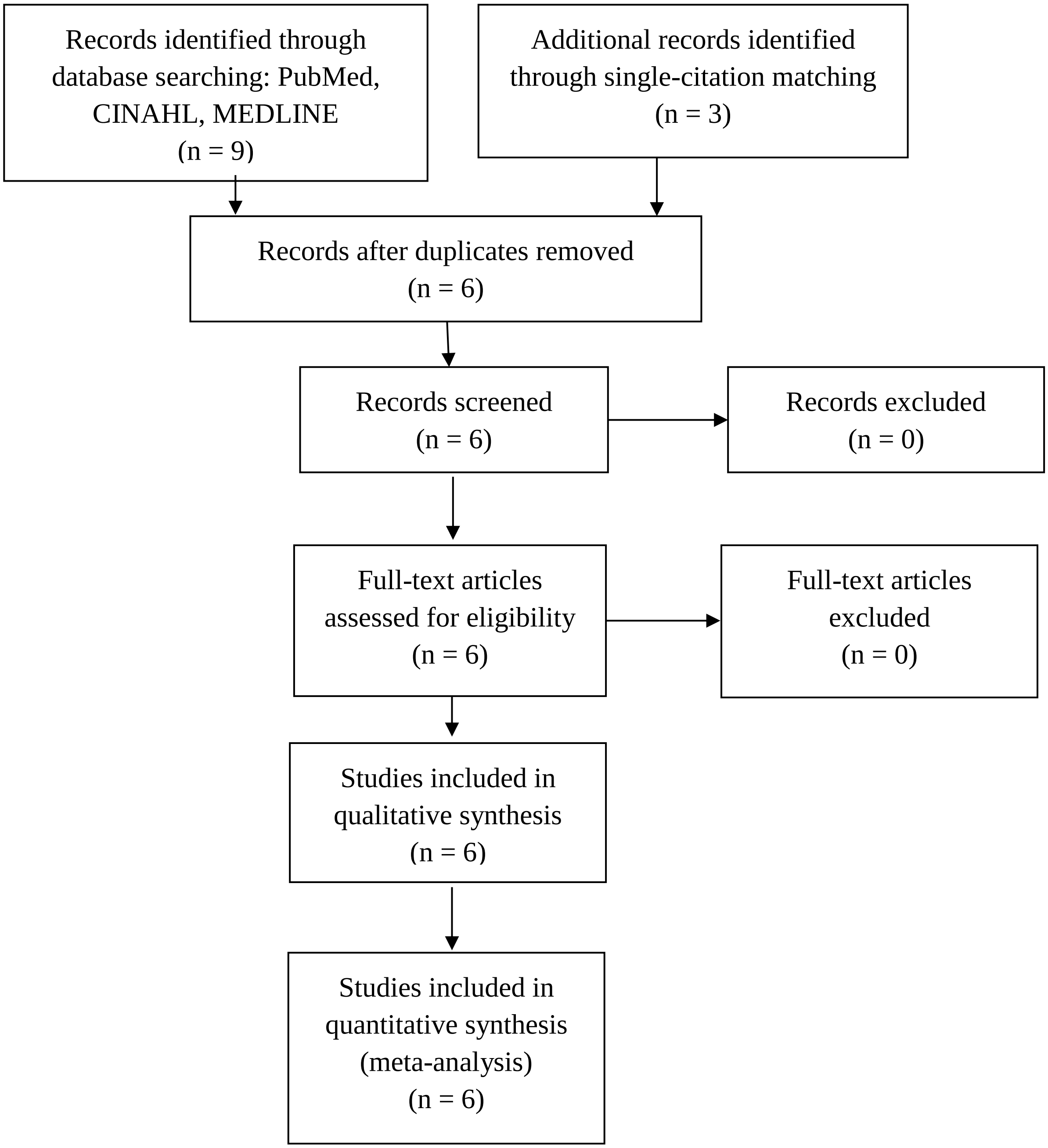
Study Selection

After title and abstract screening all 6 articles, 6 articles were considered satisfactory for a full review. To screen the articles, we examined titles for comparisons of LPT and APT. If the title fit with our study purpose, we reviewed the abstracts to determine whether the inclusion criteria were present. Articles would be excluded if they did not meet the inclusion criteria.

To be included in the study, articles (full-report or abstract) had to be written in English, be peer-reviewed, and be randomized controlled trials (RCTs) or controlled clinical trials (CCTs). In a RCT, subjects are randomly assigned to experimental or control groups and in a CCT subjects are not randomly assigned. Studies had to include at least 1 of the following key indicators of athletic performance: (1) power, (2) strength, or (3) VJ. Study subjects had to be identified as healthy individuals free of lower-extremity musculoskeletal injuries. Lastly, because young athletes often utilize plyometric exercise, subjects were excluded if they did not fall into the identified age range of 16-30 years. Of the 6 articles reviewed, all 6 were acceptable to be included in the review with a pooled sample size of 182 subjects with a mean age of 22.46±3.67 years (range

17-28 years). The study selection flowchart can be seen in Figure 1.

Figure 1 Study selection flowchart.



Data Extraction

The quality of the 6 articles was assessed and graded by 3 independent reviewers using the Physiotherapy Evidence Database (PEDro) ("PEDro Scale") and Centre for Evidence-Based Medicine (CEBM) scales ("Oxford Centre for Evidence-based Medicine - Levels of Evidence," 2009). The PEDro scale is "based on the Delphi list developed by Verhagen and colleagues at the Department of Epidemiology, University of Maastricht... to help the users of the PEDro database rapidly identify which of the known or suspected randomized clinical trials (i.e., RCTs or CCTs) archived on the PEDro database are likely to be internally valid" ("PEDro Scale", n.d.). There are 11 "yes" or "no" questions on the PEDro scale used to assess the quality of an article. It is important to note that Question 1 is not used in the calculation of a PEDro score as it is used to assess applicability. The number of "yes" answers comprises the score of the article.

Three reviewers also independently assessed the included studies according to the CEBM level of evidence classification system ("Oxford Centre for Evidence-based Medicine - Levels of Evidence", 2009). All included articles were of "Level 1b" evidence according to the CEBM scale ("Oxford Centre for Evidence-based Medicine - Levels of Evidence", 2009). When significant differences in scores or level of evidence (LOE) were found regarding any of the articles, a third party was available to review and clarify discrepancies, when applicable. Extracted data included (1) subject characteristics, (2) descriptive statistics (e.g., mean, standard deviation [SD], 95% confidence intervals [CIs] with combined means used in some instances for similar data sets), and (3) inferential statistics and effect sizes (where applicable).

Results

Six studies met the inclusion criteria; all were full reports. PEDro scores ranged from 6-7 (on a 1-10 scale) with an average score of 6.3±.3. The studies resulted in a pooled sample size of 182 with a mean age of 22.46±3.67 years (range 17-28 years). Three studies examined strength, 3 discussed power, and 3 studied VJ (Arazi & Asadi, 2011; Gulick et al., 2007; Miller et al., 2002; Robinson et al., 2004; Stemm & Jacobsen, 2004; Villarreal, Suarez-Arrones, Requena, Haff, & Veliz, 2015), Some articles included specific athletes such as basketball and water polo players. The other studies focused on healthy participants. A summary chart of the extracted data for the 6 studies can be found in Table 1.

Table 1 Summary of data extraction

Author(s)	Study Focus	Sample	Design	Outcome Measures	Results	Conclusion	LOE	Average PEDro Score
Arazi & Asadi (2011)	"Compare the effects of eight weeks of aquatic and land plyometric training on leg muscle strength…in young male basketball players"	18 semiprofessional male basketball players (age=18.81±1.46 years) who were free of lower-extremity injuries and conditions that prevented participation Three groups: APT (n=6), LPT (n=6), and CON (n=6)	Subjects were randomly assigned to LPT, APT, or CON groups. Groups trained for eight weeks, three days a week. Groups performed same exercises in respective environments.	Strength	No significant differences were found at 8 weeks between APT and LPT (p>.05) for a 1-RM leg-press. APT (200±10 kg) displayed significant (p<.05) increases compared to CON (175±10 kg).	APT and LPT are almost equal in benefits provided for athletic performance.	1b	6.5
Gulick, Libert, O'Melia, & Taylor (2007)	"Examine the effectiveness of an aquatic-based plyometric program compared to land-based program in improving	42 university students (age=24.5±3.47 years) with no prior formal plyometric training and no current or prior lower-extremity injuries, and	Subjects were randomly divided into three groups: APT, LPT, and CON. Variables were measured before training	Power and Strength	A significant increase was found in the APT group from pre- to midttest for power (Pretest average=7123±180W, Midtest average=7270±179W).	APT and LPT provided similar increases in strength compared to the control.	1b	6

	lower body strength, power, and agility.”	who had to maintain normal lifestyle during the study Three groups: APT, LPT, and CON	began, three weeks later, and three weeks after that. The study was divided into intervention phase I and II, each lasting three weeks. Skill and intensity level increased from phase I to II. CON received no intervention. Power was measured using VerTech Jumping System, and strength was measured via a MicroFET in a dynamometer chair.		No significant (p>.05) increase was found in the LPT group pretest to posttest (Pretest average=7543±180W, Posttest average=7598±179W). For strength, significant (p<.05) differences between the CON (73.87±5.53ft*lbs) and experimental groups were found with no significant (p>.05) differences between APT (77.73±4.37ft*lbs) and LPT (77.08±4.37ft*lbs).			
Miller, Berry, Bullard, & Gilders	“Compare the effects of land-based and aquatic-	40 subjects (age=21.2±3.9 years) free of lower-extremity	Subjects were randomly assigned to LPT, APT, or	Power and VJ	A paired t-test found a significant increase (p>.05) in power in the APT (Pretest	APT does not significantly improve VJ	1b	6.5

(2002)	based plyometric training programs on performance variables”	injuries whose activity level ranged from sedentary to recreationally active Three groups: LPT (n=13, age=21.5±3.6 years), APT (n=13, age=22±2.5 years), and CON (n=14, age=23±5.5 years)	CON. Measurement was collected on performance variables before and after the 8-week training period. VJ was measured using a Ver-Tec system and reported in watts; power was measured using the Margaria-Kalamen power test and reported in watts.		average=1216.8±425.0W, Posttest average=1304.1±473.3W). For VJ, ANCOVAs were performed and found no significant increases between the LPT (1062.2 ± 253.7W), APT (1092.7 ± 367.7W), and CON (1247.9 ± 295.8W) groups.	over LPT, but there is a significant increase in power in the APT compared to the LPT.		
Robinson, Devor, Merrick, & Buckworth (2004)	“Determine the effects of land vs. aquatic plyometrics on power, torque, velocity, and muscle soreness in women”	31 subjects (age=20.2±0.3 years); who were women and nonpregnant, healthy, physically active, and	Groups were measured three times: pretest, after four weeks at midtest, and posttest. The program consisted of	Power	Both the APT (pretraining average=819.68±216.42 W, midtraining average= 921.44±220.66 W, posttraining average=1046.52±222.78 W) and LPT	Regardless of training environment, either APT or LPT, both groups yielded significant increases in	1b	6.5

		regularly exercising for 6+ months, and had been involved or were currently participating in a sport for an average of five years Two groups: ATP (n=16; age=19.8±0.3 years) and LPT (n=15; age=20.6±0.6 years)	three sessions per week for eight weeks; each session was three to five sets of ten different exercises; exercises and were not reported. The sets (3-5 sets) and reps (10-20 reps) increased after two and five weeks. Both groups performed identical training regimens during the study. Power was measured using the Sargent VJ test.		(pretraining average=873.62±218.54 W, midtraining average= 937.22±216.42 W, posttraining average=1098.34±218.54 W) groups showed significant increase in power in pretraining to midtraining and midtraining to posttraining (p ≤ .001).	peak power output.		
Stemm & Jacobson (2007)	“Compare the effect of land-based and aquatic-based	21 physically active men (age=24 ± 2.5 years) who were	Subjects were randomly assigned to APT, LPT, or	VJ	Significant differences found between CON (63±3cm), LPT	Aquatic and land plyometrics improve	1b	6

	plyometric exercise on maximum vertical jump height”	healthy, recreationally active, and free of lower-extremity injuries for a minimum of 12 months Three groups: APT (n=7), LPT (n=8), and CON (n=9). Three subjects were lost to attrition, but their group allocation was not reported.	CON groups. Groups performed three sets of fifteen jumps with one-minute rests. Training occurred two times per week for six weeks. Pre- and posttest measurements made using a VERTEC to the nearest .5”. Subjects allowed three trials and the highest value was taken.		(72±3cm), and APT (73±3cm) (d=.33); however, no significant differences (p>.05) between experimental groups were noted.	athletic performance.		
Villarreal, Suarez-Arrones, Requena, Haff, & Veliz (2015)	“Examine the effect of 3 different strength and power training methods characterized	30 professional water polo players (age=23.4±4.1 years) in good health and able to freely	Subjects were randomly assigned to CG, PG, and CSG. Measurements of strength and	VJ and Strength	Lower body strength was significantly (p≤.0001) increased in both groups (WSG 10.30 kg, PG 12.20 kg), however no differences were	Both APT and LPT provide improve athletic performance, but LPT only	1b	6.5

	by their different velocity, displacement, and use of traditional versus ballistic techniques (loaded and body weight only) on strength and other qualities highly specific to WP performance …”	participate in the study Three groups: combined training (dryland and in-water-specific training) (combined training [CG], n=10), in-water-specific strength training (WSG, n=10), and upper and lower dryland plyometric training (PG, n=10)	VJ were collected before and after the 6-week training period. Subjects trained 3 days a week for 6 weeks.		noted in the magnitude of that change. Upper body strength was significantly (p≤.0001) increased in the PG group (5.32 kg). For VJ, statistically significant (p=.0002) increases were found in the PG group (2.43 cm), for the amount of increase between the PG (41.7±4.1 cm) and WSG (40.2±4.2 cm), and for the amount of increase in the CG (39.8±4.2 cm).	slightly more so.

Power

Miller et al. (2002) compared the effects of an APT program to an LPT program on power over an 8-week period. The subjects consisted of 40 volunteers (age=21.2±3.9 years) without any lower-extremity musculoskeletal injuries. Subjects ranged in activity level from sedentary to recreationally active and were randomized into 3 groups: (1) control (CON) (n=14; age=23.0±5.5 years), (2) APT (n=13; age=22±2.5years), and (3) LPT (n=13; age=21.5±3.6 years). Both experimental groups (i.e., APT and LPT) received intervention and met twice a week at the same time for training; the CON group did not receive any intervention. All 3 groups were instructed and regularly reminded not to begin or alter exercise programs for the duration of the study. The groups were measured twice, once before the training began and again at the end of the 8-week training program. Over the 8 weeks, training groups progressed from 3 to 5 plyometric drills per session. Plyometric drills varied in type, intensity, and volume as the training went on.

Table 2 Training protocol used by Miller, Berry, Bullard, and Gilders (2002).

Training Week	Plyometric Drill	Training Intensity
1	Side-to-side ankle hops	Low
	Standing jump and reach	Low
	Front cone hops	Low
2	Side-to-side ankle hops	Low
	Standing jump and reach	Low
	Front cone hops	Low
	Double-leg hops	Medium
3	Side-to-side ankle hops	Low
	Standing jump and reach	Low
	Front cone hops	Low
	Double-leg hops	Medium
	Lateral cone hops	Medium
4	Side-to-side ankle hops	Low
	Standing jump and reach	Low
	Front cone hops	Low
	Lateral cone hops	Medium
	Tuck with knees up	Medium
5	Side-to-side ankle hops	Low
	Standing jump and reach	Low
	Double-leg hops	Medium
	Lateral cone hops	Medium
	Tuck with knees up	High
6	Side-to-side ankle hops	Low
	Standing jump and reach	Low
	Double-leg hops	Medium

	Lateral cone hops	Medium
	Tuck with knees up	High
	Lateral jump over barrier	High
7	Standing jump and reach	Low
	Double-leg hops	Medium
	Lateral cone hops	Medium
	Lateral jump over barrier	High
	Single-leg lateral jump	High
8	Standing jump and reach	Low
	Lateral cone hops	Medium
	Tuck with knees up	Medium
	Single-leg lateral jump	High
	Single-leg hops	High

Adapted From "Comparisons of land-based and aquatic-based plyometric programs during an 8-week training period," by Miller, M. G., Berry, D. C., Bullard, S., & Gilders, R., 2002, *Journal of Sport Rehabilitation, 11*, p. 271.

Training volume ranged from 80-to-120 foot contacts. Gulick et al. (2007) define foot contacts as "the number of times the foot (feet) come in contact with the ground." This is the common measurement used to determine plyometric training volume. The aquatic group trained in approximately waist deep water while the land group trained on a cushioned surface with ¼-in. padded carpet.

Before and after training began, power was measured and reported in watts (W) using the Margaria-Kalamen power test. The test consists of having subjects running up steps as fast as possible. The test procedures from Miller et al. (2002) were as follows:

> Electronic switch mats were placed on the third and ninth steps to record the time. The subjects were placed 6 m in front of the stairs and instructed to accelerate toward the steps and run up them as rapidly as possible, taking 3 steps at a time. The electronic switch mat started the timing when the subjects stepped on the third step (first switch mat). Subjects then proceeded to the sixth step and then to the electronic switch mat on the ninth step (second switch mat) to stop the clock. Times were recorded using a performance-time analyzer (Lafayette Instrument Co, Lafayette, Indiana, clock model 54050) to the nearest thousandth of a second. After 2 practice trials, each subject performed 5 trials with complete recovery between efforts (p. 272).

No significant apriori differences were found among any of the groups, according to an analysis of covariance (ANCOVA). A paired *t*-test did find a significant increase ($p<.05$) in power in the APT group (pretest average=1216.8±425.0 W, posttest average=1304.1±473.3 W).

Gulick, Libert, O'Melia, and Taylor (2007) compared the effectiveness of APT and LPT on power. Forty-two university students (age=24.5±3.5 years) with no prior, formal plyometric training and no current or prior lower-extremity injuries participated in the study. Subjects had to maintain a normal lifestyle during the entire study. Subjects were divided randomly into 3 groups (sample size unavailable): (1) CON, (2) APT, and (3) LPT; group demographics were not reported. The groups were measured 3 times: (1) pretest, (2) midtest, and (3) posttest.

The study was executed in 2 phases: Intervention Phase I and II. Each phase lasted 3 weeks, and subjects were re-measured after each phase. Intervention Phase I was a basic-level program with 120-foot contacts per session. Intervention Phase II increased to an intermediate-level program with 180-foot contacts. During both phases, both experimental groups (i.e., APT and LPT) met twice a week. The CON group received no intervention.

To begin, subjects performed a pretest. Power was measured using a VerTech Jumping System (VerTech Inc, Falls Church, Virginia) (test-retest reliability=0.93, as reported by Martel, Harmer, Logan, and Parker (2005)) combined with a peak power formula. The test procedures required subjects to perform 3 vertical jumps with 15 seconds of rest between jumps. The height reached with the subject's hand was recorded using a VerTech Jumping System (Gulick et al., 2007). The 3 jumps were averaged, and peak power was calculated. The formula to calculate peak power was W=[61.9xjump height (cm)]+[36xbody mass (kg)]-1822.

A significant (p<.05) increase in power from pretest to posttest was identified in the APT group (pretest average=7123±180 W, midtest average= 7270±179 W , posttest average= 7292±179 W). There was, however, no significant (p>.05) increase found in the LPT (pretest average=7543±180 W, midtest average= 7528±179 W, posttest average=7589±179 W) group pretest to posttest.

Robinson, Devor, Merrick, and Buckworth (2004) examined the effects of APT versus LPT on power in women only. Thirty-one female subjects (age=20.2±0.3 years) met the following inclusion criteria: non-pregnant, healthy, physically active, regularly exercising for at least 6 months, and involved or currently participating in a sport for an average of 5 years. Subjects were screened for current orthopedic or musculoskeletal injuries that occurred in the last 6 months. Subjects were randomized into two groups: ATP (n=16; age=19.8±0.3 years) and LPT (n=15; age=20.6±0.6 years). The groups were measured 3 times: (1) pretest, (2) after four weeks at midtest, and (3) posttest.

The training program consisted of 3 sessions per week for 8 weeks. Each session involved 3 to 5 sets of 10 different exercises; exercises and number of foot contacts were not reported. The sets (3-5 sets) and reps (10-20 reps) were increased after 2 and 5 weeks. Both groups performed identical training regimens during the study. Power was measured using the Sargent VJ test. Test procedures were as follows: "This test involves measuring the difference between a person's standing reach and the height recorded from a jump and reach. The difference between the standing height and the jump height is the vertical jump value. Three 2-foot squat jumps were completed with a 1-minute break to ensure full recovery between jumps" (Robinson et al., 2004). The results were converted to a common variable (i.e., W) from centimeters using an average power calculator. The formula used was W = 21.2xVJ (cm)+23.0xmass (kg) -1393 (Mackenzie, n.d.).

In this study, both the APT (pretraining average=819.68±216.42 W, midtraining average= 921.44±220.66 W, posttraining average=1046.52±222.78 W) and LPT (pretraining average=873.62±218.54 W, midtraining average= 937.22±216.42 W, posttraining average=1098.34±218.54 W) groups showed a significant increase in power from pretraining to midtraining (p≤.001) and from midtraining to posttraining (p≤.001).

Vertical Jump

Stemm and Jacobson (2007) compared the effects of APT and LPT on VJ over a 6-week training program. Twenty-one physically-active (age=24±2.5 years) men without lower-extremity injuries for a minimum of 12 months were randomly assigned to LPT (n=8), APT (n=7), and CON (n=9) groups; group age demographics were not reported. Three subjects were lost to attrition, but their group allocation was not reported. The experimental groups (i.e., APT and LPT) performed in different environments twice a week for 6 weeks while the CON group did not perform any training. The aquatic group was in knee-level water adjusted to ±1 in. of the axis of the knee joint. The land group performed the same exercises as the aquatic group on a tumbling mat. Exercises included (1) squat jumps, (2) side hops, and (3) knee-tuck jumps. These exercises were performed in 3 sets of 15 jumps separated by 1-minute rests for each exercise. The number of foot contacts was not reported. Pre- and post-measurements were taken using a VERTEC jump test (Vertec Jump Training System, VerTech Inc, Falls Church, Virginia), and subjects were allowed 3 trials measured to the nearest ½ in. The highest value was recorded.

The study resulted in significant (p<.05) differences between groups as noted by ANOVA analysis. A Turkey post hoc analysis was then conducted to discover where these differences occurred. A significant (p<.05) difference between the experimental and CON (63±3 cm) groups (d=.33) was noted. There was no significant (p>.05) difference between the land (72±3 cm) and aquatic (73±3 cm) groups. The mean difference between APT and CON groups was 1.81 cm while the mean difference between LPT and the CON was 1.74 cm. The mean difference between aquatic and land groups was extremely small at 0.08 cm.

Another study on VJ was conducted by Miller, Berry, Bullard, and Gilders (2002). All study methods and subject demographics remained the same as previously stated (Table 1). Measurements were recorded using the Ver-Tec jumping system (Sports Imports, Inc., Columbus, Ohio). The test procedures from Miller et al. (2002) were as follows:

> A base measurement for reach height was determined by measuring the highest strip a subject could touch while standing flat-footed with an outstretched arm. Each subject was allowed 2 practice jumps, followed by 5 stationary vertical 2-footed jumps. Vertical jumps were recorded to the nearest half inch, and the difference between the base reach height and the highest vertical jump was recorded (p. 272).

The following equation was used to calculate VJ: VJ=maximal jump height-initial reach height. To convert to watts, the researchers used the equation: $W=4.9^5$ (mass in kg)(distance in m). ANCOVAs were performed and found no significant increases between the LPT (1062.2±253.7 W), APT (1092.7±367.7 W), and CON (1247.9±295.8 W) groups.

Villarreal, Suarez-Arrones, Requena, Haff, and Veliz (2015) compared LPT and APT in 30 professional water polo (WP) players (age=23.4±4.1 years) who were randomly divided into three groups: combined training (dryland and in-water-specific training [CG], n=10), in-water-specific strength training (WSG, n=10), and upper and lower dryland plyometric training (PG, n=10). All subjects were actively training 5-6 times per week on average. All subjects were deemed fit to participate freely in this study.

To begin, all subjects performed a pretest. Subjects were familiarized with the test and testing took place over two days in conjunction with other testing. Prior to testing, all subject participated in a standardized warm-up. To perform the countermovement (CMJ) vertical jump test, procedures from Villarreal et al. (2015) were as follows:

> The CMJ test was performed using an infrared curtain system (MuscleLab.V718; ErgoJump, Langesund, Norway) that quantified flight and contact times. Three trials were completed with 2 minutes of rest between each trial. The mean of the 3 trials was then used for subsequent statistical analyses (p. 1091).

After pretesting, subject began the training protocol using the noted protocol.

Table 3 Sample of the training protocol used by Villarreal, Suarez-Arrones, Requena, Haff, & Veliz (2015).

Session	S1-S2-S3	S4-S5-S6	S7-S8-S9	S10-S11-S12	S13-S14-S15	S16-S17-S18
Dryland Strength Training						
Bench Press	3x15, 60%	3x15, 60%	3x12, 70%	3x12, 70%	4x10, 80%	4x10, 80%
Power Clean	3x10x20% BW	3x10x20% BW	4x10x20% BW	4x10x40% BW	3x15x60% BW	3x15x60% BW
Medicine Ball	3x10x5 kg	3x10x5 kg	4x10x5 kg	4x10x5 kg	4x15x5 kg	4x15x5 kg
In-Water Strength Training						
Lateral Jumps	4x9	4x9	4x12	4x12	4x15	4x15
Back Eggbeater Kick With Resistance Band	5x20 s	5x20 s	5x40 s	5x40 s	5x60 s	5x60 s
Frontal Eggbeater Kick With Resistance Band	5x20 s	5x20 s	5x40 s	5x40 s	5x60 s	5x60 s
Plyometric Training						
Pull-Ups + Jump	3xMax	3xMax	3xMax	3xMax	4xMax	4xMax
Burpees	3xMax	3xMax	3xMax	3xMax	4xMax	4xMax
Medicine Ball Wall Throw	3x10x5 kg	3x10x5 kg	4x10x5 kg	4x10x5 kg	4x15x5 kg	4x15x5 kg

Adapted From "Enhancing Performance in Professional Water Polo Players," by Villarreal, Suarez-Arrones, Requena, Haff, and Veliz, 2015, *Journal of Strength and Conditioning Research, 29*, p. 1093.

Training took place three days a week for all groups for six weeks before normal WP training began. Each training session was 60-minutes long, with a ten-minute warm-up, 45 minutes of specific strength training, and 5 minutes of cool down. Rating of Perceived Exertion (RPE) on Borg scale-10 was used to quantify session difficulty and it was collected 30 minutes after the session ended. To represent the magnitude of internal training load, RPE was multiplied by duration of training in minutes. The CG group completed half of the repetitions in the water and the other half on land. All players attended all training sessions and all sessions were monitored. Statistically significant (p=.0002) increases were found in the PG group (2.43 cm). Significant differences were also found for the amount of increase between the PG (41.7±4.1 cm) and WSG (40.2±4.2 cm). Interestingly, significant differences were also found for the amount of increase in the CG (39.8±4.2 cm).

Strength

Gulick et al. (2007) measured the effect of an APT compared to LPT on strength. All study methods and subject demographics remained the same as previously stated (Table 1). Pretest strength measurements were assessed via a maximal isometric contraction of the quadriceps at 45° of knee flexion. Testing was completed using a MicroFET (Hoggin Industries, Draper, Utah) in a dynamometer chair with the lever arm locked at 45° of flexion. The researchers performed a pilot test and calculated testing device reliability, where (r)=0.943. The subject performed maximal muscle contraction over 3 seconds. This test was performed 3 times with a 15-second rest in between. The highest value was recorded.

The study found significant (p<.05) differences between the CON (73.87±5.53 ft*lbs) and experimental groups with no significant (p>.05) differences between the APT (77.73±4.37 ft*lbs) and LPT (77.08±4.37 ft*lbs) groups at posttest.

Arazi and Asadi (2011) compared the effect of 8 weeks of APT and LPT on quadriceps strength in young (age=18.81±2.47 years) male basketball players. Subjects in this study were free of lower-extremity injuries and had no medical conditions compromising their participation in this study; additionally, they had not done any plyometric training in the last 6 months. Subjects were randomly assigned to LPT (n=6; age=18.03±1.38 years), APT (n=6; age=18±0.60 years), and CON (n=6; age=20.4±0.64 years) groups. During the study, subjects were prohibited from weight training and were required to continue normal basketball training.

Training occurred 3 days a week for 8 weeks. The LPT performed exercises on a 3 cm mat while the APT performed the same exercises in a pool with approximately 70% of their body in the water. Four different drills were performed with 3 sets per session with increasing reps and number of foot contacts (range 117-183) as the study went on. The CON group received no intervention.

Table 4 Plyometric drills and repetitions used by Arazi and Asadi (2011).

Training Week	Ankle Jump	Speed Marching	Squat Jump	Skipping Drill	Sets	Total Foot Contacts
1	15	8	8	8	3	117
2	17	9	9	9	3	132
3	19	10	10	10	3	147
4	22	11	11	11	3	165
5	17	9	9	9	3	132
6	19	10	10	10	3	147
7	22	11	11	11	3	165
8	25	12	12	12	3	183

Adapted From "The effect of aquatic and land plyometric training on strength, sprint, and balance in young basketball players," by Arazi, H., & Asadi, A, 2011, *Journal of Human Sport and Exercise, 6*, p. 104.

To measure strength, Arazi and Asadi (2011) used a 1-Repetition Max (RM) leg press (King Body, Niroo, Iran) before the study began and after it finished. Using a standard leg press machine, subjects sat with hips at about 180° hip flexion, 80° knee flexion, and 10° dorsiflexion at ankles. On command, subjects performed concentric extension to reach full extension. Each subject performed 2 trials. The study found no significant ($p>.05$) difference between the LPT (195±15 kg) and APT (200±10 kg). There was, however, significant ($p<.05$) increases in the APT compared to the CON (175±10 kg).

Villarreal et al. (2015) also compared the effects of LPT and APT on strength. All subject characteristics and methods remained the same as previously stated (Table 1). Maximal dynamic strength for the upper and lower body were assessed before and after training using a 1 RM. Before beginning these tests, subjects performed 10 repetitions of full squats (FSs) and bench presses (BPs) at 40-60% of the perceived maximum. Then, separate, single attempts were performed until the subject was unable to complete a repetition with the weight or were unable to perform the lift with correct technique. The last acceptable lift was used as the 1RM and two minutes were allowed for rest between trials. To test maximal lower body strength, subjects performed a FS from an extended position with the bar held across the shoulders in a standardized front squat grip. Subjects then performed a controlled squat to the angle of 60° at the knee (measured using a goniometer). They were then instructed to return as fast as possible to a fully extended position. A Smith machine (Model Adan-Sport, Granda, Spain) was used to calculate the velocity of displacement for the FS. A 1RM BP was used to measure upper body strength by instructing the subject to lower the bar from a fully extended position until the bar was at chest height. Then, they were instructed to return the bar to the starting position as fast as possible. A Smith machine again measured the velocity of displacement.

Lower body strength was significantly (p≤.0001) increased in both groups (WSG 10.30 kg, PG 12.20 kg); however, no differences were noted in the magnitude of the change. Upper body strength was significantly (p≤.0001) increased in the PG group (5.32 kg). Interestingly, the CSG also significantly (p≤.0001) increased in lower body strength (12.5 kg) with no difference in the magnitude of increase from the other groups and significantly (p≤.0001) increased in upper body strength (5.32 kg).

Discussion

All studies in this review (Arazi & Asadi, 2011; Gulick, O'Melia, Libert & Taylor, 2007; Miller, Berry, Bullard, & Gilders, 2002; Robinson, Devor, Merrick, & Buckworth, 2004; Stemm & Jacobsen, 2004; Villarreal, Suarez-Arrones, Requena, Haff, & Veliz, 2015) exhibited increased performance when using APT and LPT, suggesting that APT can be an effective training method for those between age 16 through 30. There are also other various benefits to using APT over LPT. APT can offer decreased joint loading and weight-bearing status, (Gulick et al., 2007; Miller et al., 2002) which is beneficial for athletes in a rehabilitation program. Miller, Berry, Bullard, and Gilders (2002) note that healthcare providers could use aquatic plyometrics as an alternative program to initiate or advance a rehabilitation program significantly earlier. In one prospective case study by Burmaster, Eckenrode, and Stiebel (2016), aquatic rehabilitation was incorporated as part of traditional land-based rehabilitation program at two weeks instead of the usual six weeks. In another case study by Roi et al. (2010), an Italian First Division soccer player could return to play within 90-days following an anterior cruciate ligament reconstruction when aquatic rehabilitation was added as part of his plan of care. These case studies demonstrate that aquatic rehabilitation can be used to initiate rehabilitation sooner than traditional land protocols and the athletes can be returned to play sooner. This concept can also be extended to aquatic plyometrics because the technique can be used as part of a rehabilitation protocol.

An athlete in an APT program could maintain conditioning while allowing for the injury to heal, avoid further injury from LPT, and return to play faster. In a study by Kim et al. (2010), it was found that aquatic rehabilitation could be used to rehabilitate acute lower extremity injury and no significant differences were found between land and aquatic based training as measured by a Visual Analog Scale (VAS) for pain with weight bearing, static stability tests, dynamic stability tests, and percentages of single-limb support time of the affected lower extremity. The line graphs for outcomes measures were steeper in the aquatic exercise group, however, demonstrating it can be used to return athletes to play sooner. All studies in this review ((Arazi & Asadi, 2011; Gulick, O'Melia, Libert & Taylor, 2007; Miller, Berry, Bullard, & Gilders, 2002; Robinson, Devor, Merrick, & Buckworth, 2004; Stemm & Jacobsen, 2004; Villarreal, Suarez-Arrones, Requena, Haff, & Veliz, 2015) discussed how an aquatic environment can reduce joint and muscle stress, which, in turn, reduces the risk of injury. The buoyancy and resistance of the water also protect athletes from muscle damage and injuries likely to occur during land-based training (Robinson et al., 2004).

Despite these benefits, a few variables can prevent APT from being utilized in schools and universities. First, the cost and requirements to implement APT may not be feasible. In high schools and universities, access to a pool in which APT can be performed may be limited due to aquatic activity and swim team schedules, the cost of pool time, and, of course, no access to pools. Costs of APT may include equipment, lifeguards, and personnel training. Additionally, without proper land-based instruction in the transferable techniques, APT may be dangerous and could result in similar injuries that the APT technique is trying to prevent. Additionally, APT requires secure sunken equipment for patients to stand on while in the water. Limited operational budgets make covering all these equipment and training costs difficult. Further research on the cost of implementing an APT program could convince schools that the benefits outweigh the costs, but, currently, the cost of APT may not be worth the small benefits it could provide over the much simpler LPT. Second, LPT can be performed anywhere with the appropriate flooring (e.g., a rubberized floor with some spring). This is in contrast to APT, which requires at least an hour of free pool time. In schools with many aquatic sports, this time could be difficult to reserve. The supplies and space for LPT are most likely already available because it has been in use longer. The space requirement and limited equipment availability make APT less desirable than LPT.

Also, with no apparent enormous benefit of APT over LPT, besides a reduction in injury risk, some schools may decide the cons outweigh the pros and not want to implement APT. If the same benefits can be gained from LPT with few disadvantages, then there may be no point in providing something that requires training and money. On the other hand, institutions may see the reduced injury risks worth the extra cost and effort to implement APT. If athletes sustain significantly fewer injuries from APT as compared to LPT, it may be worthwhile to use APT.

Limitations

As with any study, including this one, there are limitations. The age range in this study has been limited to individuals between the ages of 16-30 years. Therefore, the conclusions in this study may not apply to populations outside of this age range, including younger adolescents and adults older than 30 years. There was also some bias in study selection. We required articles to be written in English with an available abstract. The availability of an abstract could potentially limit the information available for use. Also, language bias could exclude quality articles in other languages. Lastly, because of the nature of the topic, it was impossible to have blinded the subjects and therapists to which group subjects were assigned. This can result in the therapists' biases affecting the study or in a placebo effect on the part of the subjects and how they expect the intervention to work.

Clinical Relevance

While both APT and LPT increase athletic performance, neither appears to be greatly better than the other from a clinical standpoint. Using grade B evidence on the Strength of Recommendation Taxonomy scale, we recommend ATs consider APT as an alternative training program for athletes. With no large difference, training programs should be tailored to the needs of the patient or athlete. APT can serve as an independent training program or as a transition program into a land-based one, depending on the patient or athlete and his/her condition or injury.

Conclusions

The 6 studies in this review contribute significantly to helping ATs design the best training program for their athletes by introducing a new but equally effective training method to use. This training method provides greater customization for programs and should be utilized to create the best one possible depending on injury and conditioning status. More research is needed to discover exactly what factors increase the effectiveness of aquatic-based plyometrics. APT has been shown in this review to have similar benefits as LPT. Therefore, ATs should consider the needs of their athlete to formulate the best training program and pick the best one for their athletes. ATs also need to consider the practicality of implementing APT programs in their individual institutions. The potential benefits of APT include reduced joint loading and weight status, which could be useful in a rehabilitation program (Gulick et al., 2007; Miller et al., 2002).

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