Journal of Scientific Research & Reports
4(5): 473-479, 2015; Article no.JSRR.2015.050
ISSN: 2320-0227

SCIENCEDOMAIN *international*
www.sciencedomain.org

Effect of Different Plyometric Training on Biomechanical Parameters of Junior Male Volleyball Players

Ali Fattahi[1*], Hojat Kazemini[2], Mahdi Rezaei[3], Mazaher Rahimpour[4], Mehrnoosh Bahmani[5], Saeid Saleh Nia[4], Mitra Ameli[6] and Mohsen Einanloo[5]

[1]Department of Physical Education and Sport Science, Islamic Azad University, Central Tehran Branch, Tehran, Iran.
[2]Islamic Azad University, Nazar Abad center, Iran.
[3]Department of Physical Education and Sport Science, Kharazmi University, Tehran, Iran.
[4]Department of Physical Education, Firoozkooh Branch, Islamic Azad University, Firoozkooh, Iran.
[5]Faculty of Physical Education, Karaj branch, Islamic Azad University, Alborz, Iran.
[6]Department of Physical Education, Payam-E-Noor University, Tehran, Iran.

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JSRR/2015/13596
Editor(s):
(1) Vito Di Maio, Institute of Cybernetics "E. Caianiello" CNR, C / O Complex Olivetti, Via Campi Flegrei, 34, Italy.
Reviewers:
(1) Andrea borghini, Institute of clinical physiology- CNR, Pisa- Italy.
(2) Anonymous, Istituto Auxologico Italiano, Italy,
Complete Peer review History: http://www.sciencedomain.org/review-history.php?iid=744&id=22&aid=6799

Original Research Article

Received 25th August 2014
Accepted 16th October 2014
Published 5th November 2014

ABSTRACT

The aim of this study was to compare the effect of eight weeks of aquatic and land plyometric training on some biomechanical variables including agility, leg muscle strength, and vertical jump test in young male volleyball players. Forty five young male volleyball players (Age=19.46±2.39 years, Standing height=190.76±3.78 cm, Body Mass=77.27±2.65 kg, Sport background=3.93±0.72 years) volunteered in this study and divided to three groups; aquatic plyometric group (APG), land plyometric group (LPG) and control group (CG). APG trained spike approach, one leg bounding, squat jump, depth jump and LPG trained ankle jumps, squat jumps, and depth jump 3 times a week for 8 weeks. Both groups trained pre season volleyball training as well as control group. Data were analyzed by one way analysis of variance and paired t-test. The results showed significant

*Corresponding author: Email: fattahiali81@gmail.com;

differences between the APG and LPG groups in all variables (P<0.05). Significant increases were observed in post training of APG in all variables and for LPG group in leg press and vertical jump records compare to pre training (P<0.05). There was a significant difference in relative improvement between the APG and CG in leg press, agility and vertical jump as well as significant differences between LPG and CG in leg press and vertical jump (P<0.05). It seems that plyometric training in water can be an effective technique to improve biomechanical variables in young athletes.

Keywords: Plyometric; aquatic; volleyball; biomechanics.

1. INTRODUCTION

Biomechanical variables such as muscle strength, power, agility and speed are considered as critical elements for successful athletic performance [1,2,3] as well as for carrying out daily activities and occupational tasks [4,5]. Volleyball is one of the sports characterized by many of the basic and variable skills. Special physical preparation of volleyball players is of the main components to carry out successful and skillful performance. In volleyball certain physical motor abilities such as muscular power and strength, speed, agility are needed for a successful player [6].

In the field of training, there is a new technique emerged similar to the nature of performing volleyball skills by developing the ability of vertical jump, which is called plyometric as it includes stretching muscles (while perform it) followed by a direct fast muscle contraction [7]. Plyometric training or stretch-shortening cycle would improve performance of the concentric phase of movement [8] as well as increase power output [9,10,11] by evoking the elastic properties of the muscle fibers and connective tissue by allowing the muscles to store and release energy during the deceleration and acceleration phases, respectively [12,13]. Great Benefits of plyometric training have been observed such as increase in muscular strength and explosive power [3,10,12,14,15] sprint ability [16], joint function and stability [11,17,18], reduced incidence of serious knee injuries [17,19], and running economy [20].

Despite the numerous benefits associated with high-impact, high-intensity land-based plyometric training, certain recommendations should be considered due to the possibility exists for this type of training to induce acute muscle soreness, muscle damage, or even musculoskeletal injuries [21,22,23].

The effects of plyometric training on different surfaces like sand, grass and wood on performance with reducing injuries were investigated [24,25]. Some investigators have recommended that performing plyometric training in water, swimming pool or aquatic plyometric training (APG) would be more safe and efficient. Because of buoyancy provided in aquatic environment, weight bearing stress on the limbs is decreased, thus it seems that water reduce the pressure put on the musculoskeletal system. Performing plyometric training in water and land and their results on physical abilities such as power, vertical jump, speed, strength, agility and muscle soreness were studies by some authors [7,26,27,28]. Miller et al. [29] compared the effects of 8-week of APG and land plyometric training (LPG) on physical fitness parameters and showed increase in muscle power only in ATP group as well as no significant improvement in vertical jump of both groups. Martel et al. [7] reported significant improvements in concentric peak torque during knee extension and flexion at 60 and180º·s-1 after 6-week of Aquatic plyometric training. Robinson et al. [26] showed significant increases in vertical jump, Isokinetic torque and sprint velocity as well as significantly less soreness following 8-weeks of Aquatic plyometrics training in healthy college-aged women. Shiran et al. [28] reported that 5-week of APG provide similar benefits in physical performance with less muscle soreness in professional male wrestlers comparing with land plyometric training.

Despite the important findings, no documented researches have compared the effects of plyometric training on biomechanical variables in athletes engaged in certain sports such as volleyball in aquatic environment. Considering different results of performing plyometric training on different surfaces like water and land, the present study was conducted to determine whether adding Aquatic plyometric or Land plyometric training to traditional volleyball training leads to larger increases in some biomechanical variables comparing traditional volleyball training.

2. MATERIALS AND METHODS

2.1 Subjects

45 junior male volleyball players from Alborz State of Iran participated in this study. The participants and their legal guardians were informed about the aims, nature, potential risks and benefits of the study. The participants then provided written informed consent. The study protocol was approved by the Ethics Committee of the Department of Sport Sciences, Kharazmi University and the procedures were executed according Helsinki Declaration (1957). Participants were excluded from the study if they had current or recent past musculoskeletal injuries, cardiovascular disease, uncontrolled metabolic disorders such as diabetes mellitus, or a fear of water. After participating in biomechanical pre tests, all participants were randomly assigned to three groups; aquatic plyometric training group (n=15), land plyometric training group (n=15), and control group (n=15). The participants' characteristics are given in Table 1.

2.2 Study Design

The study Protocol was conducted concurrently with preseason volleyball training and all groups participated in three session volleyball training in a week (Sunday, Tuesday and Thursday). Each session lasting approximately 120 min. typical preseason volleyball training sessions consisted of 10–15 min warm-up exercises, followed by on court skills training, tactical situations, and actual game play. All volleyball sessions were directly supervised by Karaj volleyball association coaches who were informed about the study procedures, but were blinded to group assignment of the participants. Thus, the coaches did not include any specific strength training or high-intensity plyometric exercises as part of the preseason volleyball training, other than volleyball drills that required the players to jump as part of the activity.

Aquatic and Land plyometric groups performed plyometric exercises designed in water and mat for the lower extremity, while the control group did not participate in any type of plyometric exercises. Control group were asked to participate in regular volleyball training sessions 3 times per week, each session about 2 hours. Both APG and LPG groups trained three times in a week (Saturday, Monday, and Wednesday) for 8 weeks. Participants in the plyometric groups performed three plyometric drills - ankle jump with block form, squat jump with block form and depth jump drills on a 3 cm mat. The training protocol of this study is shown in Table 2. Depth jump drill was executed upon 5 boxes with 30 cm height, starting participants stand on the mat, jumping over the first box on the floor, repeating the same procedure on the others.

The APG program was conducted three times a week for 8 weeks in a swimming pool with a depth of approximately 120 cm and a temperature of 28℃. Each APG session lasted approximately 45 min, and consisted of a warm-up, APG, and cool-down, all performed in the water. The warm-up consisted of approximately 5 min of light jogging in the water. The APG exercises included spike approaches, single leg bounding, squat jumps with blocking form, and depth jumps [30]. The participants were encouraged to perform all APG exercises in an explosive manner, and to apply their maximal effort on all maneuvers. The spike approaches, single leg bounding performed with maximal effort along the width of the pool (~15 m) two times per session during the first and second week, three times per session during third, fourth, fifth and sixth weeks and four times per session during seventh and eighth weeks of training.

Table 1. Physical characteristics of participants (average mean± SD)

	CG (n=15)	APG (n=15)	LPG (n=15)	Total (n=45)
Age (year)	19.61±2.79	18.20±1.02	20.60±2.44	19.47±2.39
Body Mass (kg)	76.73±3.01	77.53±2.85	77.53±2.09	77.27±2.65
Height (cm)	191.87±3.20	190.53±4.51	189.87±3.51	190.76±3.78
Body mass index (kg/m^2)	20.93±4.24	21.75±3.26	20.85±4.21	20.45±2.99
Sports experience (year)	3.80±0.68	4.20±0.68	3.80±0.77	3.93±0.72

CG= control group, APG= aquatic plyometric group, LPG= land plyometric group

Table 2. Plyometric drills and sets for LPG

Training weeks	Ankle jump	Squat jump	Depth jump	Sets
1 & 2	15	8	5	3
3 & 4	15	8	5	4
5 & 6	15	8	5	5
7 & 8	15	8	5	6

LPG= land plyometric group

Bouts of continuous maximal squat jumps with block form were performed 3 sets of 10-s of continuous jumps during the first and second weeks, four sets of 10-s during the third and fourth weeks, 4 sets of 15-s in fifth and sixth weeks and 4 sets of 20-s during weeks 7 and 8 with 30-s recovery periods between each sets. A series of depth jumps were performed involving three submerged boxes (45 cm in height) two times per session during week 1 and 2, three times per session for week 3 and 4, four times in week 5 and 6 and five times in week 7 and 8. The participants began the depth-jump circuit by squat jumping from the pool floor onto the first box, then squat jumping without hesitation as high as possible and landing on the floor between the first and second box, at which point they immediately squat jumped as high as possible, landing on the pool floor between second and third box and continued this pattern over the third submerged box. Participants walked back to the beginning of the circuit and after recovering for approximately 30 s, the participants began the next interval. The cool-down period consisted of approximately 5 min of walking in the water followed by static stretching of the major muscle groups of the legs.

2.3 Testing Procedures

Biomechanical variables consisting Agility, strength and power tests were measured by 4 × 9-m shuttle test, 1RM leg press and Standing vertical jump test. Participants were tested pre and post the 8-week training. All tests were explained before performance by tester.

2.4 4 × 9-m Shuttle Run

The shuttle run test was included as a measure of the ability to sprint and change direction. With the 4 × 9-m shuttle run, participants stood behind a starting line, on command, they started the 9-m run. At the end of the 9-m section, participants were asked to stop with 1 food beyond a marker while reversing running direction and sprinting back to the start where the same reversing of movement direction was required. After the fourth 9-m section, when the participants passed a finish line time stopped by hand-held stopwatch (CASIO HS-80TW). The best of 3 consecutive trials was used for the statistical analysis.

2.5 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% of the perceived maximum. Leg press test was completed using standard leg press machine (Gym Tech). Participants assuming a sitting position with back on padded supported. On command, the participant performed a concentric extension (as fast as possible) of the leg muscles starting from the flexed position to reach the full extension of 180° against the resistance. Tester alerted the participants when the starting and finishing positions were attained. Each participant was performed 3 maximal trails. Best of three were considered as the maximum weight, measured at pre and post 8-week training.

Vertical jump test was done according to SARGENT Standard Test. First, correct process of measurement was described for participants and they warmed up completely to perform the test. Participant stands side on to a wall and reaches up with the hand closest to the wall. Keeping the feet flat on the ground, the point of the fingertips is marked or recorded. This is called the standing reach height. Then stands away from the wall, and jumps vertically as high as possible using both arms and legs to assist in projecting the body upwards. Attempt to touch the wall at the highest point of the jump. The difference in distance between the standing reach height and the jump height is the score. The best of three attempts is recorded.

2.6 Statistical Analyses

All data are presented as mean ± SD. One-way analyses of variance (ANOVA) and Paired t test were used to determine significant differences among the APG, LPG, and control groups and to identify any significant differences between the groups at the pre and post tests for the dependent variables at $P \leq 0.05$, respectively.

3. RESULTS

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

Biomechanical variables of participants are shown in Table 3.

Results of ANOVA test (significant level) were F (0.05,2,42)= 6.221 (0.001), 5.14 (0.000) and 3.99 (0.001) for agility, leg press and vertical jump respectively. Results showed significant differences between all variables in APG and LPG comparing to CG.

No significant differences between APG, LPG and CG groups at pre test. Significant differences were observed in all variables between results of LPG and APG comparing to CG at post test.

There were significant differences in variables improvement in APG comparing to CG, as well as improvement in LPG comparing to CG except agility test. Also there were significant differences between ATP and LPG results comparing together (p<0.05).

No significant changes were observed in the control group in any of the variables tested either. APG group showed significant differences in all variables (Agility ~10%, leg strength ~17.5% and vertical jump ~28%) in LPG group, significant differences were observed in leg strength (~7%) and vertical jump (~10.5%) although agility records was improved ~0.2% insignificantly, (p<0.05).

4. DISCUSSION

The present study examined the effect of 8 weeks of aquatic and land plyometric training on some biomechanical variables including strength, agility, and power performance in junior male volleyball players. Our hypothesis that the addition of APG and LPG to traditional volleyball training would lead to greater enhancements in biomechanical variables were supported, as APG resulted in a significantly larger improvement in all variables as well as LPG except for agility (p<0.05).

Numerous studies reported that plyometric training, weight training and complex training can improve of strength performance [3,12,21,31]. To our knowledge, few studies have addressed the effects of APG on strength performance. Robinson et al. [26] examined the effects of 8 weeks of land-based plyometrics and APG on vertical in physically fit college-aged women, not all of the women were currently involved in sports requiring the presence of significant leg power and jumping ability, such as volleyball or basketball. Although the participants in the present study were significantly younger than in the study by Robinson et al. our findings coincide with and extend the findings of Robinson et al. [26] in that APG can induce significant improvements in vertical jump for male athletes who are undergoing concurrent sports training. Martel et al. [7] reported significant increase in vertical jump of young volleyball players following a 6-weeks training programs which was combination of Aquatic plyometric training and volleyball training. Arazi and Asadi (2011) reported significant improvement in physical performance of junior basketball players after 8-weeks of Aquatic and land plyometric training [31].

Shiran et al. [28] reported that 5 weeks of APG and LPG improved leg muscle strength in male wrestlers.

Results of our study are in agreement with mentioned studies, although there were differences in gender, age and training sessions of samples. Perhaps nature of volleyball training and responses of young athletes to the volleyball training are of the main reasons. There must be neural adaptation of nervous system which contributes to increase in explosive power and strength following plyometric training programs. This improvement also would be affected by loads and repetitions of plyometric training sessions.

High intensity plyometric training would increase muscle coordination as well as contraction ability of muscles in Stretch-shortening cycle which finally lead to enhancement in vertical jump [30].

Table 3. Biomechanical variables of participants (Average Mean ± SD)

	4 × 9 Agility test (sec.)		**1 RM leg press (kg)**		**Vertical jump (cm)**	
	Pre	**post**	**pre**	**post**	**pre**	**post**
APG	9.33±0.38	8.37±0.43 $^{*\Delta}$	201.67±6.73	237±11.62 $^{*\Delta}$	41.93±2.76	53.73±3.84 $^{*\Delta}$
LPG	9.3±0.42	9.28±0.43	200.33±10.26	214.33±13.35 $^{*\Delta}$	43.73±2.72	48.07±2.54 $^{*\Delta}$
CG	9.27±0.39	9.28±0.42	198.67±9.35	200.67±10.83	42.07±3.59	43.14±4.00

CG= control group, APG= aquatic plyometric group, LPG= land plyometric group, ***** *Significant difference from the pre test,* Δ. *Significant differences from CG post test*

Jumping ability in product of force and velocity and hence muscular strength is a key parameter in improvement of jumping ability. Maybe increase in motor unit recruitment in agonist and antagonist muscles in another reason of improvement of physical performance following plyometric training, due to strength increase.

Increase in agility performance is also evident in our study, in agreement by other similar investigations [10,15,16,31,32]. Here again frequency and load of training would be effective in results. Agility is composed of rapid and high force movements, acceleration and deceleration as well as changing direction. Perhaps, nature of plyometric training including eccentric strength which is the main part of agility and promotion of this phase through plyometric training would be the main reason of agility improvement [33].

5. CONCLUSION

The present study indicates that 8 weeks program of APG and LPG can produce significant increases in some biomechanical variables such as agility, leg power and strength in young male volleyball players. In addition, because athletes can perform high-intensity plyometric exercises in water, it is proposed that APG could provide similar benefits as land-based plyometrics, but with lower risk of muscle soreness and/or overtraining.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Canavan PK, Vescovi JD. Evaluation of power prediction equations: Peak vertical jumping power in women. Med Sci Sports Exerc. 2004;36:1589–93.
2. Potteiger JA, Lockwood RH, Haub MD. Muscle power and fiber characteristics following 8 weeks of plyometric training. J Strength Cond Res. 1999;13:275–279.
3. Bobbert MF. Drop jumping as a training method for jumping ability. Sports Med. 1990;9:7–22.
4. Kraemer WJ, Mazzetti SA, Nindl BC. Effect of resistance training on women's strength/power and occupational performances. Med Sci Sports Exerc. 2001;33:1011–25.
5. Bassey EJ, Fiatarone MA, O'Neill EF. Leg extensor power and functional performance in very old men and women. Clinical Sci (Lond). 1992;82:321–327.
6. Milic V, Nejic D, Kostic R. The effect of plyometric training on the explosive. Facta University. 2008;6:169-179.
7. Martel GF, Harmer ML, Logan JM, Parker CB. Aquatic Plyometric Training Increases vertical jump in female volleyball players. Med Sci Sports Exerc. 2005;37:1814-1819.
8. Gehri DJ, Richard MD, Kleiner DM, Kirkendall DT. A comparison of plyometric training techniques for improving vertical jump ability and energy production. J Strength Cond Res. 1998;12:85-89.
9. Paul E, Jeffry AP, Mathew WH, John PT, Michael JC, Robert HL. Effects of plyometric training and recovery on vertical jump performance and anaerobic power. J Strength Cond Res. 2003;17:704-709.
10. Matavulj D, Kukolj M, Ugarkovic D, Tihanyi S. Effects of plyometric training on jumping performance in junior basketball players. J Sports Med Physic Fitness. 2001;41:159-164.
11. Wilkerson G, Colston A, Short I, Neal K, Hoewischer PJ, Pixley J. Neuromuscular changes in female collegiate athletes resulting from a plyometric jump-training program. J Athl Training. 2004;39:17–23.
12. Wilson GJ, Murphy AJ, Giorgi A. Weight and plyometric training: Effects on eccentric and concentric force production. Canad J Appl Physiol. 1996;21:301–15.
13. Myer GD, Ford KR, Brent JL. The effects of plyometric and dynamic stabilization and balance training on power, balance, and landing force in female athletes. J Strength cond Res. 2006;20:345–53.
14. Harrison AJ, Gaffney S. Motor development and gender effects on stretching-shortening cycle performance. J Sci Med Sports. 2001;4:406-415.
15. Hennessy L, Kilty J. Relationship of the stretch-shortening cycle to spring performance in trained female athletes. J Strength Cond Res. 2001;15:326-331.
16. Rimmer E, Sleivert G. Effects of a plyometric intervention program on sprint performance. J Strength Cond Res. 2000;14:295-301.
17. Hewett TE, Stroupe AL, Nance TA, Noyes FR. Plyometric training in female athletes. Am J Sports Med. 1996;24:765-773.
18. Chimera N, Swanik K, Swanik C, Straub S. Effects of plyometric training on muscle-

activation strategies and performance in female athletes. J Athl Train. 2004;39:24–31.
19. Heidt RS, Sweeterman L, Carlonas R, Traub A, Tekulve F. Avoidance of soccer injuries with preseason conditioning. Am J Sports Med. 2000;28:659–662.
20. Turner AM, Owings M, Schwane JA. Improvement in running economy after 6 weeks of plyometric training. J Strength Cond Res. 2003;17:60-67.
21. Adams K, O'shea JP, O'shea KL, Climstein M. The effect of six weeks of squat, plyometrics and squat-plyometric training on power production. J Appl Sport Sci Res. 1996;6:36-41.
22. Jamuratas AZ, Fatouros LG, Buckenmeyer P. Effects of plyometric exercise on muscle soreness and plasma creatinekinase levels and its comparison with eccentric and concentricexercise. J Strength Cond Res. 2000;14:68–74.
23. Grantham, N. Plyometrics and sports injures-spinal shrinkage, patellar tendinitis, lower limbs injuries, heel-pad bruising, shin splints and stress fractures. Sports Injury Bulletin; 2006.
24. Miyama M, Nosaka K. Influence of surface on muscle damage and soreness induced by consecutive drop jumps. J Strength cond Res. 2004;18:206-221.
25. Impellizzeri FM, Rampinin E, Castagna C, Martino F, Fiorini S, Wisloff U. Effect of plyometric training on sand versus grass on muscle soreness and jumping and sprinting ability in soccer players. Br J Sports Med. 2008;42:42-46.
26. Robinson LE, Décor ST, Merrick MA, Buckworth J. The effects of land vs. aquatic plyometrics on power, torque, velocity, and muscle soreness in women. J Strength Cond Res. 2004;18:84-91.
27. Stemm JD, Jacobsen BH. Comparison of land and aquatic based plyometric training on vertical jump. J Strength Cond Res. 2007;21:568-571.
28. Shiran MY, Kordi MR, Ziaee V, Ravasi AA, Mansournia MA. The effect of aquatic and land plyometric training on physical performance and muscular enzymes in male wrestlers. Res J Bio Sci S. 2008;3:457-461.
29. Miller MG, Berry DC, Bullard S, Gilders R. Comparisons of land based and aquatic-based plyometric programs during an 8-week training period. J Sports Rehab. 2002;11:268-283.
30. Maffiuletti NA, Dugnani S, Folz M, DI Pierno E. Effects of combined electro stimulation and plyometric training on vertical jump height. Med Sci Sports Exerc. 2002;34:1638-44.
31. Arazi H, Asadi A. The effect of aquatic and land plyometric training on strength, sprint, and balance in young basketball players, J human Sports & Exerc. 2011;6(1):101-111.
32. Potach DH, Chu DA. Plyometric training. In: Essentials of Strength Training and Conditioning. Baechle, T. R. (Ed.).Champaign, IL: Human Kinetics. 1994;431–436.
33. Sheffard JM, Young W. Agility literature review: Classification, training and testing. J Sports Sci. 2006;24(9):919-932.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=744&id=22&aid=6799