

Long jump training emphasizing plyometric exercises is more effective than traditional long jump training: A randomized controlled trial

SAID EL-ASHKER^{1,2}, AMR HASSAN¹ ✉, REDHA TAIAR³, MARKUS TILP⁴

¹Mansoura University, Egypt

²Imam Abdulrahman Bin Faisal University, Saudi Arabia

³University of Reims, France

⁴Karl-Franzens-University, Graz, Austria

ABSTRACT

The aim of the study was to evaluate the impact of an 8-week plyometric training program on the sprint and jump performance. The intervention study employed a controlled experimental design with two parallel groups of male long jumpers. While the experimental group (n = 18) trained with plyometric exercises, the control group (n=10) performed classical long jump training. Both groups were examined for athletic performance (30m sprint, standing long jump, vertical jump) and biomechanical parameters of a long-jump movement (max vertical height, horizontal and vertical velocity at take-off, flight time, take-off duration) prior and following the intervention. The experimental group demonstrated significantly better developments than the control group in most of the physical and biomechanical parameters respectively and improved their long jump records. Combining an 8-week plyometric program with athletics training significantly develops long jump and general athletic performance as well as biomechanical parameters. Therefore, plyometric training can be recommended to athletics coaches as an additional training alternative to improve sprint and long jump abilities in athletes. **Keywords:** Plyometric training, Long jump, Biomechanics, Physical fitness.

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✉ **Corresponding author.** Mansoura University, Egypt. <https://orcid.org/0000-0002-2053-7644>

E-mail: amrah1994@gmail.com

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INTRODUCTION

Long jump is one of the most important events in track & field competitions, as it has a long history and is involved in multiple event competitions (i.e. decathlon, heptathlon, pentathlon) (Rogers, 2000). Although long jump may seem the most simple jump discipline as compared to high jump, triple jump or pole vault, the correct technique is challenging and the physical requirements are high. All jump competitions including long jump require a maximum take-off velocity in order to move the centre of mass (CoM) as far as possible in horizontal or vertical direction (Koyama, Muraki, Takamoto, & Ae, 2008). In order to achieve high performance in long jumps, the athlete should convert the horizontal speed of the approach into vertical speed with minimal loss of the former (Arcelli, 1986; Bartlett, 2007). Hence, take-off technique which affects the CoM trajectory is an important factor to achieve high performance (Bridgett & Linthorne, 2006).

From this point of view, the training programs for long jump should therefore develop the correct motor trajectory in the approach phase and during take-off for the benefit of the flight stage (Koyama et al., 2008; Tan & Yeadon, 2005). Besides the technical aspect, the main factor in long jump performance is the strength of the lower limb muscle groups, which allows a fast running approach along with a forceful take-off movement. Improvements in lower limb strength and related explosive power are generally accompanied with improvements in a maximum vertical height and jump record (Singh & Singh, 2012). Therefore, training programs for the development of explosive power of the hip, knee, and ankle joints throughout the take-off stage are applied to improve jumping performance.

Plyometric training is a specific strategy used to develop explosive power (Brown, 2007) and coaching experts suggest this as a method to increase performance of athletes in explosive power sports (Donald & Gregory, 1998; Henson, 1994). Gambetta even suggested that using plyometric exercise in athletics training is essential, as it has become an important part in physical preparation programs utilized to develop leg explosive power especially for long, triple and high jump which require the combination of speed and strength (Gambetta, 1989).

In lower limb joints, muscles generate forces to create the movement which might be worth for the jump technique (Dziewiecki, Mazur, & Blajer, 2013). Previous studies recommended plyometric training as a direct means to develop leg explosive power because it involves a stretch-shortening cycle. Fatouros and co-workers (Fatouros et al., 2000) noted that plyometric training leads to fast decelerations immediately followed by fast accelerations. The muscle-tendon system is stretched in the initial eccentric phase of the movement and the stored elastic energy is partially retained during the shortening phase of the contraction (Donald & Gregory, 1998). Sharkey and Gaskill (Sharkey & Gaskill, 2013) stated that during plyometric training muscles are able to produce more force because they are stretched during the contraction.

On the other hand, despite the theoretical underpinnings, a number of researchers have reported a lack of significant improvements in the performance following plyometric training (Bedi, Cresswell, Engel, & Nicol, 1987; Canavan & Vescovi, 2004; Cossor, Blanksby, & Elliott, 1999). Reasons for such results could be the quality of the exercises offered within the training program and/or inadequate training program duration. Hewett et al. (Canavan & Vescovi, 2004) recommended a training phase of at least 6 weeks which was not reached these authors. Furthermore, insufficient training experience could be a reason for the lack of improvements following plyometric training which is physically demanding. Vassil & Bazanovk (Vassil & Bazanovk, 2012) reported a lack of significant improvements following plyometric training including standing long jumps and depth leap long jumps. The researchers reasoned that the depth leap long jump technique was new for athletes and therefore it was hard to adjust quickly to the new movement.

In general, plyometric training (e.g. including depth jumps) is commonly thought to be a more effective training exercise than training including countermovement jumps (Koyama et al., 2008) due to an increased stress for the lower leg muscle (Bobbert, 1990; Clutch, Wilton, McGown, & Bryce, 1983; Gehri, Ricard, Kleiner, & Kirkendall, 1998; Holcomb, Lander, Rutland, & Wilson, 1996; Thomas, French, & Hayes, 2009).

However, to the authors' knowledge, studies so far focused on the effects of plyometric training on performance parameters while biomechanical parameters were neglected.

Therefore, the aim of the study was to investigate the effect of 8-week plyometric training on several physical and biomechanical performance factors as well as long jump distance. We hypothesized to detect significantly greater improvements in the tested parameters compared to a control group performing classical athletic training.

MATERIALS AND METHODS

Procedures

To test our hypothesis we compared the effects of 8 weeks of plyometric training in an experimental group with those of a control group which used a traditional training program (TTP). Therefore, the study employed a controlled experimental design with two parallel groups including pre- and post-tests on long jump and general athletic performance as well as various biomechanical parameters during long jump.

The training bouts were controlled by one of the authors. Both pre- and post-tests were implemented at the same time of the day (9:00 to 11:00) to avoid any circadian influence.

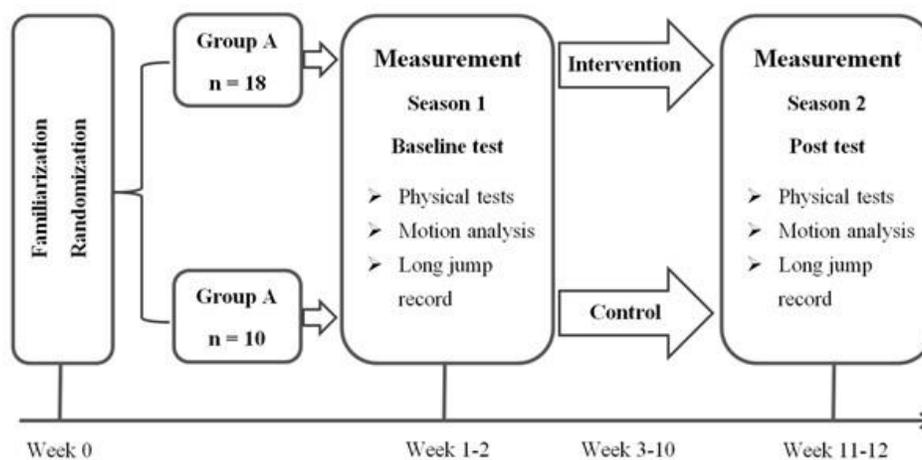


Figure 1. Experimental design: testing at baseline and subsequent to the interventions

Subjects

Thirty two long jumpers (Regional representative, table. 1) volunteered to contribute in the present study. Subjects are long jumpers that train in the center of the Egyptian Athletics Federation (EAF) in Dakahlia. Athletes at this training center have participated in national EAF competitions in Egypt. All Subjects were involved in track and field training for more than three years and had trained long jump 3 to 5 times weekly.

Subjects did not have any experience in depth jump training or workouts that involved plyometric exercises. The participants were randomly assigned to an experimental group (n= 18, 17-23 years) or a control group (n= 10, 18-25 years). The control group did not perform jumping/plyometric training during the intervention period.

Subjects were instructed not to perform any vigorous exercises 48 hours before the pre- and posttest measurements and were asked to continue their nutritional habits throughout the training period. Furthermore, subjects were asked to refrain from the consumption of any caffeine products, energy drinks, or tobacco and from any physical fitness activity the day before the testing. All subjects filled out a medical questionnaire about long-term medical conditions or other diseases that might prevent or affect their ability to perform the exercises during the study. The subjects were informed about the procedures of the study and were instructed how to execute the tests and the training exercises correctly in a separate familiarization session prior to the study (see Figure. 1).

Informed consent was sought and obtained prior to the study. The experiment was performed according to the Declaration of Helsinki and was accepted by the Ethics Committee of Review Board at Mansoura University.

Table 1. Pre-training physical characteristics N = 28

Variable	Control (n = 10) (Mean ± SD)	Experimental (n = 18) (Mean ± SD)
Age (years)	18.24 ± 4.06	19.55 ± 2.06
Height (m)	175.62 ± 3.55	177.30 ± 4.60
Weight (kg)	75.29 ± 4.08	73.59 ± 5.80
BMI (kg·m ⁻²)	24.38 ± 2.87	23.40 ± 3.90
Experience (years)	4.87 ± 2.14	4.37 ± 1.85

Research assistants transcribed all the subject characteristics (Table. 1) using a data capture form at baseline and after eight weeks. Each subject completed a controlled warm-up protocol starting with 5 min of cycling at approximately 65% of maximal heartrate, followed by 2 min of static stretching directed to lower-limbs followed by three 20-m sprints with maximal effort. Tests started following another 5 min of recovery.

Physical evaluation

Flying start 30m sprint

Subjects were asked to run 60 m starting from a standing position. During the first 30m subjects should increase their speed to a maximum and maintain this speed throughout the last 30 m. Time was taken from a line at 30 m until the 60m finish line using a stopwatch (Fastime 9; Pyramid Technologies, USA)(Rogers, 2000).

Standing long jump

Participants were asked to take a standing position behind a line marked on the ground and jump with both legs as far as possible including the use of an arm swing. They were asked to land on both feet and the distance between the contact point of the heel and the starting line was taken as measure. Each participant was allowed to perform three attempts. The best of the three attempts was considered as final result(James, Dale, James, & Minsoo, 2015; Rogers, 2000).

Vertical jump

First, standing reach height (SRH) was determined from a position where participants stood sideways of a wall with the feet flat on the ground and reaching up with the nearby hand to the wall as high as possible. The fingertips of the subjects were chalked to exactly determine the standing reach height (SRH). Then, subjects were asked to jump as high as possible starting from a static position and touch the wall at maximum height of the jump from where jump reach height (JRH) was measured. The final score was determined as the difference between the two distances (JRH - SRH)(Brown, 2007).

Motion analysis

The participant's jumping motion was captured with two digital high speed motion cameras (Casio EX-FC150), with a frame rate of 120 frames per second. Jumps from all subjects were recorded during six trials (3 pre-test, 3 post-tests) and the longest jump was selected for further analysis. All records were digitized with a motion analyzing program (Video Point 2.0, Pennsylvania, USA). Markers were placed carefully at each side of the body (head, shoulder, elbow, wrist, hip, knee, ankle, and toe). The location of the centre of mass (CoM) was calculated by the motion analyzing program based on the body segments data. Subsequently, biomechanical parameters of the CoM were determined: maximum vertical height 'flight stage', horizontal velocity at take-off, vertical velocity at take-off, flight time, take-off duration, and long jump record. Take-off duration is defined as the duration of the last ground contact and hence the ability of the athlete to generate a vertical impulse (force integrated over time).

Training protocols

During the 8 week intervention period both the experimental and the control group undertook the same general long jump training carried out by the same instructor to guarantee consistency in training methods and procedures three times a week. Both groups trained the same technical skills but participated in different athletic training programs with increasing intensity. We controlled the intensity by asking athletes to do this at 70%, 80% etc. (Table 2).

Statistical analysis

In the descriptive analysis data is reported as means \pm standard deviations and percentage of changes. Physical characteristics before the intervention were tested for difference between the groups with unpaired t-tests. Test data was examined for normality with Shapiro Wilk test and for homogeneity of variances with Levene's test. If normality of data was present a two way mixed analysis of variance (factors: group, time, and interaction (group vs. time)) was performed. Estimates of effect sizes are given in terms of partial eta-squared measures (η^2_p). In case of a significant interaction effect, post-hoc t-tests were applied to determine the source of difference. When data was not normally distributed or homogeneity of variance was not given, non-parametric tests (Wilcoxon) were applied. Estimates of effect sizes for the pre to post comparisons are given in terms of Cohen's d. Results were considered significant when $p < 0.05$. IBM SPSS statistics version 22.0 package was used.

Table 2. Athletic training programs of the experimental and control group, respectively

Week	02-ene	04-mar	06-may	08-jul
Variables				
Drills for experimental group	Dot drill	Jump & turn 90°	Ankle Hops	Power Skips
	Double leg jump backward	Long Jump and Sprint	Ankle jumps	Lateral Taps on a Ball
	Double leg jump forward	Cone/Hurdle Jumps	Backward Throw	Jump and turn 180°
	Hi-Five Jumps	Single Leg Pops	Double leg "X" hop	Standing Jump & Reach
	Lateral Cone Jumps	Zig-Zag Double Leg Hops	Hurdle hops	Split squat jump
	Drop depth jump	Single leg zig-zag drill	Box Jumps	Depth Jumps
Drills for control group	Full speed 30-50 meter	Conditioning Circuits	Landing drills	Long jump approaches 4-8
	Long jump approaches 4-8	Take off drills	Medicine Ball	Pick on additional takeoff
	Medicine Ball	Timing and coordination	coordination drills	Full speed 30-50 meter
	Pick on additional takeoff	Landing drills	Conditioning Circuits	Landing drills
	Landing drills	Medicine Ball	Full speed 30 m	Five stride jumps into pit
Intensity	70%		80%	90-100 %
Sets	2-3		3-4	2-3
Repetitions	8-10		6-8	6

RESULTS

At baseline there was no significant difference between the groups in any of the measured variables. Test data was normally distributed in 7 out of the 11 tests (Table 3).

Table (3) shows the summarized results from the tests. A mixed 2 * 2 multi-factorial ANOVA indicated a significant interaction effect for 30 m sprint ($F(1, 26) = 55, p = .00, n^2_p = .67$), standing long jump ($F(1, 26) = 37.3, p = .00, n^2_p = .59$), vertical jump ($F(1, 26) = 11.5, p = .00, n^2_p = .30$), max vertical height (flight stage) (NA), Horizontal velocity at take-off ($F(1, 26) = 71, p = .00, n^2_p = .73$), flight time ($F(1, 26) = 22.9, p = .00, n^2_p = .46$), take-off duration ($F(1, 26) = 14, p = .00, n^2_p = .35$), (14, .00, .35), long jump record (NA). No significant interaction effect was found for vertical velocity at take-off ($F(1, 26) = 32, p = .01, n^2_p = .57$).

Further analyses (using paired t-tests) revealed significant within group differences between pre- and post-tests in both groups for all variables. Effects sizes varied from $d = 0.8$ to 6.6 (see table 3).

Changes in the experimental group were significantly greater compared to the control group for 30 m sprint, standing long jump, vertical jump, horizontal velocity at take-off, vertical velocity at take-off, flight time and take-off duration. (Figure. 2).

Table 3. Test data from control and experimental groups before (pre) and after (post) the intervention

Tests	Unit	Control group (n = 10)		Experimental (n = 18)		P-value (interaction effect (η^2p))	value (d)-P	
		Mean \pm SD		Mean \pm SD			Control	Experimental
		pre	post	pre	post			
Flying start 30m sprint	s	0.19 \pm 3.89	0.19 \pm 3.63	0.26 \pm 3.59	0.18 \pm 3.36	(67.) 00.	.00* (1.4)	.00* (2.5)
Standing long jump	cm	3.33 \pm 231	4.76 \pm 239	5.50 \pm 229	11.52 \pm 252	(59.) 00.	.00* (1.9)	.00* (2.3)
Vertical jump	cm	2.15 \pm 39.14	3.59 \pm 46.26	2.27 \pm 39.06	6.33 \pm 52.39	(30.) 00.	.00* (2.7)	.00* (2.4)
Max vertical height (flight stage)	cm	5.16 \pm 113	6.76 \pm 120	4.10 \pm 118	5.36 \pm 148	NA	.00* (1.2)	.00* (6.6)
Horizontal velocity at take-off	m/s	36.0 \pm 7.63	0.30 \pm 7.83	34. \pm 7.86	0.54 \pm 8.91	(73.) 00.	.00* (.60)	.00* (2.1)
Vertical velocity at take-off	m/s	0.12 \pm 2.93	0.13 \pm 2.98	0.09 \pm 99.2	0.80 \pm 3.05	(01.) 57.	.00* (0.4)	.00* (0.8)
Flight time	s	0.34 \pm 0.64	0.02 \pm 0.68	0.33 \pm 0.68	0.04 \pm 0.72	(46.) 00.	.00* (1.2)	.00* (1.7)
Take-off duration	s	0.01 \pm 0.20	0.02 \pm 0.19	0.02 \pm 0.20	0.01 \pm 0.18	(35.) 00.	.00* (1.1)	.00* (1.8)
Long jump record	m	0.11 \pm 5.87	0.15 \pm 6.18	0.11 \pm 90.5	0.20 \pm 6.50	NA	.00* (2.3)	.00* (3.8)

(NA)Data not normally distributed, * significant change from pre to post

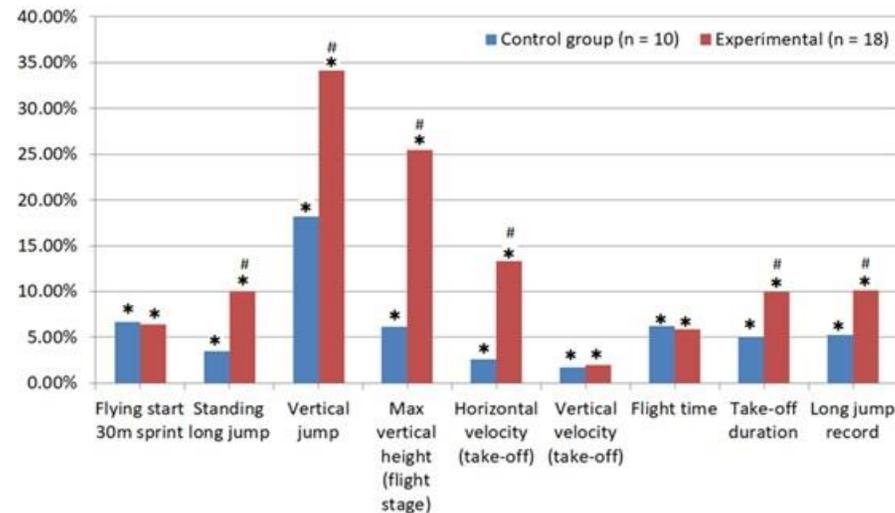


Figure 2. Percentage difference in physical, biomechanical and long jump record values in control and experimental groups following the training period

DISCUSSION

While both groups displayed improvements in jump performance during the present study, 8 weeks of long jump training with special emphasize to plyometric exercises led to greater enhancements in 6 of the 9 jump parameters (including long jump distance) when compared to a traditional training program. We observed excellent compliance (100%) and no adverse events were observed in the long jump training program.

As formerly observed in mature participants(Sale & MacDougall, 1981), our results confirm that training programs that comprise activities which are biomechanically similar to the performance task are favorable also in young adults. Plyometric exercises which, similar to the long jump take off, contain stretch-shortening cycles of the leg muscles are beneficial for improving long jump distance and other sprint- and jump-related performance parameters(Fleck & Kraemer, 2014).

The results of the present study demonstrated that plyometric training can significantly increase the long jump performance(Faigenbaum et al., 2007; Fatouros et al., 2000; Sharma, Saiyad, & Nandwani, 2013)and also have a significant effect on hip and thigh power that was estimated by vertical jump test(Canavan & Vescovi, 2004; Fleck & Kraemer, 2014; Kotzamanidis, 2006). This is also confirmed by results from Hewett et al.(Hewett, Stroupe, Nance, & Noyes, 1996)who reported an increased hamstring muscle peak torque, power, and hamstring/quadriceps ratio following a six-week plyometric jump training program.

However, we have to note that some investigators failed to show a differences between the effects of plyometric exercises compared to traditional jump training programs (Herrero, Izquierdo, Maffiuletti, & Garcia-Lopez, 2006; Markovic, Jukic, Milanovic, & Metikos, 2007).These conflicting results indicate that both types of training are effective which can be explained by the fact that traditional jump training programs also contain plyometric exercises including stretch-shortening cycles(Thomas et al., 2009). However, in the present study we could show that greater improvements can be achieved when special emphasize is put on plyometric exercises during training.

Additional to performance enhancement, plyometric might have positive effects by stabilizing knee joint motion through an increase in lower extremity strength as reported by(Hewett et al., 1996).

CONCLUSIONS

A plyometric training program was more effective in improving lower body explosive power and the jump distance compared to a traditional long jump training program. Furthermore, plyometric training had positive effects on general athlete performance measures (speed, strength) that are closely related to long jump performance. The study showed that plyometric training can be a safe and effective alternative to traditional plyometric.

CONFLICT OF INTERESTS

The authors declared no conflict of interests concerning this manuscript.

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