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ORIGINAL RESEARCH

Effect of plyometric training on improving vertical jump in female footballers (14-17 years old)

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Abstract. Plyometric training (PT) is a very popular form of physical conditioning for healthy individuals that have been extensively studied over the last decades. The study aimed to determine the effect of PT on improving vertical jump (VJ) in female footballers (14-17 years old). The study adopted a pretest-posttest quasi-experimental design. The study population was the female football players of the National Women's Football League in Algeria (LNFF). Twenty-two players were drawn from the study population (age=15.10±0.47 years, height=152.01±5.80 cm, weight=49.51±6.09 kg). The sample was divided into a control group (CG) and an experimental group (EG). Eleven players per group. The training program was made for the participants and the exercise training was supervised by the researchers. The PT exercises for the EG in which each exercise session involved 15±3 minutes of moderate-intensity exercise for the first four weeks and gradually increased to high-intensity exercises for the last six weeks. The PT was carried out for 10 weeks. Subjects were trained three times a week. A squat jump (SJ) and a counter-movement jump (CMJ) were used for data collection. Data were analyzed using mean and standard deviation, the paired t-test was used to compare pre-test and post-test data. The results marked improvements in VJ after the 10-week PT as significant gains were noticed in the post-test for EG on SJ t= 8.35, p< 0.05, CMJ t=5.70, p<0.05. When the effect of the PT program was compared among groups (CG/EG) by sport, the result showed that EG gained significantly more than CG in SJ/CMJ (F= 11.74/9.33, p<0.05). The study concluded that 10-week PT produced a significant increase in the muscular strength of Algerian female soccer players. The general recommendation states that more than 6 weeks of systematic application of PT are necessary to improve VJ and physical performance in amateur and elite players.

Keywords. Plyometric training, short-term performance, soccer, vertical jump.

Introduction

Soccer (also known as football) is the world's most popular form of sport, being played in every nation without exception (Mengesh et al., 2016), female's soccer is one of today's most popular sports (Williams, 2013). Participation rates in 2015 women's soccer world cup in Canada confirmed that 30 million women and girls play football worldwide, equating to an increase of 32% since 2010 (Dunn, 2016), and women's participation rates were projected to double to 60 million worldwide by 2026 (Griffin et al., 2020). In Algeria, women's soccer is a young discipline (Ghimouz, 2003; Mouloud, 2013; Samie & Sehlikoglu, 2015). As the participation of women in soccer increased, in addition to being psychologically strong women must be physically strong, too (Kenan et al., 2017). Like any intense sporting and competitive

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Received: April 24, 2022 - ***Accepted:*** *June 06*, 2022 - ***Published:*** June 25, 2022
To Cite: Idriss, M. M., Abdelkader, G., Madani, R., Mohammed, Z., & Ali, B. (2022). Effect of plyometric training on improving vertical jump in female footballers (14-17 years old). *Turk J Kinesiol*, 8(2), 37-43. **DOI:** 10.31459/turkjkin.1108335

activity (Abdelkader et al., 2018; Guebli et al., 2020), football can cause psychological and physiological changes in women (Mengesh et al., 2016). Where the players need the physical and physiological power necessary for the soccer game they play (Jeci et al., 2019; Randell et al., 2021). Soccer is characterized by an intermittent-activity profile with metabolic contributions from both the aerobic and anaerobic systems (Krustrup et al., 2008; Rampinini et al., 2007). Therefore, the capacity to perform quick and powerful movements in soccer is one of the most important abilities to acquire to improve performance (Mohr et al., 2003; Zerf, 2017; Henni et al., 2020), where the leg muscle power in general, and vertical jump performance in particular, are considered as critical elements for successful athletic performance (Canavan & Vescovi, 2004; Markovic, 2007). Thus, the need to develop these properties by different training occurs (Arguz et al., 2021; Guebli et al., 2021).

One of the training methods that include these actions and that is used for power (vertical jump) development is PT exercises. Although the various training methods in developing vertical jump, most coaches and researchers seem to agree that PT is a method of choice when aiming to improve vertical jump ability and leg muscle power (Ebben & Blackard, 2001; Kryeziu et al., 2019; Ozbar et al., 2014). The effects of PT may differ depending on various subjects' characteristics, such as training level gender, age, sports activity, or familiarity with PT (Brown et al., 1986; Hewett et al., 1996; Matavulj et al., 2001; de Villarreal et al., 2009). PT consists of the rapid stretching of a muscle (eccentric action) immediately followed by a concentric or shortening action of the same muscle and connective tissue, and it includes a diverse range of bilateral and unilateral jumps, bounds, and hops (Chu, 1998; Pardos-Mainer et al., 2021), where investigators are focused on PT as part of a short-term program designed for vertical jump development. Plyometric training is primarily used by strength and conditioning coaches to enhance human neuromuscular function and improve the performances of both explosive- and endurance-based athletes. It is commonly agreed that plyometric training develops the neural and musculotendinous systems of the SSC to generate maximal force in the shortest amount of time. Given this, plyometrics are often used as a method of training to bridge the division between strength and speed (Markovic et al., 2010). Even despite rigorous scientific investigation, plyometric training continues to prove itself as a potent training method for enhancing athletic performance. Several reviews and meta-analyses related to PT programs have been published in soccer (Sánchez et al., 2020). However, Research studies that combine these variables in different ways sometimes lead to conflicting results, although it has increased the scientific value of PT regarding physical fitness enhancements (Moran et al., 2018; Moran et al., 2019). Also, the opinion that PT is sufficient twice per week (Sae et al., 2009), the authors presume that 10 weeks of gradually increase in intensity PT (4 weeks moderate-intensity, and 6 weeks high-intensity) with low-to-high frequency, three days per week, could significantly increase vertical jumps performance in female soccer players. This presume also raises the question about comparative values between pre/posttest in PT program. Therefore, this study aimed to determine the effect of PT on improving vertical jump in female footballers (14-17 years old).

Methods

Subjects

Twenty-two players (females) between 14 and 17 years of age from (LNFF) - National Women's Football League on Algeria, were voluntarily enrolled to participate in this study after providing informed consent. a child's consent document was provided by the subject and an informed consent document by the parent or legal guardian. The subjects were part of two youth soccer clubs (Afek Ghilizane and Alger Center), which were playing in the first division soccer of Algeria. All of the players had at least 4±0.53 years of coaching experience. We excluded individuals, who had experienced a lower-body injury in the previous 3 months. The (OPAPS) laboratory and review board of (STAPS) institute in Abdelhamid Ibn Badiss University of Mostaganem approved this study (2019/157).

Design and Procedure

The study was designed to determine the effect of PT on improving vertical jump in female footballers (14-17 years old). For the realization of this study, the experimental protocol required athletes to perform a stress test before and after a 10-week PT period at the rate of one 15±3 minutes session per week. SJ and CMJ. These vertical jumping tests were conducted on a jump platform and camera connected to a Kinovea software that was recording the flight time (tf) and contact time

(tc) of each single jump. In order to avoid unmeasurable work, horizontal and lateral displacements were minimized, and the hands were kept on the hips throughout the tests. SJ and CMJ performance are reported as the jump height* (cm) by applying ballistic laws:

$$h = t_f^2 \cdot g^{-1} \cdot 8^{-1} \text{ (m)}$$

g is the acceleration of gravity (9.81 m·s-2).

Two different jumping tests were performed: SJ, in which subjects were jumping from a semi squatting position without countermovement (the athlete steps onto the jump plate. Athlete gets into a squatting position at roughly 90 degrees with hands on hips. After about 3 seconds, give the athlete a "ready, go" call, the athlete engages her leg muscles and explodes upwards. The athlete should stick the landing on the jump plate, keeping hands on hips, and wait until the test is completed.), and CMJ, in which subjects were allowed to perform a countermovement with the lower limbs before jumping. In both tests, the subjects were required to land in the same point of takeoff and rebound with straight legs when landing in order to avoid knee bending and alteration of measurements. Each test was measured with 3 trials, with the pause between trials being around 1-2 minute. Once the pretests were carried out, the subjects were divided into 2 groups: a control group (CG) and an experimental group (EG). Eleven players in each group. All athletes were required to complete their pre-season preparation program (football training combined with a strength training program targeting the lower body). The control group was involved only in regular soccer training. In addition to this program, the session included the PT exercises for the experimental group in which each exercise session involved 15±3 minutes of moderate-intensity exercise for the first four weeks and gradually increased to high-intensity exercises for the last six weeks. The training program was carried out for 10 weeks. Subjects were trained three times a week. The training program was made for the participants and the exercise training was supervised by the researchers. The exercise intensity was measured by using time-motion in exercise and HR of the players during that. The PT included basics such as skipping, bunny hops, jumping rope, squat jump, jump to box, split squat jump, lateral box jump, lateral box push-offs, bounding with rings, lateral hurdle jump, and depth jump. 1st three weeks consisting of simple exercises (skipping, bunny hops, jumping rope, bounding with rings ...etc.). 2nd four weeks consisting of exercises at medium intensity (squat jump, jump to box, split squat jump, lateral jump to box ...etc.), 3rd three weeks consisting of intense exercises (jump to box, split squat jump, lateral box jump, lateral box push-offs, lateral hurdle jump, and depth jump ...etc.).

Data Analysis

The data were entered using the Microsoft Excel 2019 software and then imported into SPSS software version 22.0 (Statistical Package for Social Sciences) for appropriate analysis. Quantitative variables were expressed as mean ± standard deviation. The test-retest reliability of the SJ and CMJ tests was evaluated using intraclass correlation coefficients. All tests were reliable and reliability of these tests for interrater correlation coefficient ranged between 0.91 and 0.96 with no significant differences found between mean values for tests vs. retest. Test of normal distribution (Shapiro-Wilk) were conducted on all data before analysis. The independent Student t-test was used to compare the means between the experimental and control group. Paired t-test for comparison of intragroup changes between pretest and posttest. A value of p-value ≤ 0.05 was considered a threshold of statistical significance.

Results

The homogeneity in tests was calculated based on ANOVA one-way which showed no significance in all comparisons, where the values of statistical significance are below p-value ≤0.05 (Table 1).

Table 2 shows the results of a comparison between pre/posttest of control and experimental groups in SJ and CMJ, using the t-test. For the control group, those results show the significant difference between pre/posttest in CMJ $t_{2.22}$=2.33, However, the comparison in SJ did not reveal any significant difference between pre/posttest $t_{2.22}$=1.81. For the experimental group, those results show the significant difference between pre/posttest in SJ $t_{2.22}$=8.35 and CMJ $t_{2.22}$=5.70. Depending on these results, the results of the comparison between two groups, using the ANOVA one-way-test, affirm where we obtained significant differences between groups in SJ $t_{2.08}$=11.74 and CMJ $t_{2.08}$=9.33. This difference was in favor of the experimental group. All the comparisons analyzed are significant at p-value ≤0.05 (Table 2).

Table 1
Descriptive data for anthropometric features in experimental group and control group (Mean ± SD).

Variables	CG (n=11)	EG (n=11)	F	p
Age (years)	15.08 ± 0.19	15.16 ± 0.93	0.72	p>0.05
Weight (kg)	49.66 ± 6.02	50.33 ± 6.11	0.49	p>0.05
Height (cm)	151.5 ± 5.57	153.00 ± 6.47	1.84	p>0.05

Table 2
Performance variables of pretest and posttests SJ and CMJ for experimental group and control group.

Variables		CG				EG				t	p
		Mean ± SD	Mean-D	t	p	Mean ± SD	Mean-D	t	p		
SJ	Pre-test	22.16±4.94	1.75	1.81	p>0.05	23.61 ± 5.26	5.22	8.35	p<0.05*	11.74	p<0.05*
	Post-test	23.91±5.61				28.83 ± 5.12					
CMJ	Pre-test	30.33±7.84	2.58	2.33	p<0.05*	29.50 ± 6.08	7.00	5.70	p<0.05*	9.33	p<0.05*
	Post-test	32.91±7.26				36.50 ± 5.70					

Discussion

The results of this study suggest that PT has a significant effect on the vertical jump performance of female footballers. Where the variability in performance appears to be greater after 10 weeks of training. The increased performance trend observed on the "SJ" could be due to the increased performance in CMJ (Benelguemar et al., 2020) and/or the effect of recommended plyometric training during the experimental period. According to Cometti (1987), PT causes an improvement in the nervous and elastic factors of muscle strength. For nervous factors, the plyometric action acts on the recruitment of numerous motor fibers and the synchronization of these motor fibers and for factors linked to stretching (Chu, 1998; Zamparo et al., 2015), we work on the myotatic reflex and elasticity.

Bangsbo et al. (2005) showed that after PT, members of the Danish national football team had lower body mass and fat levels, higher VO_2 Max, that they could jump higher and run longer (Markovic, 2007). Although there is very little difference between the training potential of men and women. The physical demands of women's football are no different from men's football although, for men more strength, power and speed are required (Moran et al., 2019). Overall, the intensity of a match is less for women although the players run similar distances. It was also indicated that male and female players should train similarly, although due to possible changes in menstrual cycles, the intensity of training for women should be gradually increased (Griffin et al., 2020; Mengesh et al., 2016; Moran et al., 2019). Also, Specific training to strengthen the quadriceps can help reduce this risk such as weight training and plyometric-based training (Vinu, 2018).

In a study by Newton et al. (1999) conducted on high-level volleyball players, it has been shown that load plyometrics improves performance, through an increase in the rate of development of strength and weight (de Villarreal et al., 2009; Pardos-Mainer et al., 2021). Muscle power during the concentric phase of movement and not through an increase in maximum strength (Slimani et al., 2016). Methods such as weight training and PT should only be used by players who have completed their physical growth and if good levels of fitness have already been achieved (Ozbar et al., 2014). Could have individualized the training by taking into account the starting level of the players and based on the muscular elasticity index which is represented by the difference between the CMJ and the SJ (Hansen & Kennelly, 2017). On the relevance of this work in the context of the ability to repeat jumps or improving speed (Mengesh et al., 2015; Randell et al., 2021; Zamparo et al., 2015).

Multiple authors have demonstrate that PT programs can increase maximal vertical jump height (Adams et al., 1992; Baker, 1996; Blattner & Noble, 1979; Brown et al., 2007; Hewett et al., 1996; Kannas et al., 2012; Kotzamanidis, 2006). The most previous studies involving various jump training programs ranging from six to 24 weeks (Behm, 1992; Hansen & Kennelly, 2017; Lundin, 1985; Mengesh et al., 2015), including pre-pubertal, pubertal, and adult athletes showed that improved vertical jump performance is a consistent outcome after PT (Wertheimer et al., 2010). Despite the large variety of jump training tests that have been measured to evaluate improved vertical jump height within these studies, including squat jumps, split squat jumps, bounding, countermovement jumps with and without arm swings, and drop jumps. More advanced techniques include tuck jumps, depth jumps, and single-leg hops(Chu, 1998; Jurado-Lavanant et al., 2018). Where this effect of plyometric exercises is attributed to the elastic recoil of the elastic tissues. The series elastic components (SEC) for 70-75 percent of the concentric force increases of muscle thereby making the plyometric training very efficient (Davies et al., 2015). The mechanical behavior of the SEC is a major contributor in the plyometric action. The SEC acts like a spring, where the energy release will be greater with higher forces (Albert, 1995; Goldbeck & Davies, 2000). Finally, PT is a condition format that when done correctly, can help to increase in force, speed and agility performance in elite and amateur team sport players. PT can be one of the best boosts your body needs for staying in shape.

Conclusion

In conclusion, the positive effects on our result can be explained by the subject characteristics, in particular a training level, sports activity, age, gender, familiarity with as well as the choice of plyometric exercises and a program design (program duration, volume, rest periods, frequency, the type of exercises and their combination). The present study shows that PT with moderate intensity has high effects on vertical jump. Also, the combination of plyometric drills is a more effective method compared to single plyometric drills (e.g. SJ, CMJ). This study confirmed that PT program on 10 weeks of gradually increase in intensity PT (4 weeks moderate-intensity, and 6 weeks high-intensity) with low-to-high frequency, three days per week, effect significantly increase vertical jumps performance in Algerian female soccer players. Furthermore, the general recommendation states that more than 6 weeks of systematic application of PT are necessary to improve vertical jump and physical performance in amateur/ elite players. Where the authors respectfully suggest that the more experimental design quality that establishes cause and effect of plyometric training is needed in Algerian women soccer. In addition, adequate facilities, infrastructure, equipment and supplies should be made available at the training ground to guarantee the success of the program. Where some materials are not available, they should be improvised and modified to meet specific needs.

Authors' Contribution

Study Design: GA, MMI; Data Collection: MMI, ZM; Statistical Analysis: GA, ZM; Manuscript Preparation: GA, ZM; Funds Collection: RM, BA.

Ethical Approval

The study was approved by the Abdelhamid Ibn Badiss University of Mostaganem Ethical Committee (2019/157) and it was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

Funding

The authors declare that the study received no funding

Conflict of interest

The authors hereby declare that there was no conflict of interest in conducting this research.

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