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Research Paper

Eight Weeks Plyometric Training Program Effects on Lower Limbs Power and Spike Jump Performances in University Female Volleyball Players

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ABSTRACT

Background and Objectives: The purpose of this investigation was to examine the potential effects of eight weeks volleyball specific plyometric training on lower limbs power, vertical jump and spike performances in university female volleyball players which are considered specific to volleyball success. **Methods:** Twenty university female volleyball players were randomly assigned to an intervention group (INT= 10) or an active control group (CONT= 10). INT completed an eight weeks specific plyometric training program with three sessions per week while CON continued their regular training. Training volume was similar between groups. Before (T_0) and after (T_1) the intervention, the two groups were evaluated for the squat jump (SJ) countermovement jump (CMJ) test, the spike jump test (SP), the five time-jump test (FJT) and Standing long jump test (SLJ). **Results:** For SJ, post-hoc tests revealed significant pre-to-post improvements for both groups [INT (p =0.001, ES=0.45, small); CONT (p =0.002, ES=0.51, small)]. For CMJ, post-hoc tests revealed a significant pre-to-post improvement for INT (p = 0.001, ES = 0.72, moderate), and a significant lower improvement for CONT (p = 0.016, ES = 0.63, moderate). For SP, post-hoc tests revealed a significant pre-to-post improvement for INT (p = 0.004, ES = 0.78, moderate), and a significant lower improvement for CONT (p = 0.011, ES = 0.67, moderate). For FJT, post-hoc tests revealed only a significant pre-to-post improvement for INT (p = 0.002, ES = 0.85, moderate). For SLJ, post-hoc tests revealed a significant pre-to-post improvement for INT (p = 0.001, ES = 0.74, moderate). **Conclusions:** Eight weeks specific plyometric training program had a positive impact on improving lower limbs power, vertical jump and spike performances in university female volleyball players.

Keywords: Team sports; vertical jump; explosive; physical fitness

INTRODUCTION

Volleyball is a team sport in which explosive power is the most essential part of most player skills (Polglaze and Dawson. 1992; Sheppard et al., 2007; Gabbett and Georgieff. 2007; Ziv and Lidor. 2010). In fact, during games players can perform 250 to 300 actions dominated by the explosive type of strength of the leg muscles (Soundara et al., 2010). Also, players are involved in defensive and offensive jumping activities (Hwett et al., 1996; Gabbett and Georgieff. 2007; Ziv and Lidor. 2010; Gjinovci et al., 2017). The total number of actions as jumps takes up around 50-60% (Soundara et al., 2010). In this context, previous studies showed that both countermovement jump (CMJ) ability (i.e., jump and reach height) and jump ability (i.e., spike jump) are considered critical performance

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indicators in volleyball (Smith, et al., 1992; Palao et al., 2014; Gjinovci et al., 2017; Tsoukos et al., 2018).

Moreover, improving vertical jump performance in volleyball is usually the key to winning point (De Villarreal et al., 2009; Soundara et al., 2010). Tsoukos et al. (2018) when comparing female and male volleyball players, noted that better-performing teams were comprised of players with high vertical jumps. For the above reasons, the purpose of an explosive power training for volleyball is necessaire and should take in consideration the development of specific physical attributes necessary to improve a Volleyball player's performance (Stojanovi´c et al., 2017; Ziv and Lidor. 2010; Silva et al., 2019). In this context, fitness trainers and couches had to use the plyometric method which is ranked among the most frequently used methods for conditioning in volleyball (Martel et al., 2005; Turgut et al., 2016; Trajkovic et al., 2016; Silva et al., 2019). In fact, this training strategy leads to the development of explosive power and reactive speed of the muscle systems systems (Hwett et al., 1996; Mili´c et al., 2008; Ramlan et al., 2018). Also, it is based on the reflex muscle fiber contraction, which gives a response to the quick stretch caused mostly by kinetic energy during the deceleration movement phase (Hwett et al., 1996; Mili´c et al., 2008). Lehnert et al. (2009) mentioned that plyometric method increases functional power and enables the muscles to reach a higher power level than the maximum volitional power.

Previous studies have tried to investigate various protocols and training programs involving plyometric in different team sports (i.e., including volleyball) (Hwett et al., 1996; Lehnert et al., 2009; Silva et al., 2019). In this context, Silva et al. [11] in a systematic review reported an improvement on the jumping performance after the implementation of a plyometric training intervention, with larger increases in counter-movement and drop jumps in both males and females and independently of age. Moreover, after a plyometric training protocol that lasted 12 weeks, improvements of 16.9% in counter-movement jumps were found in under-17 women players [9]. Also, for the same test in under-22 women players, an improvement of 27.6% was recorded. Studies conducted by Mili´c et al. [10] and Çımenlı et al. [4] revealed a significant increase in horizontal jump performance after the plyometric training intervention. However, Gjinovci et al. [6] presented only a small effect of plyometric training on horizontal jump performance. Taken together, these findings from the available studies on the effects plyometric training appear to vary according to the programming parameters applied such as training time, frequency, and intensity. Thus, it will be interesting to assess a more specific plyometric training program in female volleyball players.

To the best of our knowledge, there are no studies available that assessed specific plyometric training on lower limbs power and spike jump performance in university female volleyball players. Therefore, the aim of this study was to examine the effects of eight weeks plyometric specific training program on jump and spike performances in female university volleyball players. Considering the previous literature (Mili´c et al., 2008; Lehnert et al., 2009; Soundara et al., 2010; Gjinovci et al., 2017; Çankaya et al., 2018), we hypothesized that plyometric specific training program improves lower limbs power and enhance spike performance.

MATERIALS AND METHODS

Participants

Twenty university female volleyball players participated in this study. Players exercised between 4-5 days per week with a daily training time of > 60 min, and a training experience of 7.4 ± 3.8 years. Athletes were randomly assigned according to their playing position to intervention, group (INT, n=10) and active control group (CONT, n=10) (Table 1). This study was conducted during the competitive season and it was approved by a local Clinical Research Ethics Committee. The experimental protocol was conducted according to the latest version of the Declaration of Helsinki. All participants provided their written informed consent before study participation.

Table 1: Characteristics of volleyball players

Volleyball players	Age (yrs.)	Height (cm)	Mass (kg)	BMI (kg.m^{-2})
INT (n=10)	20.90±0.88	1.66±0.06	65.70±7.61	23, 82±1.23
CONT (n=10)	20.70±1.06	1.62±0.05	59.50±6.96	22,78±1.05

Data are means and standard deviations. INT: intervention group; CONT: control group; BMI: Body mass index.

Procedures

All participants completed two familiarizations trials of all except measurements in the 2 weeks before definitive data collection. Baseline testing was undertaken in the last 2 weeks of April 2019, and tests were repeated after the eight weeks intervention in July 2019. The test protocol comprised, (jumping (squat (SJ), counter-movement (CMJ), Spike jump (SP) and five jump (FJT) and standing long (SLJ) tests). Measurements were made at a consistent time of day and under the same experimental conditions, at least 3 days after the most recent competition and (for the final tests) 5–9 days after completion of the intervention. A normal intake of food and fluids was maintained except that participants drank no caffeine-containing beverages for 4 h and ate no food for two hours prior to testing. Verbal encouragement ensured maximal effort throughout.

Plyometric Training Program

INT completed specific plyometric training program every Tuesday, Thursday and Sunday for eight consecutive weeks, while the active CON completed the daily traditional training program. Training volume was similar between groups. Both groups performing plyometrics on gymnasium floor. The plyometric training program for INT consisted of three principal work-shops (Table 2). Each workshop began with plyometric exercises (using the medicine ball; using the jump box and using sand weights (for the legs)) and finished with performing the skill of spiking from different positions. Sessions began with a 10-min warm-up and lasted 35 min (Table 3), always supervised by the same coach. Verbal encouragement ensured a high level of motivation throughout.

Training Load Monitoring

To determine whether the subjects' global training load remained consistent through the study, the session rating of perceived exertion (RPE) training score was taken following each session. About 30-minutes after training sessions subjects were asked to rate the global intensity of the entire workout session using the category ratio-10 RPE scale according to the methods described by Foster et al. [5]. A daily training load was created by multiplying the training duration (minutes) by the session RPE. The weekly training load was determined by summing the daily training loads for each athlete during each week (Figure 1).

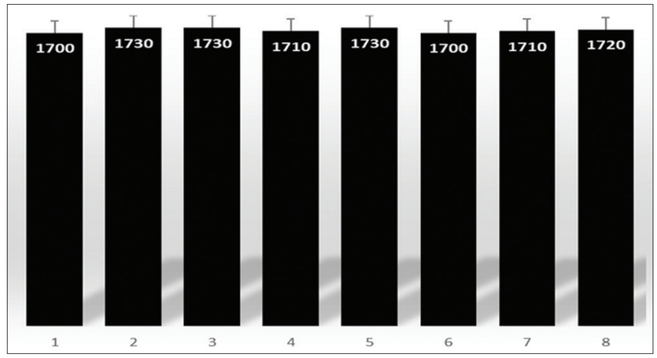

Figure 1: Total weekly training load during the experimental period for INT

Assessment

Anthropometrics

Measurements included height (accuracy of 0.1 cm; Holtain stadiometer, Crosswell, Crymych Pembs, UK) and body mass (0.1 kg; Tanita BF683W scales, Munich, Germany).

Vertical Jump Tests

Vertical jumps height was evaluated using an optoelectric system (Opto-Jump Microgate - ITALY). Players performed the countermovement (CMJ) and the squat jumps (SJ) according to the previously described protocols [1]. Before testing, players performed submaximal CMJs and SJ (2 repetitions each) after the warm-up. Each participant performed 3 maximal CMJs and SJs, with approximately 2 min of recovery in between. Players were asked to jump as high as possible. The best trial was used for further analyses.

Spike Jump Testing

The examinee stands facing the wall and resting both outstretched arms on the board next to the fixed measuring tape, so that they are on the same level. After noting the height within reach for the spike jump, the examinee takes a step back, and with a running start of just one step, takes off with both feet, and touches the board that is next to the steel measuring tape with the fingers of both hands, which have previously been coated with red dye. The evaluator should be standing on the wooden case so that his head is at level with the height within reach of that jump, so as to increase the accuracy of the results. Three jumps are made. Any incorrectly performed jumps are repeated. The height within reach for that jump is measured in centimeters, and then the height within reach is subtracted from it, and we get the height of that jump. Only the best

Table 2: Plyometric training program for the experimental group

Day	Exercise	Sets	Repetitions	Between-Set Recovery (minutes)
Sunday	****workshop 1: -Box jump-up with stabilization.	5	10	3
	****workshop 2: -Plyometric push up /set up with medicine ball.	7	12	3
	****workshop 3: -Multiplanar jump using sand weights (for the legs).	5	10	3
Tuesday	****workshop 1: -Box squat-jump with stabilization.	5	10	3
	****workshop 2: -Plyometric push up /set up with medicine ball.	7	12	3
	****workshop 3: -Tuck jump using sand weights (for the legs).	5	10	3
Thursday	****workshop 1: -Box jump-down with stabilization.	5	10	3
	****workshop 2: -Plyometric push up /set up with medicine ball.	7	12	3
	****workshop 3: -Butt kick using sand weights (for the legs).	5	10	3

Table 3: Intraclass correlation coefficients (ICCs) for relative reliability and coefficients of variation for absolute reliability of the applied physical fitness tests

Measures	ICC	95% CI	% CV
Squat jump	0.94	0.81–0.96	4.3
Contremouvement jump	0.92	0.88–0.98	4.2
Spike jump testing	0.90	0.85–0.97	3,2
Five- time jump test	0.94	0.90–0.96	3.5
Standing long jump test	0.91	0.83–0.95	4.1

ICC - intraclass correlation coefficient; CI–confidence interval; CV–coefficient of variation (%).

attempts are actually used in the statistical analysis. No double takes off is allowed. The examinee can jump either barefoot or in his sneakers, but his fingers should previously coat with red dye [12].

Five-time Jump Test (FJT)

The FJT test is a practical and valid test and is often used as a proxy for lower limbs muscle power [2]. At the beginning of the test and after the fifth jump, feet are in parallel position. FJT performance was recorded in meters (m) to the nearest cm. Participants performed two trials and the best trial was used for further analyses.

Standing Long Jump Test (SLJ)

The SLJ was performed from a standing position using a standardized measuring mat. Standardized instructions were given to the participants to begin the jump with bent knees and to swing their arms to assist in the jump [6].

Statistical Analyses

Data are presented as means and standard deviations (SD). Normality of data was tested and confirmed using the Shapiro-Wilk test, baseline between group differences were computed using t-tests for independent samples. The effects of training were evaluated using a 2 (groups: INT, CON) x 2 (time: Pre-test, Post-test) mixed model ANOVA. If a statistically significant interaction effect was found, Bonferroni corrected post-hoc tests were calculated. Additionally, effect sizes (ES) were determined from ANOVA output by converting partial eta-squared to Cohen's d. In addition, within-group ES were computed using the following equation: ES = (mean post – mean pre)/SD [3]. Following [8], ES were considered trivial (<0.2), small (0.2–0.6), moderate (0.6–1.2), large (1.2–2.0) and very large (2.0–4.0). Additionally, intraclass correlation coefficients (ICC) and coefficients of variation (CV) were computed to assess relative and absolute test-retest reliability. ICCs were classified as ICC < .50 weak, 0.50 to 0.79 moderate, and ≥0.80 strong. The level of significance was set at $p < 0.05$. All statistical analyses were computed using SPSS for Windows, version 20.0 (SPSS Inc., Chicago).

RESULTS

All players from both experimental groups completed the study according to the previously described study design and methodology. No injuries related to training or testing occurred over the course during the experimental period.

Table 4 shows the findings for the jump tests. Significant main effects for time and group were observed for SJ, CMJ, SP, FJT and SLJ.

A significant group × time interaction was found for SJ performances (p = 0.001, ES = 0.72, moderate). Bonferroni corrected post-hoc test significant pre-to-post improvements for both groups [INT (p =0.001, ES=0.45, small); CONT (p =0.002, ES=0.51, small).

Moreover, a significant group × time interaction was observed for CMJ height (p = 0.006, ES = 0.86, moderate). Bonferroni corrected post-hoc tests revealed a significant pre-to-post improvement for INT (p = 0.001, ES = 0.72, moderate), and a significant lower improvement for CONT (p = 0.016, ES = 0.63, moderate).

A significant group × time interaction was observed for SP (p = 0.004, ES = 0.77, moderate). Bonferroni corrected post-hoc tests revealed a significant pre-to-post improvement for INT (p = 0.004, ES = 0.78), and a significant lower improvement for CONT (p = 0.011, ES = 0.67, moderate) (Table 4).

Significant group × time interaction was observed for FJT (p = 0.001, ES = 0.75, moderate). Bonferroni corrected post-hoc tests revealed only a significant pre-to-post improvement for INT (p = 0.002, ES = 0.85, moderate).

Significant group × time interaction was observed for SLJ (p = 0.003, ES = 0.72, moderate). Bonferroni corrected post-hoc tests revealed a significant pre-to-post improvement for INT (p = 0.001, ES = 0.74, moderate).

DISCUSSION

The aim of this study was to identify the potential effects of eight weeks volleyball specific plyometric training on lower limbs power, vertical jump and spike performances. The main findings of this study were that eight weeks specific plyometric training program had a positive impact on improving lower limbs power, vertical jump and spike performances in university female volleyball players which support our study hypothesis. Moreover, the daily training program adapted by the active control group improved these some of those qualities but in a less important way compared to the experimental group.

Concerning vertical jump performances, our study revealed that eight weeks specific plyometric training program enhanced SJ, CMJ and SPJ performances in INT group. Moreover, the daily training program adapted by the CONT group improved these qualities but in a less important way compared to the INT group. In fact, this between-group difference could be explained by the fact that we did not include any specific training to improve jumping or lower limb strength training for CONT group in our intervention. In this context, Ziv and Lidor [14] reported the key role of short plyometric training sessions as part of the strength and conditioning program to enhance vertical jump performances in volleyball players. Otherwise, concerning the improvement of CMJ, SJ and SPJ our findings were similar to those recorded by

Table 4: Jump tests performances determined before (pre-test) and after (post-test) the training program for training group and control group

					p-value		
Jump tests	**INT (n=10)**		**CONT (n=10)**		**Time**	**Group**	**Group xTime**
	Pre Test	**Post Test**	**Pre Test**	**Post Test**			
SJ (cm)	33.8 ± 6,28	35.76 ± 5.23**	33.21± 5.91	34.21± 6.11*†	0.003(0.67)	0.001(0.63)	0.001(0.72)
CMJ (cm)	32.5 ± 6,36	37,36 ± 5.86***	32.82 ± 6.02	34.52±5.93**†	0.001(0.76)	0.001(0.74)	0.006(0.86)
SP (cm)	37.3±6.52	42.36 ± 5.63***	36.98 ± 6.40	38.62±6.33**†	0.002(0.75)	0.005(0.69)	0.004(0.77)
FTJ (m)	6.15± 0.6	6.42 ± 0.42**	6.09± 0.52	6.12±0.63††	0.001(0.73)	0.002(0.66)	0.001(0.75)
SLJ (cm)	182.51±18.2	189.46 ± 19.21**	180.24±19.50	182.12±18.70†	0.006(0.63)	0.001(0.67)	0.003(0.72)

Data are mean and standard deviations. ES, Effect size; *p<0.05, **p<0.01, ***p<0.001, †: INT vs CONT with p<0.05 ††: INT vs. CONT with p<0.01, SJ: squad jump test, CMJ: countermovement jump test, SP: spike jump test FJT: five jump test

Martel et al. [28], those authors showed that a four-week-long aquatic plyometric training intervention lead to an improvement of 3.9 cm in vertical jumps in under-14 female volleyball players. Moreover, Hewett et al. [7] reported that vertical jump improved (by 9.2%) after six weeks of regular plyometric training on a gymnasium floor in under-15 female volleyball players. In the same context, Lenhert et al. [9] showed that 12 weeks and lead to significant improvements of 16.9% in CMJ in under-17 female players. Also, Gjinovci et al. [6] reported a significant improvement of 27.6% in under-22 female volleyball players. In a study conducted in both men and women players (~21 years old), it was observed that plyometrics training interventions carried out on grass and on concrete for four weeks promoted improvements of 3.34 cm and 3.67 cm, respectively, in the counter-jump performance of players [29].

Concerning the FJT which is a good alternative to measure the lower limb explosive power when testing team sport players in the field [2], with no particular equipment required, hence our choice of the test in the present study. Our results showed a significant improvement for INT group after eight weeks of specific plyometric training program which was expected and in accordance with the review of Ziv and Lidor [14]. Those authors explained that at least eight weeks of plyometric training are needed, specifically for motor capacity, for the development of strength.

Concerning horizontal jump performance, our study showed that horizontal jump improved significantly for INT group at the end of the training intervention which was similar to previous studies [6,30,31]. In fact, after12 weeks of plyometric training the standing long jump, significantly improved of 7.6% in senior female players after 12 weeks of plyometric training [6]. The only possible explanation for the weaker effect of plyometrics on horizontal jump performance in comparison to vertical jump performance is the specificity of the plyometric training and the optimization of the force vector and muscle stimulation during the exercises [11]. In fact, the nature and the design of our training program was more oriented to improve the vertical jump performances (for example: jump box workshop; spike jump workshop…).

LIMITATIONS

Our study has some limitations. The first being the small sample size, which reduces our statistical power. Secondly, our study was conducted only among university female volleyball players, thus it will be interesting to examine the effect of this specific plyometric training program in elite players.

CONCLUSIONS

The results of the present study indicated that eight weeks specific plyometric training program had a positive impact on improving lower limbs power, vertical jump and spike performances in university female volleyball players. Moreover, the daily training program adapted by the active control group improved these qualities but in a less important way compared to the experimental group.

PRACTICAL APPLICATONS

- Using plyometric training in the training and educational process in volleyball by coaches, because it has an important role and a positive impact in developing physical fitness and specific skills.
- Holding educational sessions for specialized volleyball trainers, for the latest methods and types of training, especially plyometric training, in order to improve volleyball specific performance.
- Conducting similar studies, exploring gender effects, with measuring the effect of plyometric training on volleyball specific skills.
- The necessity of the availability of special tools and sophisticate devices to measure spike performance and to well control plyometric training sessions.

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CONFILCTS OF INTEREST

The authors declare no conflict of interest.

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