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Training strategy of explosive strength in young female volleyball players

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ABSTRACT

Objective: The aim of this study was to examine the effect of an 8-week combined jump and ball throwing training program in the performance of upper and lower extremities among young female volleyball players of the high school.

Materials and methods: A total of 20 young female volleyball players playing at Scholar Sport in High School at the district level were divided in two groups: the experimental group ($n = 10$; 14.0 ± 0.0 years; 1.6 ± 0.1 m; 52.0 ± 7.0 kg and $20.7 \pm 2.4\%$ body mass) and the control group ($n = 10$; 13.8 ± 0.4 years, 1.6 ± 0.1 m; 53.5 ± 4.7 kg and $20.3 \pm 1.7\%$ body mass). The experimental group received additional plyometric and ball throwing exercises besides their normal volleyball practice. The control group underwent only their regular session of training.

Results: Strength performance in the experimental group significantly improved (medicine ball and volleyball ball throwing: $P = 0.00$; and counter movement jump: $P = 0.05$), with the improvement ranging from 5.3% to 20.1%. No significant changes in strength performance were observed in the control group ($P > 0.05$).

Conclusions: The 8-week combined jump and ball throwing training can significantly improve muscular performance in young female volleyball players. These findings may be useful for all physical education teachers and volleyball coaches.

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1. Introduction

Volleyball is one of the world's most popular sports and because of its enormous popularity many studies have been conducted in an attempt to understand the better program training required to develop total body performance by a volleyball player [1,2]. Unfortunately, the scientific understanding of this issue remains unclear, with most young participants acquiring muscular performance through individual experience rather than research-based instructions [3,4]. Indeed, volleyball is a sport that requires strength in upper and lower limbs [5–7]. The development of muscle strength and specific technical skills are particularly important for young players and especially to female athletes [6], as priority factors to achieve success [8–10].

Both ball throwing and jumping performance are important factors for successful volleyball performance [1]. The distance in ball throwing is an important component and previously studies [1,11] concluded that strength training based on explosive movements during the competitive season can improve performance in upper extremity [5]. The literature seems to suggest that this may be the transfer to specific tasks in volleyball in terms of ball speed, since the athlete's training period allow these adaptations happen. Additionally, muscle strength in the lower limbs is also crucial in volleyball – the performance in the vertical jump is directly related to the performance of the players since the jump is one of the components of service and defense movement of volleyball [12], being used in case of interception and shot blocking [13].

There is a greater risk of injury during the execution of multiple jumps and further develops jumps without power. Also due to the impact of hundreds of jumps, the ligaments may be affected, as well as the joints and knees. In this way, strength training appears to have a decisive influence on motor performance of young players of this sport. Although some authors could identify significant relationships between the strength of the upper and lower limbs amongst volleyball players [4] but there is a lack of information concerning the effects of a plyometrics training program especially in young and trained female volleyball players. Several authors [4,6,14] stated that the discrepancy in the results of previous experiments studies may be caused by different research protocols such as different durations of training methods, different status of the subjects, or different training loads.

Nevertheless, in young female players that have a lower level of physical activity and for that reason also a muscular weakness, the implement of a program training based on strength performance has greater importance in the quality of specific skills of the game [9]. Motor development, is one of the basis of a total physical fitness that will ensure the health and well-being levels necessary for quality of life. Volleyball associated with the development of strength performance seems to be crucial and it is definitely a topic that deserves great attention within the framework of physical education classes [15].

To the best of our knowledge, no study investigated simultaneously jumping and ball throwing performances after a plyometrics training regimen of young female competitive volleyball players attending the high school. Therefore, the aim of this study was to examine the effect of 8-week combined plyometrics and ball throwing program on upper and lower body performance among young volleyball players. It was hypothesized that the training group would enhance jumping and ball throwing ability since they would train this.

2. Materials and methods

2.1. Experimental approach to the problem

Two groups (training group and a control group) of subjects were recruited to determine the effectiveness of plyometric and ball throwing training program on the upper and lower body performance in young volleyball players during an 8-week training program. A randomized controlled study was conducted with one team of young female volleyball players at the beginning of the competitive season. The players were equally divided at the pretest. Half of each team received the plyometrics and ball throwing program besides their normal volleyball practice and the other half just continued with their usual training. The evaluation process requires reliability, specificity and facility of application, especially when participants are inexperienced. We thus selected protocols that were time-saving and that had been previously used in several studies with these characteristics [6].

2.2. Subjects

A total of 20 competitive female volleyball players were divided into two groups: the experimental ($n = 10$; 14.0 ± 0.0 years; 1.6 ± 0.1 m; 52.0 ± 7.0 kg and $20.7\% \pm 2.4\%$ body mass) and the control ($n = 10$; 13.8 ± 0.4 years, 1.6 ± 0.1 m; 53.5 ± 4.7 kg and $20.3\% \pm 1.7\%$ body mass). Efforts were made to recruit subjects so as to form comparable groups. Apart from routine daily tasks, the experimental group underwent a plyometric training program of two training sessions per week for 8 weeks. The control group just executed the usual volleyball session and did not undergo any specifically orientated program training. The participants were from the team playing at the district level in their age class. None of the participants had a history of strength training. Written informed consent was obtained from each parent of the participant and they were fully informed about the protocol before participating in this study. Further, the Direction of the High School was informed about the main goal of the study. This study was approved by the local health services research ethics committee and was carried out according to the Declaration of Helsinki (Table 1).

2.3. Procedures

Before the pretest the participants were familiarized with the different tests in a practice session to avoid a learning effect. Pre- and posttests (T1 and T2, respectively) were performed on maximal countermovement jump and throwing a medicine and volleyball ball. All tests were conducted in an indoor facility to avoid weather changes during the pre- and posttest.

Table 1 – Anthropometric characteristics of the study population.

Variables	Group	T1	T2	P (T1 vs. T2)
Age (years)	CG ($n = 10$)	13.8 ± 0.4	13.8 ± 0.4	0.17
	EG ($n = 10$)	14.0 ± 0.0	14.0 ± 0.0	
Body weight (kg)	CG ($n = 10$)	53.5 ± 4.7	53.5 ± 4.7	0.57
	EG ($n = 10$)	52.0 ± 7.0	52.0 ± 7.0	
Total standing height (cm)	CG ($n = 10$)	1.6 ± 0.1	1.6 ± 0.1	0.18
	EG ($n = 10$)	1.6 ± 0.1	1.6 ± 0.1	
BMI (kg/m^2)	CG ($n = 10$)	20.3 ± 1.7	20.3 ± 1.7	0.68
	EG ($n = 10$)	20.7 ± 2.4	20.7 ± 2.4	

Values are mean ± standard deviation. CG, control group; EG, experimental group; BMI, body mass index, a weight-to-height ratio, calculated by dividing one's weight in kilograms by the square of one' height in meters; T1, pretest; T2 posttest after 8 weeks.

2.3.1. *Anthropometric measures*

Total height (m) and body weight (kg) were measured according to the international standards for anthropometric assessment [16].

2.3.2. *Power tests*

Vertical jump. After a general warm-up of around 15 min, the participant was tested in explosive strength of lower limbs by a counter movement jump (CMJ) [1]. The participant started from a standing position with their hands on their waist on a contact mat (Ergojump, 1000 Digitime, Digest, Finland). Three attempts were made with 2 min rest in between.

Ball throwing. Ball throwing performance was tested with a 1.5-kg medicine ball (MBT) (Ø 0.60 m) and a volleyball ball (VBT) (1 kg). Each subject sat on a chair with the posterior trunk region positioned against the chair back and held the ball to the front with both hands. Three approved attempts were made with 1-min rest intervals. The maximal throwing distance was determined using a flexible steel tape. Only the best attempt was used for further analysis [1].

Plyometric and ball throwing exercises protocol. The RT program consisted of two sessions per week over 8 consecutive weeks. Table 2 provides a detailed description of the training program. The exercises focus jump upon height and short ground contact, which is important for increasing the explosive power of the lower limbs [17]. The training program was increased to follow the principle of overload [1]. In each session after the regular volleyball training, the experimental group performed 4 jump exercises following medicine ball throwing drills. Rest intervals of 2 min between sets and 3 min between exercises were deployed. The volume of the strength-speed training program equaled 20 min. An expert who had years of experience in plyometrics and ball throwing training supervised each training session to ensure that the participants performed the program with maximal effort. The control group just continued with their regular training regime, twice a week, for the duration of the experiment. Before completing the session, the participants performed a few exercises to improve stability, balance and stretching. The program training was conducted every Monday and Wednesday (10:00 p.m.), throughout the 8 weeks of training. The subjects did not undertake any additional formal strength training activities during the testing or training period.

2.4. *Statistical analysis*

Standard statistical methods were used for the calculation of means and standard deviations. The normality and homoscedasticity assumptions were checked, respectively, with the Shapiro–Wilk and the Levene tests. The test–retest reliability (3 repeats per condition) as indicated by intraclass correlations (ICC) was 0.93, 0.89, and 0.92 for all measures (CMJ, BT, and VBT, respectively). The level of significance was set at $P \leq 0.05$ for all analysis. All data were analyzed using SPSS 17.0. The training-related effects were assessed using a two-way

Table 2 – Training program for upper and lower-extremity between 1 and 8 weeks.

Exercises[a]	Session 1	Session 2	Session 3	Session 4	Session 5
Bilateral jump (without bending knees)	3 × 20	3 × 20	3 × 20	3 × 25	3 × 25
Bilateral jump (with bending knees)	3 × 10	3 × 10	3 × 10	3 × 10	4 × 10
Unilateral jump short and as fast as possible (with the dominant leg on the floor)	3 × 10	3 × 10	3 × 10	3 × 10	2 × 10
Unilateral jump as far as possible (with the dominant leg on the floor)	2 × 8	2 × 8	2 × 8	2 × 8	3 × 8
Medicine ball throwing[b]	3 × 8:1 kg	3 × 8:1 kg	3 × 8:1 kg	3 × 8:1 kg	3 × 8:1 kg

	Session 6	Session 7	Session 8
Bilateral jump (without bending knees), for one stair	4 × 20	4 × 20	5 × 20
Bilateral jump (with bending knees) as far as possible	4 × 10	4 × 10	4 × 10
Unilateral jump short and as fast as possible (with the dominant leg on the floor)	3 × 10	3 × 10	3 × 10
Medicine ball throwing	2 × 6:1 kg	2 × 6:1 kg	2 × 6:1 kg
Unilateral medicine ball throwing (dominant and non-dominant member)	2 × 4:1 kg	2 × 4:1 kg	2 × 4:1 kg

[a] Rest intervals of 2 min were permitted between sets and between categories.
[b] Example: 2 × 6:1 kg indicates 2 sets of 6 reps with 1 kg medicinal ball.
[c] Example: 3 × 12 indicates 3 sets of 12 reps.

ANOVA with repeated measures (groups × time). A t test for independent samples determined the differences between the groups. The probability-adjusted Student paired t test was used for pair-wise comparisons.

3. Results

There were no significant differences in anthropometric or power variables between the groups at the beginning of the protocol ($P > 0.05$) (Table 3). No significant changes in height, weight, or BMI were observed (Table 2) between the first (T1) and second evaluations (T2) in either the experimental or the control group ($P > 0.05$).

Concerning the upper body, significant improvements in the medicine ball (1.5 kg) and volleyball ball (1 kg) throwing distance were found in the experimental group (3% and 19.6%, respectively, $P = 0.00$). Significant improvements in the countermovement jump performance was also found (20.1%, $P = 0.05$). Significant main effects for time were observed on CMJ, MBT, and VBT ($F = 31.6$, 29 and 14.7, respectively; $P < 0.05$). The control group showed no significant improvements in these parameters (MBT, VBT and CMJ, $P > 0.05$).

4. Discussion

The aim of this study was to examine the effect of eight weeks combined plyometrics and ball throwing program on the upper and lower body performance in young female volleyball players. The main finding was that the experimental training group enhanced their jumping performance and ball throwing distance significantly over the short period of training. Furthermore, the increments observed in EG results were achieved in context of High School during Scholar Sport.

Vertical jump height increased only for the experimental training group (+20.1%) while no significant changes were found in the control group (3.2%) which was in line with the findings of Marques et al. (2008) who also found an increase of 11.2% in jump height after 12 weeks of plyometrics training in female volleyball players. In addition, the ability to jump as differentiating factor for the volleyball players performance, since the jump efficiency is one of the components of attack and defense movement of volleyball game and being recruited in an interception, and shot blocking [18,19].

The improvement in jump height indicates that adaptations relating to increases in leg power have occurred. The adaptations of training are likely to be neural because these predominate in the early stages of strength and power training [17] and have been shown to be the main adaptation to plyometrics exercise [12,20]. Other factors may have contributed to the changes in vertical jump in the experimental group, including a better synchronization of body segments, increased coordination levels, and a greater muscular strength/force [21]. These factors may be related to a more effective skill domain in vertical jump, contributing also to explain the lack of improvement of the control group. Nevertheless, CG in our study showed a few enhanced their CMJ performance is not surprisingly, since they train volleyball in their regular training sessions.

The results in the present study also agree with those observed by Marques and González-Badillo in 2005, who studied the influence of application of strength training developed with free weights and a half squat exercises in a group of young basketball players [22]. They found differences statistically significant in vertical jump in the EG. Although in our study was not used any additional load, only a medicine ball, but we obtained the same conclusion – strength training is an efficient method to obtain better performance in upper extremity in young athletes. Nevertheless, the difference in frequency until 6- to 12-weeks of training could be the reason of the discrepancy in results between studies [1,7]. In addition, the innovative method that we present, confirms the vast majority of the evidence, that indicate the gains in strength in prepubertal female athletes are relate more to the neural mechanisms than to muscle hypertrophy [12]. Further studies that focus on neuromuscular factors are needed to corroborate that statement. Such improvement of muscular coordination after the training period would also be partly related to the specificity of movements used during the plyometric training program [12].

Comparatively to the upper limbs, in medicine ball and volleyball ball throwing EG showed increases by 5.2% and 23.3% (respectively) in distance from the beginning to the end of the training program. These improvements demonstrate the effectiveness of combined training applied during the 8 weeks performed only twice a week. Upper limb muscle strength is widely used in volleyball and this seems to be a differentiation between the results of the teams [1]. Decrease the frequency of technical errors that young athletes execute is one of the main advantages of strength training, because many of the mistakes should not be the cause as a poor technique or a failed motor coordination, but rather to the lack of strength in the muscles of the members participating in the specific execution of movements [1,12]. In accordance, the study by Marques et al. in 2008 and a review of observational and experimental studies by Ziv and Lidor in 2010 reported that for the development of strength, 8 weeks of training are needed specifically for motor capacity, especially when participants are young [1,21]. Results examined by these authors, show that a structured plan for strength and conditioning training with a feasible schedule of two resistant

Table 3 – Effect of exercise program training at baseline and after 8 weeks of training.

Variables	Group	T1	T2
MBT (m)	CG ($n = 10$)	6.70 ± 94.2	6.0 ± 43.8
	EG ($n = 10$)	7.51 ± 15.2	7.9 ± 14.3†
VBT (m)	CG ($n = 10$)	8.2 ± 14.1	8.2 ± 92.2
	EG ($n = 10$)	9.0 ± 89.7	11.1 ± 11.9*,†
CMJ (cm)	CG ($n = 10$)	25.0 ± 3.7	25.8 ± 3.7
	EG ($n = 10$)	26.9 ± 4.5	32.3 ± 9.0*,†

Values are mean ± standard deviation.
MBT, medicine ball throwing; VBT, volleyball ball throwing; CMJ, counter movement jump. T1, pretest; T2, posttest after 8 weeks.
* $P \leq 0.05$ within each group between T1 and T2.
† $P \leq 0.05$ between CG and EG.

training sessions per week, can induce strength performance in upper extremity. In the present study, we confirm this sentence performed by young female volleyball players, especially this have a relatively importance as it was performed in the context of high school. By other hand, the increment in regular practice of sport and exercise, specifically better muscular performance, accomplished in the most regular and diary activities. Another factor that may have influenced our results, and that has increased the discrepancy between the CG and the EG, was the acquisition of the technical gesture of throwing movement release over time during the 8 weeks by the EG plus the volleyball training and may thus have contributed to a better result in an increased distance in the posttest. Thus, our results indicate that 8 weeks of power training that focus on the muscles of the upper limbs, is enough to increase the levels of muscle performance but also optimizes learning effect. These factors seem to be essential, because the female athletes are in a phase in which the assimilation of technical gestures in volleyball are being consolidated. In addition, our study shows that only with the release of a ball with additional weight to the ball of the game, can instill the necessary capacity improvement to a good performance in the game. The development of strength in young people result mainly from learning and improved neuromuscular activation and not of substantial increases in the size of the muscles. According to Madsen et al. (1998) neural mechanisms are responsible for increases in strength and interventions programs focused in strength performance promote significantly bone mineral density in children's and adolescents, preventing a possible osteoporosis in aging [23].

In addition, the changes observed in the present study possibly display an adaptation in the ball throwing movement after the gains in distance and may be the result of an altered stretched-shortening cycle of the musculature involved [24]. However, in the current study we did not register these variables, but the improvements in ball distance could be caused by the increased transfer of energy from proximal flexion and extension of upper distal segments, which may have contributed to a higher ball distance value after the plyometric training intervention program. Furthermore, the participants are young players that are still developing and through training they probably increased volleyball ball throwing performance. Furthermore, the total training program only costs around 20 min per time, which is easy to incorporate to a regular volleyball training twice a week. This is an advantage of this training program. In the past [25] it was highlighted some of the benefits of strength training in young people, where in addition to improving performance there is an increase in performance of motor skills, increase bone mineral density, body composition improvement, and even a reduction of injuries. Future studies should focus on the effect of strength training in specific technical skills; significant adaptations are expected to occur particularly in the ability to jump and spike or block near the net. Also compare muscular performance between players of different specific positions.

4.1. *Practical applications*

Volleyball coaches and especially, physical education teachers it may be helpful to take into account that plyometrics training should be combined with regular volleyball training to transfer the gains in explosive strength to the kinematic parameters of the service, block and spike movement.

5. Conclusions

Our results showed that eight weeks of combined plyometrics and ball throwing program on the upper and lower body can induce significant adaptation in young female players performance in young female volleyball players.

Conflict of interest

The authors state no conflict of interest.

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