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RESEARCH ARTICLE

A Study on SSC (Stretch - Shortening Cycle) Training and Its Contribution to Vertical Leap Improvements in Volleyball Player

Neyas[1,*], M Prasanna[1], Shivakumar[1]

[1] *Krupanidhi College of Physiotherapy, Bangalore, Karnataka, India*

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[*] *Corresponding author.*
Neyas

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ABSTRACT

The high-intensity, anaerobic sport of volleyball requires explosive movement, especially vertical leaps. Power output is essential for activities like jumping and quick direction changes, making explosive strength a crucial component of good sports performance. By contrasting Technically Tactical Training (TTT) with a combined regimen of Technically Tactical Training and Plyometric Training (TTTP), this study sought to determine how plyometric training affected volleyball players' vertical jump performance. Thirty male volleyball players between the ages of sixteen and nineteen took part in the eight-week study. They were randomized to either the experimental group (TTT plus plyometric training) or the control group (TTT only). The Sargent leap Test was used to evaluate vertical leap height, and the Lewis Nomogram was used to measure anaerobic power before and after the training session. The experimental group engaged in a systematic plyometric program that included exercises with escalating intensities, such as depth jumps and squat jumps. Both groups' vertical jump power and height shown notable gains. In comparison to the control group, the experimental group showed statistically significant differences ($P < 0.0001$) in vertical jump height (22.9 cm vs. 11.7 cm) and power (32.2 kg-m/s vs. 5.8 kg-m/s). This study offers further proof of the better advantages of combining sport-specific training with plyometric activities to improve volleyball players' vertical jump performance.

Keywords: Plyometric Training; Vertical Jump; Volleyball; Explosive Strength

1 INTRODUCTION

In the high-intensity, anaerobic sport of volleyball, explosive vertical and horizontal movements must be mixed with short rest intervals.[1] Therefore, a key element of good athletic performance is explosive strength, which is the neuromuscular system's capacity to generate force in the shortest amount of time. Maximum strength, speed, and agility work together to produce more power.[2] Muscular strength is necessary for activities like sprinting and jumping because it enables muscles to generate more work in the same amount of time or to complete the same amount of work more rapidly,[3] and quick direction changes.[2] Research has repeatedly demonstrated a substantial relationship between vertical jump performance and power.,[3,4] implying that increasing vertical jump ability requires a significant amount of power.[5] Being a complicated exercise, a vertical jump necessitates the coordinated use of several trunk, arm, and leg muscle groups.[6] Given that a five-set match requires volleyball players to make around 250 leaps,[7,8] Jumping skill is now a key factor in determining how well a player does in the sport.[9]

Research has highlighted the relationship between vertical jump performance and overall athletic capability. For example, Smith[10] observed that national-level Canadian volleyball players exhibited superior vertical jump performance compared with their university counterparts. Similarly, Ziv and Lidor[11] found that teams with higher vertical jumps tended to perform better, regardless of gender. By putting stress on the musculotendinous unit, plyometric training—often linked to jump training—has been shown to be very successful in improving vertical leap performance.[12,13] Research, including that conducted byde Villarreal[14] have demonstrated that the vertical jump height can be increased by 4.7% to 15% when bodyweight plyometric exercises, such as squat jumps, depth jumps, and countermovement leaps, are combined. This form of training enhances neuromuscular coordination by improving the

nervous system's response, particularly through the stretch-shortening cycle (SSC)—a rapid lengthening (eccentric) followed by shortening (concentric) movement.[15] Jump performance is also increased by plyometric activities, which similarly increase muscle stored elastic energy, activate more muscle units, increase neuronal firing frequency, and improve joint proprioception.

Although plyometric training's effects on athletes from different sports have been the subject of numerous research, nothing is known about how precisely plyometric workouts affect volleyball players' vertical jump performance. Most previous studies have either focused on generalized sports populations or used different training protocols, making it unclear how plyometric training alone or in combination with sport-specific training can enhance vertical jump performance in volleyball players. The purpose of this study was to look at how plyometric activities affected volleyball players' vertical jump height. Specifically, it sought to compare the impact of Technically Tactical Training (TTT) alone versus a combined regimen of Technically Tactical Training and Plyometric Training (TTTP). This study sought to shed light on the possible advantages of adding plyometric exercises to volleyball players' training regimens by comparing the changes in vertical jump height and power performance before and after the training session. The results of this study could help improve training methods for enhancing vertical leap ability and, in turn, volleyball players' overall athletic performance.

2 METHODS

The study was conducted at Krupanidhi Institutions, Koramangala, Bangalore, and Karnataka, where the participants were students. The sample included 30 healthy,16-year-old male volleyball playersand above, who were selected through random sampling. The inclusion criteria required participants to have represented their school or college volleyball teams, had prior volleyball training experience of 2 to 3 years, and engaged in regular volleyball training for at least five sessions a week. Subjects with a history of injury were excludedfrom the research. The participants were randomly assigned to two groups: a Control Group of 15 players who followed the regular technically tactical training (TTT) schedule, and an Experimental Group consisting of 15 players who underwent plyometric training combined with technically tactical training (TTTP), and the primary outcome measure was vertical jump height, assessed using the Sargent Jump Test, a reliable and valid tool for measuring explosive leg strength. Additionally, anaerobic power was measured using the Lewis Nomogram, which calculates power output based on jump height and body weight.

Before the intervention, all subjects underwent a baseline evaluation, followed by an 8-week training program for the experimental group. The first three weeks served as a preliminary period to build endurance and strength for takeoff, with five training sessions per week. During this phase, the subjects engaged in a combination of endurance training and strength exercises in the gym. Following this first stage, the experimental group began a plyometric training regimen in tandemwith regular volleyball training. This plyometric program included five specific exercises designed to enhance vertical jump performance: multiple box-to-box squat jumps, depth jumps, 30-60-90 second box drills, split squat jumps, and rim jumps. The training intensity was gradually increased from 60% in the first week to 100% in the final week, with varying sets and repetitions based on the week of training.

The training regimen was structured such that plyometric exercises were carried out after a 30-minute volleyball warm-up at the start of every training session. Power and vertical leap height were assessed once more at the conclusion of the 8-week period to assess improvements. Data were collected and analyzed to determine the effects of plyometric exercises on vertical jump development, specifically examining the differences between the experimental and control groups. The reliability and validity of the tests used, such as the Sargent Jump Test and Lewis Nomogram, ensured that the outcomes were accurately assessed.

3 RESULTS

In the control group, participants in the control and experimental groups ranged in age from 17 to 19. A balanced representation of age across both groups facilitated a comparative analysis of the effects of plyometric exercises on vertical jump performance in volleyball players.

Table 1 presents the results of the control and experimental groups in terms of vertical jump height (measured in centimeters) and power (measured in kg-m/s) before and after the training period. For the control group, which underwent only Technically Tactical Training, the pre-training mean for vertical jump height (D) was 46.6 cm, with a post-training mean of 58.3 cm. This indicated an improvement of 11.7 cm in the vertical jump height. The corresponding pre-training mean power was 94.9 kg-m/s, and the post-training mean power was 100.7 kg-m/s, showing a slight increase of 5.8 kg-m/s. The experimental group, which combined Technically Tactical Training with plyometric exercises, showed more substantial improvements. The pre-training mean vertical jump height for this group was 46.6 cm, which increased to 69.5 cm post-training, reflecting an improvement of 22.9 cm. The pre-training mean power for the experimental group was 95.8 kg-m/s, which increased to 128.0 kg-m/s post-training, demonstrating a significant enhancement of 32.2 kg-m/s.

Both groups showed a range of values in their pre- and post-training measurements, with the experimental group showing a slightly higher variability in both jump height and power. The control group had a vertical jump height ranging from 4 cm to 6 cm and a power range of 23 to 28 kg m/s, while

the experimental group showed a vertical jump height range of 4 cm to 9 cm and a power range of 10 to 26 kg-m/s. The standard deviations (SD) were generally lower in the control group than in the experimental group, with the control group's vertical jump height SD being 1.30 cm and power SD being 5.80 kg-m/s, whereas the experimental group had SDs of 2.61 cm for jump height and 8.57 kg-m/s for power. The coefficient of variation (C.V%) values were also slightly higher in the experimental group, indicating greater variability in their results. The skewness values for both groups were relatively low, suggesting a fairly symmetric distribution of the data, although the experimental group showed a more pronounced positive skew in power scores. The kurtosis values indicated a slightly negative skew for both groups in jump height and a positive skew for power, with the experimental group exhibiting more pronounced kurtosis values. The data showed that the experimental group, which incorporated plyometric exercises, achieved higher gains in vertical leap height and power than the control group, which only received Technically Tactical Training. This highlights the effectiveness of plyometric training in enhancing explosive leg strength and vertical jump performance among volleyball players.

The mean scores and standard deviations (SD) for power performance (P) and vertical jump height (D) in the control and experimental groups are shown in Table 2, along with an analysis of changes before and after training. For the control group, which underwent only Technically Tactical Training (TTT), the mean vertical jump height (D) increased from 46.6 cm pre-training to 58.3 cm post-training, with a standard deviation of 1.30 cm pre training and 1.80 cm post training. This showed a significant improvement in jump height, as indicated by the calculated t-value of 39.07, which was far greater than the table value at $P < 0.0001$, signifying aimportant distinction between the before- and after-training measurements. Power performance in the control group also showed an increase, with the mean rising from 94.98 kg-m/s pre-training to 100.7 kg-m/s post-training. The SD for power performance was 5.80 kg-m/s before training and 7.04 kg-m/s after training. The calculated t-value for power performance in the control group was 4.21, which was also highly significant when compared to the table value ($P < 0.0001$).

In the experimental group, which participated in Technically Tactical Training with Plyometric exercises (TTTP), the mean vertical jump height (D) increased substantially from 46.6 cm pre-training to 69.5 cm post-training, with a standard deviation of 1.30 cm before training and 2.61 cm after training. This improvement was even more pronounced than that in the control group, with a calculated t-value of 58.82, which was highly significant ($P < 0.0001$). For power performance, the experimental group saw a significant increase from a mean of 95.8 kg-m/s pre-training to 128.0 kg-m/s post-training, with standard deviations of 3.41 kg-m/s and 8.57 kg-m/s, respectively. The calculated t-value for power performance was 18.24, which was also highly significant ($P < 0.0001$).

The findings unequivocally demonstrated that both groups' post-training vertical jump height and power performance had significantly improved.However, the experimental group, which received plyometric training in addition to Technically Tactical Training, demonstrated a greater enhancement in both vertical jump height and power performance than the control group.These results highlight how well plyometric training work to increase volleyball players' explosive strength and vertical leap ability.

The comparison of the control and experimental groups' post-training vertical jump height and power performance is shown in Table 3. At a significance threshold of $P < 0.0001$, the computed t-values were contrasted with the table values. For the control group, which underwent only Technically Tactical Training (TTT), the calculated t-value for post-training measurements was 13.58, which was highly significant, indicating a substantial difference between pre- and post-training results. Similarly, for the experimental group, which combined Technically Tactical Training with plyometric exercises (TTTP), the calculated t-value was 9.54, which was also highly significant, further demonstrating the effectiveness of the training protocol.

These results imply that following training, both groups' vertical jump height and power performance significantly improved. However, the higher t-value for the control group indicated a stronger overall improvement in this group, although the experimental group, which included plyometric exercises, also showed significant progress. The results underline the effectiveness of both training methods, with the experimental group likely to benefit more from the added plyometric exercises.

4 DISCUSSION

The results of this study highlight how plyometric activities significantly improve volleyball players' vertical jump performance. The results demonstrated that the experimental group, which combined Technically Tactical Training (TTT) with plyometric exercises, exhibited greater improvements in both height of vertical jump and power than the control group, which underwent only TTT. These results are in line with earlier studies showing how beneficial plyometric exercise is indeveloping explosive strength and improving jump performance, particularly in sports that require powerful lower-body movements, such as volleyball. A review of forty studiesfound a strong positive relationship between plyometric training and overall volleyball performance, highlighting the importance of standardized protocols to maximize benefits.[16] An eight-week program combining different plyometric exercises, such as squat thrust jumps and push-ups, was effective in enhancing leg muscle power, which is directly related to vertical jump performance.[17]

Table 1: Results of Vertical Jump Height (D) and Power Performance (P) for Control and Experimental Groups Before and After Training

Variables	Control Group				Experimental group			
	Technically Tactical training				Technically Tactical training with polymetric			
	Before-training score		After training score		Before-training score		After training score	
	D (cm)	Power Kg-m/s	D (cm)	Power Kg-m/s	D (cm)	Power Kg-m/s	D (cm)	Power Kg-m/s
N	15	15	15	15	15	15	15	15
M	45	85	55	90	45	92	66	118
Max	49	108	61	118	49	102	75	144
Range	4	23	6	28	4	10	9	26
Mean	46.6	94.9	58.3	100.7	46.6	95.8	69.5	128.0
Median	47	94	58	98	47	95	69	122
Mode	45	94	58	98	47	94	66	122
SD	1.30	5.80	1.80	7.04	1.30	3.41	2.61	8.57
C.V%	2.79	6.12	3.08	6.99	2.79	3.56	3.76	6.69
Skewness	0.20	0.66	-0.24	0.94	0.20	0.80	0.54	0.46
Kurtosis	-1.01	1.04	-0.59	1.38	-1.01	-0.52	-0.20	-1.25

Table 2: Mean Scores and Standard Deviations of Vertical Jump Height (D) and Power Performance (P) for Control and Experimental Groups, Pre- and Post-Training Analysis

Variables	Test	Control group (TTT)	Experimental (TTTP)
		Mean $\pm$ SD (cm)	Mean $\pm$ SD (cm)
Vertical jump height	Pre-training	46.6 $\pm$ 1.30	46.6 $\pm$1.30
	Post training	58.3 $\pm$ 1.80	69.5 $\pm$ 2.61
Power performance	Pre-training	94.98 $\pm$ 5.80	95.8 $\pm$ 3.41
	Post training	100.7 $\pm$ 7.04	128.0 $\pm$ 8.57
Vertical jump height	Measurement	Pre vs post	Pre vs post
	't' Calculated values	39.07	58.82
	't' Table values at p<0.0001	Highly significance	Highly significance
Power performance	't' Calculated values	4.21	18.24
	't' Table values at p<0.0001	Highly significance	Highly significance

Table 3: Analysis of Vertical Jump Height and Power Performance Between Control and Experimental Groups at Post-Training

Groups	Measurement	't' value	't' Table values at p<0.0001
Control group (TTT)	Post vs post	13.58	Highly significance
Experimental (TTTP)	Post vs post	9.54	Highly significance

Training with plyometrics has consistently demonstrated a favourable effect on vertical jump performance in volleyball players, with studies indicating significant improvements in jump height after structured training programs.[17,18] Plyometric exercises, which focus on explosive movements that increase strength, power, and speed, have been widely adopted in sports training to improve athletic performance, particularly in activities that require powerful jumps and rapid takeoff.

A meta-analysis revealed a strong correlation (r = 0.7531) between plyometric exercises and overall performance in volleyball, emphasizing the effectiveness of these training protocols.[16] Various studies employed different techniques to evaluate the effect of plyometric exercise on vertical jump height, such as quasi-experimental designs and randomized controlled trials.[18,19] Training durations varied from four weeks to several months, with frequency and intensity tailored to the athletes' needs, showcasing the adaptability of plyometric protocols.[20] Results consistently indicate that plyometric training not only enhances vertical jump height but also contributes to overall athletic performance, making it a vital component of volleyball training programs.[21] The integration of sensory technology in training has further optimized outcomes, particularly in youth athletes, by improving jump mechanics and cognitive responses during performance.[21] A meta-analysis of forty studies found a

strong positive relationship between plyometric training and overall volleyball performance, highlighting the importance of standardized protocols to maximize benefits.[16] An eight-week program combining different plyometric exercises, such as squat thrust jumps and push-ups, was effective in enhancing leg muscle power, which is directly related to vertical jump performance.[17]

In the current study, the experimental group demonstrated remarkableincrease in vertical leap height and force, demonstrating how well plyometric exercises work to build explosive strength. The experimental group improved vertical jump height from 46.6 cm to 69.5 cm, a gain of 22.9 cm, while the control group improved from 46.6 cm to 58.3 cm (11.7 cm). The calculated t-values for the experimental group (58.82) and control group (39.07) indicated highly significant differences ($P < 0.0001$) in vertical jump performance. Similar results were observed in the study of Keoliya et al and Ali et al.[16,22] Power performance in the experimental group increased from 95.8 kg-m/s to 128.0 kg-m/s, a significant enhancement of 32.2 kg-m/s, compared to the control group's increase of 5.8 kg-m/s which is reliable with the study of Chaturvedi et al., 2023.[20] These results are corroborated by recent research, which shows that plyometric training greatly improves volleyball players' vertical jump and general athletic performance.[16,23]

Research suggests that plyometric exercise effectively enhancesvolleyball players' vertical leap height, with studies reporting improvements of up to 8.8% over training periods.[24] A systematic review found a moderate effect size (ES = 0.82) for plyometric jump training, confirming its efficacy in increasing vertical jump height across various demographics.[25] Short-duration plyometric training (e.g., 4 weeks) has shown significant results, particularly in vertical jump height, emphasizing the importance of training specificity.[20] Effective plyometric training requires consideration of individual athlete characteristics and training loads, as highlighted in literature reviews.[23]

Plyometric training aims to increase the force of following motions by utilizing the stretch reflex and the muscles' and tendons' inherent elastic components.[26] Considering that jump performance ability is highly influenced by the individual's ability to take advantage of the elastic and neural benefits of the SSC, well-developed strength and the rate of excursion of the activated musculature during the contraction, it is expected thatPlyometric exercise may improve athletes' ability to jump.[27] Indeed, the body of research consistently indicates that plyometric exercise aids in landing mechanism optimization.,[28] improvements in eccentric muscle control and an increase in knee flexion and hamstring activity.[29] In the current study, while both groups showed significant improvements, the experimental group's superior results indicate that plyometric exercises play a crucial role in maximizing vertical jump potential, which is vital for success in volleyball. The long-term impacts should be investigated furtherof plyometric training and its potential to enhance other physical attributes essential for volleyball performance, such as agility and endurance.

5 CONCLUSION

The results of this study showed that plyometric training greatly increased volleyball players' vertical leap height and power. Compared to the control group, which only received Technically Tactical Training, the experimental group, which also included plyometric activities, had larger gains in vertical jump height and force. These findings demonstrate the value of plyometric training in enhancing explosive strength and maximizing athletic performance, especially in sports like volleyball where vertical leap ability is essential.

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