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Effects of plyometric training on volleyball smash performance: A pre-experimental study

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ABSTRACT

Background: Volleyball requires explosive leg power and coordination for effective spike performance, yet many adolescent athletes in sports-specialization classes in Indonesia show limited lower-limb power. This study aimed to compare the effects of two plyometric exercises, box jumps and squat jumps, on improving spike performance among these students in Yogyakarta.

Methods: Twelve male sports-specialization students participating in extracurricular volleyball were purposively assigned to box jump or squat jump training groups (n = 6 each). Spike performance was assessed using a standardized skill test, and results were analyzed with descriptive statistics and paired-sample t-tests.

Results: Both training groups showed improvements in volleyball spike performance. The box jump group increased from a pretest mean of 34 to a posttest mean of 64 spikes (t = 2.19), while the squat jump group improved from 31 to 45 spikes (t = 1.26). Neither change reached statistical significance at α = 0.05 (critical t = 2.571). Numerically, the box jump group showed a larger and more consistent gain than the squat jump group.

Conclusion: Plyometric training led to practical improvements in volleyball spike performance, especially in the box jump group, though changes were not statistically significant. These results indicated that plyometric exercises could benefit school-based volleyball programs, while further research with larger samples and longer interventions is needed to confirm their effectiveness.

Keywords: box jump, plyometric training, school-based training, spike performance, volleyball.
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INTRODUCTION

Sports play a crucial role in maintaining physical fitness, developing motor skills, and enhancing performance. In educational settings, physical and health education fosters holistic development physical, mental, and social through structured activities.[1,2] Among team sports, volleyball is a popular and dynamic game that integrates technical skill, teamwork, and endurance.[3]

Volleyball was introduced by William G. Morgan in 1895 as Mintonette, a less intense alternative to basketball for older Young Men's Christian Association members. Today, it is a high-performance sport requiring significant physical abilities, especially explosive power, to execute key techniques such as spiking, serving, and blocking.[4] The spike, a decisive offensive move, often determines the outcome of rallies and relies not only on technical skill but also on lower-body strength, coordination, and the ability to generate maximal force quickly.

In Indonesia, volleyball is widely practiced in schools and extracurricular programs. However, many student athletes, including those in sports specialization classes, show limited explosive leg power and vertical jump ability, which directly affect spike performance. Despite government efforts to develop sport specific training curricula, empirically tested models adapted to local school conditions and available facilities are still needed.[5] Therefore, evidence-based and feasible interventions for resource-limited school settings are especially important.

Plyometric training is based on the stretch-shortening cycle (SSC) theory, which highlights how muscle elasticity and neuromuscular coordination can be optimized to enhance explosive power.[6] It combines strength and speed through rapid eccentric concentric muscle actions.[6,7,8] Exercises such as box jumps and squat jumps improve jump performance and lower-limb power.[9] However, most studies have focused on adult or professional athletes, with limited evidence among adolescent volleyball players in school settings, particularly in Indonesia.[10,11]

Based on this background, the present study aims to evaluate the effectiveness of box jump and squat jump exercises in improving volleyball spike performance among students in a sports-specialization class in Yogyakarta. The study aimed to provide empirical support for the role of plyometric training in enhancing volleyball specific technical skills, as well as practical implications for curriculum design, coaching strategies, and talent development programs within Indonesia's

educational sports system.[12] Furthermore, incorporating evidence-based plyometric programs in school settings can contribute to long term athlete development and help bridge the gap between youth and elite-level performance.[13]

METHODS

This study involved 12 male students from a sports-specialization class in Yogyakarta, Indonesia, selected through purposive sampling based on their participation in extracurricular volleyball and comparable basic volleyball skills. All participants were in good physical condition and free from injury. The research procedures were fully explained, and all participants and their parents voluntarily agreed to participate in this study by signing informed consent forms. The study was approved by the local ethics committee at the Institute for Research and Community Service, Universitas Diponegoro, Semarang, Indonesia, under ethics clearance number 058/142001/LPPM/X/2025.

The research employed a two-group pretest-posttest experimental design to examine the effect of plyometric training on volleyball spike performance. Participants were assigned to two plyometric training groups (box jump or squat jump, n = 6 per group). Spike performance was assessed before and after the intervention using a standardized spike skill test evaluating accuracy, power, and ball control.

The intervention consisted of three times weekly training sessions over a specified period. Each session included warm-up, the main plyometric exercise (box jump or squat jump), and cool-down with stretching. The program focused on enhancing explosive leg power, with a theoretical basis in the stretch-shortening cycle (SSC), where repeated eccentric–concentric muscle actions improve neuromuscular efficiency and power output both essential for executing powerful spikes.[6,9,14,15] Training intensity and volume were progressively adjusted according to participants' abilities and safety considerations.

Data were analyzed using SPSS version 26. Descriptive statistics, including mean, standard deviation, and total scores, summarized participants' performance. Normality tests confirmed that data met parametric assumptions, and paired-sample t-tests were used to compare pretest and posttest scores within each group.

RESULTS

A total of 12 participants took part in this study, evenly divided between the box jump (n=6) and squat jump (n=6) groups. The mean age of all participants was 16.6±0.7 years, with both groups showing similar age distributions (box jump: 16.5±0.5 years; squat jump: 16.7±0.8 years). Body mass index (BMI) was also comparable across groups, with an overall mean of 21.3±1.5 kg/m² (box jump: 21.3±1.4 kg/m²; squat jump: 21.3±1.8 kg/m²). These results indicate that the groups had similar baseline characteristics, minimizing the likelihood that age or anthropometric differences influenced the intervention outcomes (**Table 1**).

The main analysis focused on the effects of plyometric box jump and squat jump training on volleyball spike performance. Results showed that the box jump group increased their scores from a pretest mean of 34 to a posttest mean of 64 spikes, with t = 2.19, which is below the critical t-value of 2.571, indicating that the increase was not statistically significant at α = 0.05. The squat jump group improved from a pretest mean of 31 to a posttest mean of 45 spikes, with t = 1.26, also not statistically significant. Numerically, both groups demonstrated posttest improvements compared to pretest scores, with the box jump group showing a larger mean increase than the squat jump group; however, these differences remained statistically non-significant at α = 0.05 (**Table 2**).

DISCUSSION

This study investigated the effects of plyometric training, specifically box jump and squat jump exercises, on volleyball spike performance among students in a sports-specialization class in Yogyakarta. The primary aim of this study was to determine whether plyometric training could enhance spike performance, a crucial technical skill in volleyball. Both intervention groups demonstrated improvements in spike performance from pretest to posttest. Although paired-sample t-tests indicated that these improvements were not statistically significant (t-calculated < t-table at the 5% significance level), descriptive analysis revealed a clear upward trend in both groups. The box jump group, in particular, showed more consistent improvements and higher posttest scores compared to the squat jump group, indicating that box jump training may offer greater practical benefits in developing lower-limb explosive power and coordination necessary for effective volleyball spikes.

These findings are consistent with previous studies reporting that plyometric training can enhance lower-limb strength and power.[6,14,15] Other research has

Table 1. Characteristics of research subjects

Characteristics	All participants (n=12) Mean ± SD	Box jump participants (n= 6) Mean ± SD	Squat jump participants (n= 6) Mean ± SD
Age, year	16.6±0.7	16.5±0.5	16.7±0.8
Body mass index, kg/m2	21.3±1.5z	21.3±1.4	21.3±1.8

Table 2. Comparison of spike test scores before and after plyometric training

Group	Pretest score	Posttest score	Mean difference (MD)	t-calculated	t-table (α = 0.05)	Significance
Box jump	34	64	5.00	2.19	2.571	Not significant
Squat jump	31	45	7.50	1.26	2.571	Not significant

also shown that plyometric training contributes to improved performance in sports requiring rapid force production and efficient neuromuscular responses.[16,17,18] Experimental studies on school and club volleyball athletes have reported that structured plyometric training can significantly increase vertical jump height and lower-limb muscle power, which are key factors for explosive movements such as spikes and smashes.[19] Additionally, recent meta-analyses have found that plyometric jump training (PJT) produces small to moderate effects on physical performance in amateur and professional volleyball players, including spike jump height with an effect size of 0.84.[20] Plyometric exercises also promote neuromuscular adaptations by enhancing muscles' ability to generate rapid force through the efficient utilization of elastic energy stored in tendons and muscle fibers, allowing the stretch–shortening cycle (SSC) to be used more effectively to produce explosive power during jumps.[21]

Applying these findings to Indonesian schools, this study highlights the potential benefits of structured plyometric training for adolescent volleyball players in sports-specialization classes. Research in youth athletes shows that even short-term plyometric programs can enhance explosive performance, especially when implemented in well-organized settings such as schools or sports clubs.[22,23,24] Proper supervision, progression, and technique monitoring in these environments support neuromuscular adaptations and program adherence, promoting the development of sport-specific skills.[25] Although the small sample size and brief intervention limited statistical significance, observed trends indicate that short-term plyometric training can still improve key performance measures.

Plyometric exercises, particularly box jumps, are effective for enhancing explosive lower-limb strength and sport-specific performance in adolescent athletes. Their integration into structured school-based or club training programs can induce neuromuscular and mechanical adaptations beyond natural growth, supporting key skills such as spiking and rapid directional changes.[26] Consequently, plyometric training serves as a critical bridge between general physical education and sport-specific demands, optimizing athletic development during adolescence.[27]

The study reinforces that plyometric training improves neuromuscular coordination and power output required for explosive sports actions. Specifically, stretch-shortening cycle (SSC) based movements enhance muscle elasticity and energy utilization, critical for successful spike performance. Earlier studies have shown that SSC exercises increase tendon stiffness and neuromuscular responsiveness, contributing to higher jumps and faster force production.[28,29] Examining these mechanisms in a school-based program broadens understanding of how structured physical training facilitates the transition from general physical education to specialized athletic performance. Overall, the findings offer both practical and theoretical insights into the role of plyometrics in developing sport-specific skills among adolescent athletes.

This study has limitations. The small sample size (n = 12) reduced statistical power, and the short intervention may have constrained measurable performance gains, as prior research suggests significant improvements in explosive power typically require at least 8–12 weeks of training.[30] Only male participants were included, and potentially influential factors such as baseline strength, jump height, overall fitness, and extracurricular training were not controlled. Future research should involve larger, more diverse samples, extend program duration, and incorporate additional outcome measures such as biomechanical analysis, vertical jump height, or electromyography (EMG) to better understand underlying neuromuscular mechanisms. Moreover, comparing different plyometric combinations and integrating them with strength or agility training could optimize performance gains in young volleyball athletes.

CONCLUSION

Plyometric training produced practical improvements in volleyball spike performance, particularly with box jumps, though the changes were not statistically significant. These results support incorporating plyometric exercises into school-based volleyball programs. Future research should use larger samples, longer interventions, and diverse plyometric protocols to maximize training benefits for adolescent athletes.

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ETHICAL CONSIDERATION

The research was carried out following ethical clearance from the Institute for Research and Community Service, Universitas Diponegoro, Semarang, Indonesia: 058/142001/LPPM/X/2025.

AUTHOR CONTRIBUTIONS

S conducted data collection, developed the study methodology, and prepared the manuscript draft. DDK led the study's conception and design and contributed critical revisions. Both authors collaborated on data analysis, interpretation, and manuscript editing. All authors approved the final manuscript.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest related to the publication of this study. The research was carried out independently, and no financial or personal relationships influenced the study outcomes or their interpretation.

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