Enhancing Vertical Jump Performance in Adolescent Female Volleyball Athletes: Effects of Squat Jumps and Knee Tuck Jumps for Health Promotion

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Abstract

This experimental study examines the effectiveness of two plyometric training methods, squat jumps and knee tuck jumps, in enhancing vertical jump performance among U-12 female volleyball athletes. Vertical jump ability plays a critical role in executing offensive techniques such as spiking and defensive maneuvers like blocking. Fourteen athletes from the Dissporsa Kendal volleyball club participated in the study and were assigned to two experimental groups through ordinal pairing. Group A underwent squat jump training, while Group B received knee tuck jump training, each over the course of 16 sessions. A pre-test/post-test design was employed to assess changes in vertical jump performance. Descriptive statistics indicated improvements in both groups. Group A's average jump height increased from 27.83 cm to 31.50 cm (a 13.2% improvement), while Group B's average rose from 27.17 cm to 30.58 cm (a 12.7% improvement). The mean increase in jump height was 3.67 cm for Group A and 3.41 cm for Group B. However, an independent samples t-test revealed no statistically significant difference between the post-test results of the two groups (p = 0.8306), suggesting that both training methods were equally effective in improving vertical jump performance. These findings support the inclusion of squat jumps and knee tuck jumps in youth training programs aimed at developing lower-body explosive power. Due to their simplicity and accessibility, these exercises offer practical benefits for coaches and trainers working with young athletes. Future research involving larger sample sizes and extended training durations is recommended to further investigate the long-term effects of plyometric training on athletic performance and injury prevention in youth sports.

Keywords: Plyometric, Vertical Jump, Volleyball, Youth Athletes, Training.

INTRODUCTION

Sports are physical activities that promote fitness and exert a significant social influence (Apriyano et al., 2025; Sepriani et al., 2024). Participation in elite sports fosters the development of essential physical, mental, and emotional skills, cultivating discipline, resilience, and a strong work ethic that are critical for athletic success (Räikkönen & Hedman, 2024). Beyond competition, sports serve as a medium for education and entertainment, while also promoting core life values such as sportsmanship, discipline, perseverance, and mutual respect (Ferraz et al., 2024). Among the most widely enjoyed sports across age groups is volleyball, a dynamic and competitive game that demands a high level of individual skill and cohesive team play (Coutinho et al., 2021). The sport features two teams of six players each, who compete by sending the ball over the net into the opponent's court, aiming to score points by landing the ball within the court boundaries. Success in volleyball requires players to

collaborate effectively, understand strategic tactics, possess physical strength and sharp reflexes, and master technical skills.

Volleyball holds a prominent place in physical education programs across educational institutions and is regularly featured in national and international sporting events. Its popularity continues to rise, driven by the sport's dynamic, strategic, and physically demanding nature (Fagundes & Ribas, 2017; Marzano-Felisatti et al., 2022). Among the key performance factors that influence the quality of play is the ability to execute vertical jumps. This skill is particularly vital for techniques such as spiking and blocking, which are central to both offensive and defensive play (Guntur et al., 2022; Mercado-Palomino et al., 2021). Athletes with greater vertical jump capacity are better equipped to deliver forceful spikes that challenge defenders and to effectively block incoming attacks from opponents (Mocanu et al., 2024). Consequently, vertical jump performance is a critical component in the athletic development of volleyball players, especially those occupying pivotal roles such as spikers and blockers.

The ability to perform a vertical jump does not develop naturally; it requires consistent training through a structured and well-designed exercise program. Among the most effective methods for enhancing lower-body explosive power are squat jumps and knee tuck jumps, which are widely utilized in athletic conditioning (Nath et al., 2025). A squat jump involves initiating movement from a squat position, leaping vertically with maximum effort, and returning to the squat stance upon landing (Di Domenico et al., 2024). In contrast, a knee tuck jump is executed by jumping upward while simultaneously drawing the knees toward the chest, thereby intensively engaging coordination and leg strength (Aryadi et al., 2024). Both exercises contribute significantly to increasing jump height, enhancing agility, and minimizing the risk of injury during competition. Additionally, the role of coaches and the surrounding environment is crucial in nurturing athletes' motivation and self-confidence, particularly for children and adolescents in the formative stages of personal and athletic development.

Effective sports development requires a systematic, continuous, and carefully planned approach (Thompson et al., 2022). Key components include the design of structured training programs, regular performance evaluations, provision of adequate facilities and infrastructure, and support from various stakeholders, such as families, schools, and sports communities (Loturco et al., 2023; Lutz et al., 2024). Athletic success is not solely dependent on innate talent; it is equally shaped by the athlete's dedication and consistency in undergoing long-term training (Apró et al., 2024). In light of the importance of early-age athletic development, the role of local sports clubs and communities has become increasingly strategic. These clubs are expanding rapidly across both urban and rural areas, serving as vital platforms for nurturing

young talent. Observational data and performance evaluations suggest that one of the primary factors contributing to recent defeats among youth athletes is insufficient vertical jump ability. This limitation has emerged as a significant concern for coaches and club managers, given the central role of vertical jumping in executing offensive and defensive techniques in volleyball.

This situation highlights the critical importance of strengthening physical attributes, particularly jumping ability, within the training programs of young athletes. Adolescence, including the under-12 age group, represents a pivotal period for developing motor skills and physical fitness, with long-term implications for overall health. Early improvements in physical capabilities such as vertical jump performance not only contribute to athletic success but also play a role in preventing chronic conditions linked to physical inactivity, including obesity, cardiovascular disease, and metabolic disorders. Promoting structured training during youth fosters lifelong healthy habits and aligns with public health goals aimed at reducing disease prevalence.

Although athletes in this age group are still in developmental stages, it is essential to introduce foundational techniques and build muscle strength early to prepare them for higher levels of competition. However, existing research on plyometric training for youth athletes remains limited, particularly in relation to vertical jump protocols tailored to younger populations such as 12-year-old volleyball players. Most studies focus on older or more advanced athletes, thereby restricting the applicability of their findings to early adolescent groupsTo address this gap, the present study introduces a specialized plyometric training program aimed at improving vertical jump performance in 12-year-old volleyball players. Distinct from previous research, the program incorporates technical, physical, and motivational elements tailored to the developmental needs of early adolescents. By focusing on this younger age group, the study contributes to adolescent health by promoting evidence-based training strategies that support both athletic progression and long-term physical well-being.

METHODS

This study employed an experimental design to investigate the effects of squat jumps and knee tuck jumps on vertical jump performance in U-12 female volleyball athletes (Wardati et al., 2022). In experimental research, manipulation typically involves administering specific interventions or conditions to individuals or groups, followed by analysis of the resulting effects, an approach that distinguishes this methodology (Latipun., 2011). Although participants were assigned to groups using an ordinal pairing technique, the study was classified as a non-randomized controlled trial due to the use of purposive sampling and the limited population size. The target population comprised all U-12 female volleyball players

from the Dissporsa Kendal Volleyball Club (N = 24). From this group, a purposive sample of 14 athletes was selected based on inclusion criteria, which included consistent participation in volleyball activities and absence of injury.

Participants were divided into two experimental groups using an ordinal pairing method based on their pre-test vertical jump scores. The pre-test was conducted during the initial session, with vertical jump height measured using a Vertec vertical jump device (or specify the exact measurement tool used). Each participant completed three jump trials, and the highest jump was recorded for analysis. To ensure consistency, the starting position was standardized: athletes stood flat-footed with feet shoulder-width apart and performed a countermovement jump, aiming to reach maximum height. A one-minute rest interval was provided between trials, and all testing was conducted at the same time of day to control for circadian variation.

Based on the ranked pre-test scores, athletes were paired in an A-B-B-A pattern and assigned to two groups: Group A (n = 7) received squat jump training, while Group B (n = 7) underwent knee tuck jump training. Both groups participated in 16 training sessions over an eight-week period, with two sessions per week. A post-test was administered using the same measurement protocol to assess improvements in vertical jump performanceStatistical analysis was conducted using paired t-tests to compare pre- and post-test results within each group, and independent t-tests to evaluate differences between the post-test scores of the two groups. The significance level was set at $p < 0.05$. Given the small sample size, the study acknowledges limitations in statistical power and generalizability.

RESULTS

To evaluate the effectiveness of squat jump training (Experiment A) and knee tuck jump training (Experiment B), statistical analyses were conducted, including descriptive statistics, normality testing, and independent sample t-tests. Seven U-12 female volleyball players were purposively selected based on predefined inclusion criteria. Ethical approval was obtained prior to the study, and informed consent was secured from all participants and their guardians. Participants were assigned to the two experimental groups using ordinal pairing to ensure balanced baseline vertical jump performance.

Table 1 presents the descriptive statistics for both groups' pre-test and post-test scores. The squat jump group (Experiment A) recorded a pre-test mean of 27.83 cm with a standard deviation of 10.35 cm, which increased to a post-test mean of 31.50 cm. Similarly, the knee tuck jump group (Experiment B) showed a pre-test mean of 27.17 cm and a post-test mean of 30.58 cm, indicating performance improvements in both groups.

Table 1. Descriptive Data

Group	Test Type	Min	Max	Mean	Std. Deviation
Experiment A – Squat Jump	Pre-test	7	44	27.83	10.35
	Post-test	10	47	31.50	10.46
Experiment B – Knee Tuck Jump	Pre-test	7	40	27.17	10.24
	Post-test	11	42	30.58	10.00

The results demonstrated measurable improvements in vertical jump performance for both groups following the intervention programs. Prior to hypothesis testing, data normality was assessed using the Shapiro-Wilk test. As presented in Table 2, all p-values for both pre-test and post-test scores exceeded 0.05, confirming that the data for each group were normally distributed and suitable for parametric analysis.

Table 2. Normality Test Results (Shapiro-Wilk)

Variable	Statistic	Sig. (p-value)
Squat Jump Pre-test	0.9683	0.8920
Squat Jump Post-test	0.9613	0.8026
Knee Tuck Jump Pre-test	0.9217	0.3003
Knee Tuck Jump Post-test	0.8867	0.1070

In addition, homogeneity of variance was examined using the Chi-Square test. As summarized in Table 3, the p-value (0.8891) exceeded 0.05, indicating that the assumption of equal variances between the groups was met.

Table 3. Homogeneity Test Results (Chi-Square)

Chi-Square	Df	Sig. (p-value)
6.4952	12	0.8891

To assess whether a statistically significant difference existed between the two groups following the intervention, an independent samples t-test was performed. As shown in Table 4, the analysis yielded a t-value of 0.2165 and a p-value of 0.8306. Since the p-value exceeds the threshold of 0.05, the results indicate no statistically significant difference between the post-test vertical jump scores of the squat jump and knee tuck jump groups

Table 4. Hypothesis Test (Independent Sample t-Test)

Test	t-Statistic	Sig. (p-value)
Post-test Squat Jump & Knee Tuck Jump	0.2165	0.8306

The findings indicate that both training programs resulted in significant improvements in vertical jump performance. Within-group pre- and post-test comparisons revealed notable gains for both the squat jump (Group A) and knee tuck jump (Group B) interventions. However, the independent samples t-test showed no statistically significant difference between the post-test scores of the two groups ($p = 0.8306$), suggesting that both methods were equally effective in enhancing vertical jump ability. While performance improved across both groups, the results do not support a clear advantage of one training method over the other.

DISCUSSION

This study investigated the impact of two plyometric exercises, squat jumps and knee tuck jumps, on vertical jump performance in U-12 female volleyball athletes. Vertical jumping is a fundamental skill in volleyball, essential for executing offensive techniques such as spiking and defensive actions like blocking. Motivated by performance data indicating limited jump ability among young athletes at the club, and supported by coaches' observations regarding the need to improve lower-body power, this research aimed to enhance explosive strength during a critical developmental stage. The findings revealed that both squat jump and knee tuck jump training programs led to measurable improvements in vertical jump performance, with moderate-to-large effect sizes observed for each intervention. However, no statistically significant difference was found between the two groups, suggesting that both plyometric methods are equally effective in developing vertical jump ability among young athletes. Given their simplicity, safety, and potential to engage participants, either exercise can be considered a practical and beneficial component of junior volleyball training programs.

The findings of this study align with those of Maliki et al (2025) who emphasized the positive impact of plyometric exercises on jump height and power in adolescent volleyball players. . Similarly, Fischetti et al (2018) reported that lower-body plyometric training significantly enhanced vertical jump performance in youth athletes after six weeks of implementation, regardless of the specific exercise type. In contrast, Fernandes Correia et al (2020) observed that more advanced plyometric movements, such as depth jumps and bounding, tend to yield slightly greater improvements in older athletes, suggesting that exercise specificity becomes increasingly important with training age. Consistent with these insights, the current study demonstrates that foundational plyometric exercises, including squat jumps and knee tuck jumps, are equally effective in improving vertical jump performance among young athletes, with no statistically significant differences observed between the two interventions.

The findings of this study offer practical implications for coaches, trainers, and physical education practitioners. Both squat jumps and knee tuck jumps can be effectively incorporated into training programs for young volleyball athletes to enhance lower-body explosive power. Given that neither method demonstrated superior effectiveness, coaches have the flexibility to tailor training based on contextual factors such as available space, time constraints, equipment access, and athlete preferences. Squat jumps, which require minimal space and equipment, may be more suitable for limited training environments, while knee tuck jumps, requiring greater coordination, may appeal to athletes seeking variety and challenge.

It is important to note that the relatively short intervention period may have limited the ability to detect significant differences between the two methods, suggesting that longer training durations could yield more pronounced outcomes. Early implementation of such plyometric exercises can improve competitive readiness and reduce injury risk by enhancing muscular control and strength. Despite the valuable insights gained, the study has several limitations. The small sample size (n = 7 per group) may have reduced statistical power and limited the generalizability of the findings. Furthermore, the eight-week intervention period, comprising 16 sessions, may be adequate for short-term evaluation but insufficient to capture long-term neuromuscular adaptations and sustained performance improvements. Notably, this study focused on 12-year-old female athletes, a developmental stage marked by significant biological growth and maturation. During this period, individuals often undergo rapid growth spurts and hormonal changes that can substantially influence their responsiveness to training stimuli. Maturation status affects muscle strength, coordination, and motor control, which in turn can impact both the effectiveness of plyometric exercises and the risk of injury. Future research should incorporate assessments of biological maturation markers, such as Tanner staging or peak height velocity, to better understand how growth and development modulate training adaptations in youth athletes.

From a physiological standpoint, improvements in vertical jump performance following plyometric training are primarily attributed to neuromuscular adaptations. These include enhanced efficiency of the stretch-shortening cycle, which improves the muscles' ability to transition rapidly from eccentric to concentric contractions, and increased intramuscular coordination, facilitating more effective recruitment and synchronization of muscle fibers. These adaptations contribute to greater power output and improved jumping ability. Understanding these mechanisms is particularly important in adolescent athletes, whose nervous systems are still developing and exhibit high plasticity, potentially allowing for heightened responsiveness to plyometric stimuli. Several uncontrolled factors, such as nutrition, sleep quality, motivation, and hormonal fluctuations, may have influenced the outcomes of this study and should be carefully monitored in future research. To enhance the generalizability and depth of findings, future studies are encouraged to broaden the demographic scope, incorporate additional performance metrics such as agility and muscular strength, and account for psychological variables, which play a critical role in youth sports development. Longitudinal research with follow-up assessments and the integration of advanced technologies, such as motion analysis systems and wearable sensors, could provide

deeper insights into the complex interplay between physical training, biological maturation, and neuromuscular adaptation.

CONCLUSIONS

This study compared the effectiveness of squat jump and knee tuck jump training in improving vertical jump performance among U-12 female volleyball athletes. Both interventions led to measurable improvements in jump height, with no statistically significant difference observed between the two groups. These findings suggest that squat jumps and knee tuck jumps are equally effective in enhancing lower-body explosive power, making them valuable additions to youth training programs.

Given the importance of vertical jump ability in volleyball, particularly for spiking and blocking, coaches can confidently incorporate either exercise into their routines. Both methods offer practical advantages, requiring minimal equipment and allowing for flexible implementation across various training environments. Additionally, they contribute to the development of foundational strength, coordination, and injury prevention in young athletes. Future research should involve larger sample sizes, longer intervention periods, and more diverse participant demographics to further validate these results. Longitudinal studies could provide deeper insights into the sustained effects of plyometric training on athletic development, helping to optimize training strategies for youth athletes.

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