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Effectiveness of the complex training method in improving the jump height of volleyball athletes

Masya Bunga^{1abcde)*}, Dikdik Zafar Sidik^{2abcde)}, Oktoviana Nur Ajid^{3abcde)}^{1,3} Study Program of Sport Physical Coaching, Faculty of Sport and Health Education,
Universitas Pendidikan Indonesia, Indonesia²Sports coaching education and Faculty of Sport and Health Education, Universitas Pendidikan Indonesia, Indonesia

ABSTRACT

A high vertical jump is an indispensable component for volleyball athletes to support optimal court performance, particularly in executing explosive smashes and solid defensive blocks. To optimize this physical attribute, coaches require a structured program such as complex training, which strategically integrates heavy resistance training and explosive plyometric exercises within a single session. This study aims to determine the effectiveness of a complex training method, specifically combining squats and hurdle jumps, in improving the vertical jump height of volleyball athletes. Utilizing an experimental approach with a one-group pretest-posttest design, this study involved 12 active athletes from the Bivota Karawang Club selected through total sampling. The structured intervention was conducted over a 6-week period with a training frequency of three times per week. Jump performance was precisely measured using the Sargent Jump Test before and after the treatment. After confirming data normality and homogeneity, a paired-sample t-test was executed via SPSS. The statistical analysis revealed a significant increase in the mean jump height, progressing from 37.00 cm at pretest to 40.83 cm at posttest, with a significance value of 0.000 ($p < 0.05$). This substantial improvement is attributed to the mechanism of Post Activation Potentiation (PAP), which enhances neuromuscular efficiency and muscular power output. In conclusion, the complex training method serves as a highly efficient and effective alternative program to increase lower-body explosive power. Consequently, volleyball coaches can integrate this method into routine training to maximize technical execution during high-intensity matches.

Keywords: complex training, back squat, hurdle jump, vertical jump, volleyball performance, explosive power.

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Copyright © 2026 Masya Bunga, Dikdik Zafar Sidik, Oktoviana Nur Ajid**Corresponding Author:** Masya Bunga, Study Program of Sport Physical Coaching, Faculty of Sport and Health Education, Universitas Pendidikan Indonesia, Indonesiaemail: masyabunga69@gmail.com

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Authors' Contribution : a – Study Design; b – Data Collection; c – Statistical Analysis; d – Manuscript Preparation; e – Funds Collection

INTRODUCTION

Volleyball is one of the fastest-growing sports in Indonesia and is played by people from all walks of life, ranging from students to professional athletes (Indah Pratiwi and Mansur 2019). In modern volleyball, physical ability is a key factor in mastering techniques. One technique that significantly contributes to scoring points is the smash. A smash (Indah Pratiwi and Mansur 2019) is a powerful, fast attacking hit delivered from top to bottom toward the opponent's court (Bumburo et al. 2023). The success of a smash is heavily influenced by an athlete's ability to reach a high point of contact with the ball; thus, vertical jump ability is a critical physical component (Vassil and Bazanov 2012). Athletes with good vertical jump ability have a greater chance of executing effective smashes and performing optimal blocks.

Vertical jump ability is closely related to lower-body muscle power—that is, the muscles' ability to generate maximum force in a short period of time (Bompa and Buzzichelli 2019). However, various observations indicate that many volleyball players still have suboptimal jump height, which results in low effectiveness in both offense and defense. This situation calls for a training program capable of effectively and measurably improving the explosive capacity of the lower-body muscles. One widely recommended training method for improving explosive power is complex training—a method that combines strength training and plyometric exercises into a single training sequence (De Salles et al. 2012). This combination is designed to take advantage of the Post-Activation Potentiation (PAP) phenomenon—an increase in muscle contraction capacity following a resistance training stimulus—thereby enabling more explosive movement performance in subsequent exercises (Najafi et al. 2026) (Yin et al. 2023)

In practice, complex training can be carried out through a combination of squats and hurdle jumps. Squats serve to increase lower-body muscle strength, while hurdle jumps are a plyometric exercise aimed at developing explosive power through repeated movements of jumping over hurdles (Cakrawijaya 2021). Several studies have shown that squat exercises can increase lower-body muscle strength, while hurdle jump exercises are effective at improving athletes' explosive power and jumping ability (Calero-Morales et al. 2024). showed that complex training has a positive effect on improving physical performance that requires both strength and speed simultaneously. These findings indicate that a combination of strength and plyometric exercises has the potential to produce greater improvements in jumping ability compared to using either training method separately (Berriel et al. 2022; Thapa et al. 2024).

Nevertheless, a review of the literature reveals that most previous studies have focused on the effects of plyometric or strength training—when performed separately—on improving lower-body explosive power. Research specifically combining squats and hurdle jumps within a complex training method for volleyball athletes remains relatively limited (Candra 2016). Furthermore, most studies have primarily measured general increases in lower-body muscle power and have not specifically examined improvements in jump height that support volleyball players' smashing ability. These findings indicate a research gap that requires further investigation, particularly among developmental-age volleyball players who require optimal physical development (Kons et al. 2023; Sole et al. 2021; Ahmadi et al. 2021).

Based on this review, the novelty of this study lies in the application of the complex training method, which combines structured squat and hurdle jump exercises to increase the jump height of volleyball athletes. Unlike previous studies, which generally examined strength training and plyometric training separately, this study combines both methods into a single training program using a complex training approach. This program utilizes the Post-Activation Potentiation (PAP) mechanism to optimize the increase in lower-body muscle power. Therefore, this study is of significant importance as it is expected to provide scientific evidence regarding the effectiveness of complex training as a potential training method for improving the vertical jump height of volleyball athletes (Rong and Xiu 2024; Xie et al. 2024).

Based on these issues, this study aims to analyze the effectiveness of a complex training method combining squats and hurdle jumps in improving the vertical jump height of volleyball athletes. The results of this study are expected to contribute theoretically to the development of sports coaching science, particularly in the field of physical training, and to serve as practical recommendations for coaches in designing effective training programs to improve the performance of volleyball athletes (Burta 2018).

METHOD

This study employed an experimental method using a one-group pretest-posttest design to determine the effect of a Complex Training program on improving the vertical jump height of volleyball athletes. The study design involved a pretest measurement before the intervention, the implementation of the training intervention, and a posttest measurement after the intervention was administered. The study subjects were 12 active athletes from Bivota Karawang, selected using total sampling. The inclusion criteria for the study subjects were athletes who were actively participating in a training program, were aged 16–19 years, had at least one year of competitive experience, had no history of injuries that could interfere with training performance, and were willing to participate in the entire research process.

The instrument used to measure jump height was the Sargent Jump Test (Ayán-Pérez et al. 2017). Measurements were taken in three trials, and the highest value was used as the final result. The validity of the instrument was first assessed through expert judgment. The training program lasted 6 weeks with a frequency of 3 sessions per week. The intervention consisted of a complex training program that combined strength training (squats) with plyometric training in the form of hurdle jumps in a single training session. The pretest was conducted before the training program began, while the posttest was conducted after the entire training program was completed.

The research data were analyzed using IBM SPSS Statistics, including tests for normality, homogeneity, and hypothesis testing using a paired-sample t-test at a significance level of 0.05 to determine the effect of the training program on improving athletes' jump height. This study used an experimental method with a one-group pretest-posttest design to determine the effect of the Complex Training program on improving the jump height of volleyball athletes. This research design involved an initial measurement (pretest) before the treatment, the delivery of the training intervention, and a final measurement (posttest) after the treatment was administered.

RESULTS

Table 1. Descriptive Statistics of Vertical Jump Performance

Statistic	Pretest	Posttest	Change
N	12	12	—
Minimum (cm)	20.00	26.00	+6.00
Maximum (cm)	46.00	51.00	+5.00
Mean (cm)	37.00	40.83	+3.83
Standard Deviation	7.72	7.87	+0.15

Based on the results of the descriptive analysis, it was found that the mean pretest score for the vertical jump of volleyball athletes was 37.00 with a standard deviation of 7.72, while the mean posttest score was 40.83 with a standard deviation of 7.87. These data indicate an average increase of 3.83 after the athletes participated in the complex training program.

Table 2. Normality Test Results

Variable	Sig.	Interpretation
Pretest	0.253	Normally distributed
Posttest	0.474	Normally distributed

The results of the normality tests using the Kolmogorov-Smirnov and Shapiro-Wilk tests showed significance values of 0.253 for the pretest and 0.474 for the posttest ($p > 0.05$), indicating that the data are normally distributed and meet the requirements for parametric testing. Furthermore, the results of the Paired Sample t-Test showed a t-value of -11.913 with a significance value of 0.000

($p < 0.05$). These results indicate that there is a significant difference between the pretest and posttest values, thus proving that the complex training method is effective in increasing the jump height of volleyball athletes.

Tabel 3. Paired Sample t-Test

Comparison	Mean Difference	t-value	Sig. (2-tailed)	Interpretation
Pretest – Posttest	-3.83	-11.913	0.000	Significant

This increase in jump height occurred because complex training combines strength training and plyometric exercises into a single training sequence. In this study, the squat exercise served to increase lower-body muscle strength, while the hurdle jump enhanced muscle explosiveness through the utilization of the stretch-shortening cycle. The combination of these two exercise forms led to an improvement in the muscles' ability to generate force rapidly, resulting in higher jumps (Ervantoro, Raharjo, and Andian 2023). These findings align with a study published in the Journal of Sport Area, which stated that complex training effectively increases lower-body power in adolescent volleyball athletes by systematically combining weight training and plyometric exercises (Pisz et al. 2023; Masel and Maciejczyk 2024).

The results of this study are also supported by research by (Bagaskara 2019), who found that plyometric exercises can significantly improve the vertical jump ability of volleyball athletes. That study demonstrated that both box jumps and standing jumps increased jump height by stimulating the explosive capacity of the lower-body muscles. The improvements observed in this study indicate that incorporating hurdle jumps as a plyometric component in complex training provides similar benefits for enhancing athletes' vertical jump ability (Winata 2021).

The results of the descriptive analysis showed an improvement in the vertical jump performance of athletes from the Bivota Karawang Club across all indicators following the training intervention. The athletes' minimum jump height increased from 20.00 cm to 26.00 cm, while the maximum jump height also rose from 46.00 cm to 51.00 cm. For the group as a whole, the mean jump height of the athletes increased by 3.83 cm, rising from 37.00 cm at the pretest to 40.83 cm at the posttest. Furthermore, the standard deviation remained relatively stable 7.72 during the pretest and 7.87 during the posttest indicating that the data distribution, or variation in vertical jump ability among athletes within the group, was consistent and even both before and after the complex training program.

The results of the study show that the complex training method has a significant effect on improving the vertical jump height of volleyball athletes. This is indicated by an increase in the mean score from 37.00 on the pretest to 40.83 on the posttest, with a significance value of 0.000 ($p < 0.05$). This improvement indicates that a combination of strength and plyometric training can enhance the explosive power of the lower-body muscles, which plays a crucial role in achieving higher jumps. In volleyball, vertical jump ability is one of the key physical components determining the success of smash, block, and jump serve techniques, as it enables athletes to make contact with the ball at its highest poin (Tarigan and Hidayat 2022).

This performance improvement occurs because the structured integration of strength training via squats and plyometric training via hurdle jumps optimally stimulates lower-body muscle power. In practical application on the court, achieving these higher jumps provides biomechanical advantages for athletes to make contact with the ball at its highest point, thereby significantly improving the effectiveness of executing score-determining techniques such as smashes, blocks, and jump serves.

These findings align with a study (Yu et al. 2025). that found complex training significantly increases lower-body muscle power in adolescent volleyball players. This improvement occurs because complex training combines resistance and plyometric exercises, resulting in more optimal

neuromuscular adaptation compared to using a single training method alone. The findings of this study also support the results of a study by (Wahyu Cirana et al. 2021), which stated that training that structurally combines elements of strength and speed can more effectively improve athletes' explosive movement performance.

These positive results confirm the theory proposed by (Wahyu Cirana et al. 2021), which states that a training program that structurally combines strength and speed elements can more effectively improve athletes' explosive movement performance. By systematically combining squat exercises (strength component) and hurdle jumps (speed component) in a single session, this approach successfully triggers optimal physical adaptation to generate greater vertical thrust when athletes perform jumps on the field.

The increase in jump height observed in this study was influenced by the squat and hurdle jump exercises incorporated into the complex training program. Squats serve to increase lower-body muscle strength, which is fundamental to generating force during the takeoff phase. Good muscle strength enables athletes to generate greater power, thereby increasing jump height. According to (Cakrawijaya 2021), the squat is one of the most effective resistance training exercises for increasing lower-body muscle strength and supporting explosive movement performance in sports.

The success of the complex training program in increasing athletes' average jump height from 37.00 to 40.83 is closely tied to the crucial role of squat exercises as a tool for enhancing lower-body muscle strength. The positive results of this study are fully consistent with Cakrawijaya's (2021) assertion that squats are a highly effective form of resistance training for increasing lower-body muscle strength to support explosive movement performance in sports. By building a solid foundation of strength through structured squat movements, athletes from the Bivota Karawang Club were able to generate significantly greater force against the floor; thus, when combined with plyometric training, the athletes' bodies could propel themselves higher during vertical jumps on the court.

Additionally, the hurdle jump as a form of plyometric training plays a role in enhancing the muscles' ability to generate force rapidly through the stretch-shortening cycle mechanism. Repeatedly jumping over hurdles trains neuromuscular coordination and enhances the explosive capacity of the lower-body muscles. Research findings indicate that plyometric training can significantly improve volleyball players' vertical jump ability. These findings reinforce the results of this study, which show that incorporating hurdle jumps into complex training contributes to an increase in athletes' jump height.

Combining squats and hurdle jumps in a single training session enables the post-activation performance enhancement (PAPE) effect an improvement in muscle performance following a strength training stimulus prior to explosive activity. This condition allows the nervous system and muscles to function more optimally, resulting in higher jumps. Therefore, the implementation of complex training is an effective method for improving the vertical jump ability of volleyball athletes.

DISCUSSION

The findings of this study indicate that the complex training program combining squat and hurdle jump exercises effectively improved the vertical jump height of volleyball athletes. This finding suggests that integrating strength training and plyometric exercises in a single training session provides an optimal stimulus for increasing lower-body explosive power (Saharullah et al. 2023). The improvement in jump height demonstrates that the athletes experienced positive neuromuscular adaptations, enabling them to produce greater force in a shorter period of time. These findings are consistent with (Tarigan and Hidayat 2022), who reported that complex training significantly

improves leg muscle power and arm muscle power in adolescent volleyball athletes through the integration of resistance and plyometric exercises (Zhao et al. 2025; Páez-Maldonado et al. 2024).

The increase in the athletes' average vertical jump from 37.00 cm to 40.83 cm also indicates that the combination of squat and hurdle jump exercises can improve performance in volleyball-specific movements. Squat exercises contribute to increasing lower-body muscle strength, while hurdle jumps improve the ability to generate force rapidly during take-off. This combination supports athletes in reaching a higher point of ball contact during smashes, blocks, and jump serves. Similar findings were reported by Hidayat et al. (2020), who concluded that complex training is more effective in improving muscle power than conventional training methods because it combines strength and explosive exercises within the same training session. The discussion should explore the significance of the results of the work, not repeat them. Make the discussion corresponding to the results, but do not reiterate the results. Often should begin with a brief summary of the main scientific findings (Feng et al. 2024).

The findings of this study indicate that the complex training program combining squat and hurdle jump exercises effectively improved the vertical jump height of volleyball athletes. This finding suggests that integrating strength training and plyometric exercises in a single training session provides an optimal stimulus for increasing lower-body explosive power. The improvement in jump height demonstrates that the athletes experienced positive neuromuscular adaptations, enabling them to produce greater force in a shorter period of time. These findings are consistent with Hidayat, Pratama, and Makorohim (2020), who reported that complex training significantly improves leg muscle power and arm muscle power in adolescent volleyball athletes through the integration of resistance and plyometric exercises.

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CONCLUSION

Based on the research findings, it can be concluded that a complex training program combining squats and hurdle jumps is effective in increasing the vertical jump height of volleyball athletes. The analysis revealed an increase in the average vertical jump height from 37.00 during the pretest to 40.83 during the posttest, with a significance value of 0.000 ($p < 0.05$). These findings indicate that a training program combining strength and plyometric elements can optimally enhance lower-body muscle explosiveness. The increase in jump height is supported by the role of squat exercises in enhancing lower-body muscle strength and hurdle jump exercises in improving muscle explosiveness. Therefore, complex training can be recommended as an effective alternative training program to improve the vertical jump ability of volleyball athletes. Future research is recommended to include a control group, a larger sample size, and a longer training duration to obtain more comprehensive results

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

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