14 (3) (2025) 1216 - 1221
Journal of Physical Education, Sport, Health and Recreations
https://journal.unnes.ac.id/journals/peshr

Relationship Between Leg Muscle Power, Arm Muscle Power, and Anthropometry with The Speed of The Ball Resulting from an Open Spike in Athletes of The Sumedang Integrated Indonesian Generation School Volleyball Team

Resik Citra Gemilang[1]✉, Tono Haryono[2], Finaldhi Palgunadhi[3]

Department of Sports Science, Faculty of Sports and Health Education, Universitas Pendidikan Indonesia, Jl.Dr. Setiabudhi No 229 Bandung, 40154, Indonesia[123]

Article History

Received October 2025
Accepted October 2025
Published Vol.14 No.(3) 2025

Keywords:
Leg Muscle Power; Arm Muscle Power; Anthropometry; Ball Speed; Open Spike; Volleyball

Abstract

This study aims to analyze the relationship between leg muscle power, arm muscle power, and anthropometry with the speed of the ball resulting from an open spike in athletes from the Sumedang Integrated Indonesian Volleyball Generation School. The study used a quantitative approach with a correlational method. The sample consisted of 21 athletes, with leg muscle power measured using the Vertical Jump Test, arm muscle power measured using an 8-second push-up test, and anthropometric data obtained through Karada Scan. The speed of the open spike ball was measured using a Speed Radar Gun. The data were analyzed using descriptive statistics, normality tests, Pearson or Spearman correlations, and multiple regression with a significance level of $p < 0.05$. The results showed that arm muscle power, height, weight, and body muscle mass were significantly related to ball speed, while several other variables such as leg power (Spearman), leg muscle mass, and BMI showed no significant relationship. Multiple regression analysis shows that the three independent variables simultaneously contribute 45.4% to ball speed. This finding confirms that spike performance is the result of an interaction between muscle strength and anthropometric characteristics. This study recommends a training program that focuses on strengthening the arm muscles, developing core strength, and managing body composition to improve spike speed in volleyball athletes.

How to Cite

Gemilang, R. C., Haryono, T., & Palgunadhi, F. (2025). Relationship Between Leg Muscle Power, Arm Muscle Power, and Anthropometry with The Speed of The Ball Resulting from an Open Spike in Athletes of The Sumedang Integrated Indonesian Generation School Volleyball Team. Journal of Physical Education, Sport, Health and Recreation, 14 (3), 1216-1221.

✉ Correspondence address :
E-mail: resikcgemilang2244@upi.edu

p-ISSN 2460-724X
e-ISSN 2252-6773

INTRODUCTION

An open spike smash is one of the main attacks in volleyball, used to score points directly by hitting the ball hard into the opponent's court. (Farihandiandra et al., 2024). The success of an open spike is largely determined by the player's physical abilities, particularly the power of the leg muscles, which play a role in generating optimal jumps, and the power of the arm muscles, which determine the strength and speed of the ball strike. (Tokay & Akil, 2025). However, in reality, there are many variations in spike performance between players even though they have undergone relatively similar training programs (Sarvestan et al., 2020). The difference is thought to be related to the quality of leg muscle power in jumping and arm muscle strength in delivering punches (Haqmal Proja et al., 2023). Previous studies have focused more on the relationship between muscle strength and jump height or smash accuracy, while studies focusing on the simultaneous contribution of these two factors to the speed of the ball resulting from an open spike are still limited. This condition creates an interesting knowledge gap that warrants further research, particularly with a quantitative approach using modern measurement technology such as the Speed Radar Gun. Therefore, this study focuses on analyzing the relationship between leg and arm muscle power and the speed of the open spike in volleyball athletes.

Leg muscle power plays a fundamental role in the initial phase of the spike, particularly during the jump phase (Baena-Raya et al., 2021a). The explosive legs allow players to reach optimal heights, resulting in sharper shots that are difficult for opponents to anticipate (Fuchs et al., 2021). Previous studies have shown that leg muscle explosive power is significantly correlated with jump height and smash effectiveness in volleyball athletes (Insanistyo et al., 2023). This confirms that the quality of a jump is not only a matter of technique, but also the result of the leg muscles' ability to generate explosive power efficiently (Insanistyo et al., 2023). Thus, the better an athlete's leg power, the greater their chances of producing a fast and sharp spike (Insanistyo et al., 2023).

In addition to the legs, the arm muscles also play an important role in determining the quality of a spike (Wang et al., 2024). The arm is the part of the body that directly transfers power to the ball, so its strength will affect the speed and direction of the ball (Wang et al., 2024). Several studies have found that arm muscle strength is closely related to hitting speed, whereby athletes with greater arm power are able to hit the ball harder and make it more difficult for their opponents to block (Wang et al., 2024). The movement of the shoulders, elbows, and wrists also supports the optimization of the spike, so that the combination of arm muscle strength and movement coordination becomes a crucial factor in spike performance (Saputra, 2023).

In addition to muscle power, the anthropometry of athletes, which includes height, arm length, and body composition, also plays an important role in influencing spike performance in volleyball. These anthropometric variables determine the range of the punch, vertical jump efficiency, as well as the effectiveness of power transfer from the body to the ball when spiking, which can indirectly affect the results of an athlete's hits. (Siregar et al., 2023). Athletes with optimal height and arm length tend to be able to generate spikes with steeper angles and more effective power. In addition, body composition, including muscle mass percentage and weight distribution, can also affect the ability to perform explosive jumps and transfer power from the legs to the ball (Legg et al., 2021). Thus, anthropometry becomes an important confounding variable that must be controlled in order to analyze the relationship between muscle power and ball speed more accurately.

Although various studies have examined the role of leg and arm muscle strength separately, studies linking the two to open spike ball speed are still relatively rare (Najib et al., 2023). Most previous studies have focused more on jump height, hitting accuracy, or the biomechanics of movement, so few have explicitly analyzed the simultaneous contribution of both factors to ball speed (Galib Feratulloh, n.d.). In fact, ball speed is an important indicator of the effectiveness of attacks in modern games characterized by fast tempo (Baena-Raya et al., 2021a). Therefore, this study aims to fill this gap with a quantitative approach using a Speed Radar Gun, so that it can provide a more comprehensive picture of the relationship between leg and arm muscle power and the speed of the open spike in volleyball athletes. The novelty of this study lies in the simultaneous testing of leg muscle power, arm muscle power, and anthropometric components against open spike ball speed, supported by modern measuring instruments such as the Speed Radar Gun and Karada Scan, which improve data accuracy. This study also provides added value because it was conducted on athletes aged 12–15 years who were in the "Train to Train" stage within the LTAD

framework, which is an important phase for the development of basic physical capacity and explosive abilities. Unlike previous studies that only assessed physical factors separately or focused on jump height and hitting accuracy, this study offers a comprehensive approach to explaining the physical factors that contribute to spike speed in adolescent athletes. These findings provide an empirical basis for designing more targeted training programs tailored to the developmental needs of school-age athletes.

METHODS

This study used a quantitative approach with a correlational method to determine the relationship between leg muscle power, arm muscle power, and anthropometry with the speed of the ball resulting from an open spike in athletes from the Generasi Indonesia Terpadu Sumedang. The sample in this study consisted of 21 athletes selected purposively, namely athletes who actively participated in training and had structured volleyball playing experience. The research instruments used included the Vertical Jump Test to measure leg muscle power, an 8-second push-up test to measure arm muscle power, Karada Scan as a tool to obtain anthropometric data such as height, weight, fat percentage, and body muscle mass, and a Speed Radar Gun as a tool to measure the speed of the ball resulting from an open spike. The entire measurement process was carried out at the Sumedang training ground following standard testing procedures and accompanied by a coach. The data was analyzed using SPSS software. The analysis stage begins with descriptive statistics to describe the characteristics of the data. The Shapiro-Wilk normality test is used to determine the distribution of data. Pearson or Spearman correlation tests were applied to determine the relationship between each independent variable and ball speed, while multiple regression analysis was performed to assess the simultaneous contribution of the three variables to ball speed. The significance level used is $p < 0.05$ as the basis for statistical decision making.

RESULTS AND DISCUSSION

Table 1. Normality Test

Variabel	Shapiro-Wilk	Sig.	Normality
Power_Arms	0.904	0.041	Not
Power_Leg	0.896	0.030	Not
Speed_Ball	0.939	0.204	Normal
Height	0.940	0.219	Normal
Weight	0.952	0.376	Normal
Fat	0.956	0.448	Normal
Kcal	0.948	0.308	Normal
BMI	0.873	0.011	Not
M_Trunk	0.883	0.017	Not
M_Arms	0.909	0.053	Not
M_Legs	0.840	0.003	Not
M_Whole_Body	0.904	0.041	Not

Non-normal variables are analyzed using Spearman, while normal variables can be analyzed using Pearson.

Table 2. Combined Correlation Test

Variabel	Pearson r	Sig. (2-tailed)	Spearman P	Sig. (2-tailed)	Sig.
Power_Arms	0.547	0.010	0.541	0.011	(+) sig.
Power_Leg	0.509	0.018	0.323	0.153	(+) sig. r (-) sig. p
Height	0.649	0.001	0.649	0.001	(+) sig.
Weight	0.547	0.010	0.547	0.010	(+) sig.
FAT	0.525	0.015	0.525	0.015	(-) sig.
M_Trunk	0.594	0.004	0.594	0.004	(+) sig.
M_Legs	0.397	0.075	0.380	0.090	(+) - sig
M_WholeBody	0.547	0.010	0.541	0.011	(+) sig.
BMI	0.054	0.817	0.073	0.754	(-) sig.

The correlation analysis results show that several variables have a significant relationship with ball speed. Variables that have a significant positive relationship include arm power, height, weight, trunk muscle mass, and whole-body muscle massConversely, body fat percentage (FAT) is significantly negatively correlated with ball speed. Several other variables did not show a significant relationship, namely leg power (with Spearman), leg muscle mass (M_LEGS), and body mass index (BMI). The difference in results between Pearson and Spearman is particularly evident in leg power, which is significant in Pearson but not in Spearman, possibly due to the non-normal distribution of data and the more conservative nature of Spearman.

This model shows that the combination of Arm Power, Leg Power, and TB simultaneously contributes 45.4% to ball speed ($R^2 = 0.454$). The F value is significant ($p = 0.014$), meaning that the regression model as a whole is valid for use.

Individually, none of the variables were significant. This insignificance was likely due to the small sample size ($n = 21$). However, the direction of the relationship remained positive, consistent with previous correlation findings.

The results of the study indicate that athletes' physical abilities, particularly arm muscle strength, play an important role in spike perfor-

mance in volleyball. This is in line with the principles of biomechanics, whereby the arm muscles function to transfer energy from the body to the ball effectively, so that the stronger the arm muscles, the greater the potential speed of the ball (Baena-Raya et al., 2021b). This finding is also supported by previous literature emphasizing the importance of arm strength in generating explosive and accurate hits in volleyball athletes (Wismiarti & Hermanzoni, 2020).

When viewed from the perspective of sports development based on Long-Term Athlete Development (LTAD), the 12–15-year-old sample in this study is in the "Training to Train" phase, which is the stage where athletes begin to experience rapid development in physical abilities, movement coordination, and basic techniques in a systematic manner. During this phase, there is a critical window for improving strength adaptation, so that the development of physical capacity, such as arm and leg muscle power, will have a real impact on game skill performance, including ball speed on open spikes. (Balyi & Hamilton, 2004). Other studies also confirm that strength training during adolescence can improve physical performance without interfering with growth, and is consistent with long-term development planning in accordance with LTAD. (Granacher et al., 2016). In addition, variations in performance among athletes in this age range are a natural phenomenon because biological development and physical maturity levels are not uniform among individuals. (Albaladejo-Saura et al., 2022). Thus, the results of this study are consistent with the characteristics of athlete development in the LTAD phase, where improvements in physical abilities contribute directly to the achievement of technical performance such as speed open spike.

Leg muscle strength plays a role in body stability and jumping ability, which indirectly affects ball speed (Bobula et al., 2024). Athletes with good leg power have more optimal body thrust when spiking, making their spikes more effective (Přidal et al., 2023). Although its influence is more supportive than that of the arm muscles, leg strength remains an important component in overall spike performance.

In addition to muscle strength, several anthropometric components also affect ball speed. Optimal height and weight allow athletes to achieve better leverage and body position when spiking, thereby maximizing energy transfer (Riyad Fadhli et al., 2021). Core strength and overall muscle mass also support an athlete's ability to control their body, transfer power from their legs to their arms, and generate more explosive spikes (Bora & Dağlıoğlu, 2022) Conversely, a high percentage of body fat can reduce an athlete's explosive ability, as fat mass does not contribute to muscle power (Apollaro et al., 2024)

These findings indicate that spike performance is not influenced by a single variable, but is the result of the interaction of several factors, including muscle strength, body posture, and body composition (Dopsaj et al., n.d.). Therefore, effective training to increase ball speed should be multifactorial, including strengthening the arm muscles, developing core strength, and improving body composition (Saeterbakken et al., 2025)

The limitations of this study include the relatively small sample size and the fact that the study focused only on athletes from certain schools. Therefore, these findings should be interpreted with caution and not immediately generalized to the wider population of volleyball athletes. Nevertheless, this study provides clear practical implications for coaches and athletes, namely the importance of combining strength training and technical training in a balanced manner to improve spike performance.

CONCLUSION

Based on the results of the study, it can be concluded that arm muscle power, height, and trunk strength have a positive relationship with ball speed, indicating that certain physical abilities and body composition play an important role in spike performance. Leg muscle power, BMI, and several other anthropometric components did not show a significant relationship with ball speed in this study sample. These findings emphasize the importance of exercises that focus on strengthening arm muscles, developing core strength, and managing body composition to improve spike speed. Limitations of the study, such as the limited sample size and focus on specific school athletes, mean that the results should be interpreted with caution. Further research is recommended using a larger and more diverse sample, as well as considering other factors that may influence ball speed to gain a more comprehensive understanding.

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