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Original Article Research

Path Analysis Model to Assess the Effects of Anthropometry and Power on the Vertical Jump Performance of Youth Volleyball Athletes

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Abstract

Background. length of lower leg, *body mass index* (BMI), and power affects the vertical jump performance of volleyball. The direct and indirect relationships of such variables have not been thoroughly explored. Purpose. Evaluate how power functions as a mediator and how lower leg length and BMI impact vertical jump performance. Method. This study has a quantitative design and uses methods *path analysis*. The purposive sampling method was used to select 24 volleyball athletes, each with an average age of 18.46 years. Anthropometric, BMI, power, and vertical jump performance data were directly collected and tested using a path analysis model using SPSS and AMOS software version 26. Results. Lower leg length has a negative direct impact on jump performance (-0.308; $p< 0.05$), but has a positive impact on power (0.481; $p< 0.05$). BMI has a negative direct impact on vertical jump performance (-1,032; $p <0.05$), but has a positive impact on power (0.713; $p< 0.05$). Power mediation is responsible for 94.5% of vertical jump performance variance, indicating that this element is crucial in the relationship between leg length and BMI with vertical jump. conclusion. Although lower leg length and BMI have a negative effect on vertical jump performance, power is an important mediator in the relationship between lower leg length and BMI to vertical jump. Exercises that focus on developing effective power to improve jump performance.

Keywords: lower leg legnth, BMI, power, vertical jump, volleyball, teen athletes

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1. INTRODUCTION

Athletic performance, especially vertical jumping ability, is crucial in volleyball. Professional athletes record more than 40,000 spikes and 77% to 90% of the number of jumps per set each year (Hernandez-martinez et al., 2024). These parameters are often used to assess a person's strength, explosive power, and biomechanical mechanisms and measure the body's explosive power (Fuchs et al., 2021; Kurniawan et al., 2024; Saç, 2021; Wdowski et al., 2023). Anthropometric factors such as leg length, body mass (BMI), and muscle explosiveness are some of the ones that influence jumping ability, according to previous studies(Jiang et al., 2024; Pavlovic et al., 2022; Setiyawan et al., 2021).

A study indicates that the length of the lower leg plays an important role in jumping (Altavilla et al., 2022). As a result, the movement mechanism has an impact on torque and thrust. According Pavlovic et al., (2022) leg length increases strength and thrust during jumps. Another study indicates that volleyball players with longer legs improve their jumping abilities through their biomechanical efficiency (Nasrulloh et al., 2021). However, lower leg length has a different effect on jumping ability(Altavilla et al., 2022).

On the other hand, the relationship between body mass index and the performance of volleyball athletes becomes more complex (Fatahi et al., 2021). A study indicates that there is a relationship between body mass index and the jump performance of volleyball athletes (Emamian Shirazi et al., 2022). Pocek et al., (2021) found that volleyball athlete with body mass index higher ones have an impact on vertical jump performance, especially if there is a relationship with increased body fat mass (Jiang et al., 2024). It was shown that this predictor did not play a significant role in the parameters of jump performance, contrary to previous studies, such as (Karadağ et al., 2024).

From the explanation above, it can be concluded that body mass index and lower leg length is an important predictor of jump performance. However, different perspectives from previous research still exist. Besides body mass index and the lower leg length parameter, there are other important components, such as explosive power. The ability to jump is greatly aided by this element. There is a direct effect of 90.8% to 92.2% of the limb's explosive power on vertical jump performance, according to (Kurniawan et al., 2024; Putra et al., 2024). This indicates that explosive power greatly affects jump performance (Putra et al., 2024).

Direct and indirect relationships between anthropometric, power and vertical jump performance aspects are still under-explored, although many studies have identified the influence of each variable. Many previous studies have also not considered mediation variables simultaneously in a single path analysis model. This is especially true for active or non-professional adolescent populations. The ambiguity regarding the indirect influence of power as a mediator on vertical jumps and lower leg length is the gap in this research. Volleyball athletes often say that power is very important for their performance. However, the role of mediation in this relationship has not been widely studied, especially in athletes with lower BMI or in younger age groups.

The aim of this research is to fill this gap by integrating the length of the lower leg, *body mass index* (BMI), and power in path analysis models. The aim of these findings is to provide a better understanding of how body parts interact with physical abilities in vertical jumps and contribute to the development of research that improves vertical jumping techniques.

2. METHOD

The research design used in this study is quantitative through the path analysis method which aims to describe how a relationship can affect between variables. In line with the research of Gao et al., (2025) which discusses how path analysis is applied to analyze the causal relationship between variables in quantitative research. In the scope of volleyball, this study can provide more in-depth knowledge in knowing the relationship between power, BMI, anthropometry, and vertical jump performance. To find the relationship between variables among volleyball athletes, quantitative data can be systematically collected and analyzed.

2.1 Participants

A total of 24 volleyball athletes involved in this study were selected based on specific criteria. The selection of participants was carried out using the purposive sampling method, in which subjects were chosen based on characteristics relevant to the research objectives (Nyimbili & Nyimbili, 2024). The participating athletes had an average age of 18.46 years, with demographic characteristics including an average body weight of 55 kg, a lower limb length of 100.33 cm, and a BMI of 19.45 kg/m². In sports research, subjects must have homogeneous physical characteristics to control variables that could influence the study outcomes (Gunnell et al., 2022). Therefore, only specific athletes meeting the required criteria were eligible to participate in this study.

2.2 Research Design

The study was designed as a quantitative study, using a path analysis model and a correlational approach. The aim of this design is to study direct and indirect relationships between anthropometric variables (such as *body mass index* and lower leg length) with vertical jump performance, as well as the power mediation role in the model. Recent research supports the aplication of path analysis in sports science, highlighting its physiological factors (Novak et al., 2021). Moreover, studies indicate that anthropometric variables significantly influence jump performance, with power acting as a crucial mediator (Hermassi et al., 2024).

2.3 Instruments

Test and measurements are the research equipment utilised in this paper. These tools are used to collet information on anthropometry (length, weight, and height), body mass index (BMI), muscular explosive power, and vertical jump performance. The use of direct testing aligns with recent methodologies emphasizing precision in biometric assessments (Ortiz-Padilla et al., 2022). These measurements are analyzed using a path analysis model, which has been validated for biomechanical research to determine causal relationships between variables (Gao et al., 2025). The application of SPSS and AMOS software (version 26) ensures robust statistical modeling, enabling comprehensive insights into the relationships between anthropometric indicators and physical performance (Ke et al., 2025).

2.4 Procedures

Anthropometric measurements, including lower leg length, weight, and height, alongside body mass index (BMI) calculations and vertical jump performance tests, serve as fundamental methodologies for data collection in biomechanical and sports science research. The assessment of lower limb power is conducted through the vertical jump test, a widely recognized indicator of neuromuscular performance and explosive strength (J. Wang et al., 2025). Power is measured using the vertical jump test, then entered into the power formula (Badby et al., 2023). To establish the interrelationships among these variables, a path model is employed, enabling a robust multivariate analysis to determine causal pathways and predictive relationships in sports performance research.

2.5 Data Analysis

For descriptive and regression analysis, as well as for building and testing path models, SPSS and AMOS version 26 were used. According to Al-Fadhali, (2024), AMOS is widely utilized in structural equation modeling (SEM) for estimating path coefficients and evaluating complex causal relationships. In the analysis, path coefficient estimation is used to check the relationship between both direct and indirect variables, as described by Gao et al., (2025), who emphasized that path analysis allows researchers to assess multiple relationships simultaneously while accounting for mediation and moderation effects.

To ensure that the data meet statistical assumptions, the Shapiro-Wilk method is used to perform normality tests. This method is particularly suitable for small to moderate sample sizes and provides a more robust assessment of normality compared to other tests like Kolmogorov-Smirnov (Bilon, 2023). The results of the path analysis also verified the power mediation effect in the relationship between vertical jump performance and independent variables, aligning with previous studies that highlight the importance of mediation analysis in sports performance research (Liu & Fu, 2024).

3. RESULTS

To investigate the relationship between anthropometric elements, power, and vertical jump performance, this study analyzed data using path models and statistical methods. Several tables and figures indicate the interpretation of the analysis results; each provides detailed information about the research results. This is an explanation of the findings:

3.1 Tables

Table 1

Descriptive Statistics: Research Subject Profile

	N	Mean ± Std. Deviation
Age		18.46 ± 1,103, year
Weight		55.00 ± 9,381, kg
Height		1.6833 ± 0.04743, m
Lower Leg Length	24	100.33 ± 4,146, cm
Body Mass Index		19.4482 ± 3.49105, kg/m^2
Power		39.4523 ± 4.74755, w/kg
Vertical Jump		59.67 ± 9,517, cm

Source: spss version 26

The following table provides a general visualization of the demographics of the study subjects. Age, weight, height, length of lower leg, *body mass index* (BMI), power, and vertical

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jump performance are the information required. With an average weight of 55.00 ± 9.381 kg and average height 1.6833 ± 0.04743 m, and average lower leg length 100.33 ± 4.146 cm, the population has an average BMI of 19.4482 ± 3.49105 kg/m^2. This indicates this population is relatively young. For physical performance, the average explosive power is 39.4523 ± 4.74755 w/kg and the average jump performance is 59.67 ± 9.517 cm. These data provide the basic context for the analysis of the relationships between research variables.

Table 2

Residual Normality Test: Shapiro-Wilk's

	Statistics	df	Sig.
Unstandardized Residuals	0.963	24	0.511

Source: spss version 26

To ensure that the data meet the normal distribution assumptions required for additional statistical analysis, the results of the normality test are presented in Table 2. The results of the Shapiro-Wilk test indicate that residual data has a normal distribution ($p > 0.05$). This suggests that the data are eligible for further analysis using pathway and regression models.

Table 3

BMI and Leg Length as Power Determinants

Aspect	Determinant R^2	Standardized Coefficients β	Significant
BMI	0.604	0.713	0.000
Lower Leg Length		0.481	0.003

Source: spss version 26

The results of the regression analysis presented in Table 3 show the relationship between the two anthropometric elements of lower leg length and *body mass index* (BMI) to power. The findings indicate that the length of the lower leg contributes significantly to power with standard coefficients (β) of 0.481 and value $p = 0.003$, while BMI has a greater contribution to power with a determination coefficient (R^2) amounting to 0.604, in the sense that there are variants, this result indicates that anthropometric factors, especially BMI, are very important in determining the power of volleyball athletes.

Table 4

Effect of BMI, Leg Length, and Power on Vertical Jumps

Aspect	Determinant R^2	Standardized Coefficients 6	Significant
BMI		-0.308	0.000
Lower Leg Length	0.945	-1.032	0.000
Power Legs		1.428	0.000

Source: spss version 26

Table 4 displays regression analysis investigating the influence of lower leg length, BMI, and power on vertical jump performance. power has the most significant positive influence with a coefficient of 1.428 ($p < 0.05$), while BMI has a negative influence with a coefficient of -1.032 ($p < 0.05$), and the length of the lower leg has a negative influence with a coefficient of -0.308 ($p < 0.05$). The result of the determination coefficient (R^2) of 0.945 indicates that this model is responsible for 94.5% of the variance in vertical jump performance. The results show that power is very important for determining jump performance.

Table 5

Power Mediation in the Relationship between BMI and Legs and Vertical Leaps

Aspect	Power	Vertical Jump
BMI	0.000	1.018
Lower Leg Length	0.000	0.686

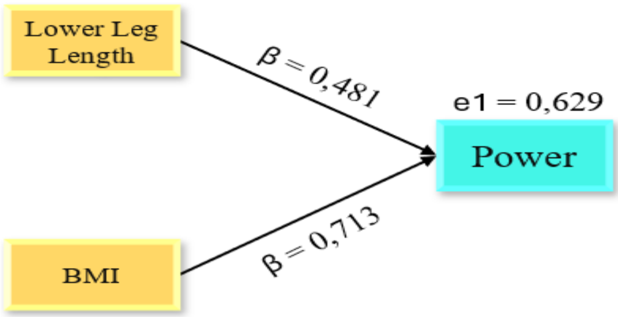
Source: spss and amos version 26

As shown in Table 5, lower leg length has an indirect effect of 0.686 on vertical jump performance, while BMI has an indirect effect of 1.018 on vertical jump performance. This indicates that power functions as an important mediator in the relationship between anthropometric aspects and vertical jump performance. The fact that the BMI is greater than the length of the lower leg indicates that body composition is very important for maximizing physical performance.

3.2 Figures

Figure 1

Effect of Lower Leg Length and BMI on Vertical Jumps with Power Mediation



In the path model indicating the direct influence of BMI and lower leg length on power, Figure 1 indicates that both independent variables have a significant path to the dependent variable, or power. Although higher coefficients indicate that BMI is the main predictor, lower leg length also plays a significant role.

Figure 2

Relationship between BMI, Lower Leg Length, Power, and Vertical Jump: Complex Path Analysis

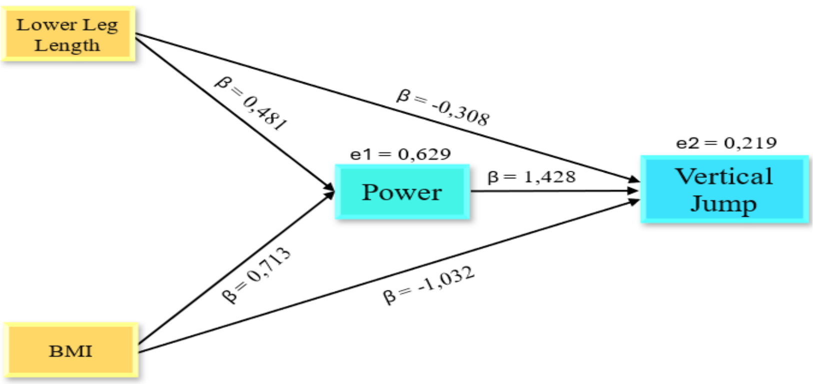
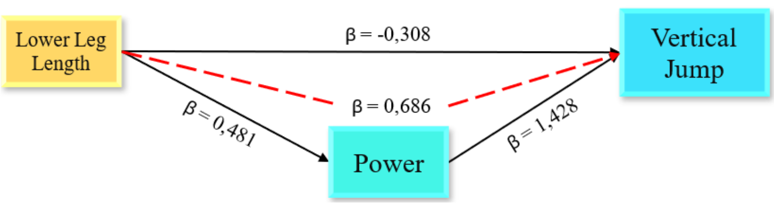


Figure 2 indicates a path diagram showing a direct relationship between lower leg length, BMI, power, and vertical jump. This diagram indicates that each path contributes to improving the performance of vertical jumps. The largest coefficients are presented in the power path, indicating how important power is in this model.

Figure 3

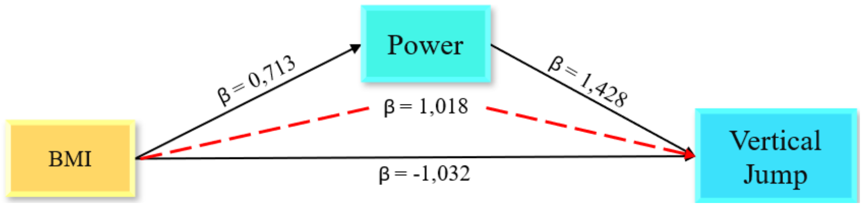
Effects of Lower Leg Length on Vertical Jump Performance: Complex Paths with Power Mediation



Lower leg length, power, and jump performance are depicted in this model. The length of the lower leg has a positive direct influence on power, as shown by the path from the length of the lower leg to power with a positive coefficient of 0.481. Thus, volleyball athletes have a larger lower leg length, which can help improve their explosive abilities. However, the path is directly from the length of the leg the bottom to vertical jump shows a negative coefficient of -0.308 which indicates that the length of the leg has a negative influence on the ability of the vertical jump when not mediated by power. This negative influence can stem from biomechanical constraints or lack of movement efficiency in people with very long legs. A positive coefficient of 0.686 from the indirect path through power indicates that power mediates the relationship between lower leg length and vertical jump. In other words, while the length of the lower leg may have a direct negative effect on the vertical jump, this effect can be offset by the increase in power, which results in a much better vertical jump.

Figure 4

BMI and Power as Key Determinants of Vertical Leap: Integrated Path Model



In this model, the relationship between BMI, power, and vertical jump performance is explored. With a path coefficient of 0.713, the relationship between BMI and power indicates a positive and significant relationship. This indicates that power can be increased with a higher BMI as long as the ideal body composition, namely the proportion of fat and body muscle mass, is balanced. However, because the body's greater contribution, especially consisting of body fat, has a negative coefficient of -1.032 between BMI and vertical jumping, BMI directly negatively impacts vertical jumping ability. In addition, there is an indirect path through power from BMI to the vertical jump with a path coefficient of 1.018. This pathway indicates that power mediates the relationship between BMI and vertical jump. In other words, while BMI negatively impacts directly on vertical jumps, BMI-mediated power increases can offset the adverse effects. As a result, the role of power as a mediator is very important in this model.

4. DISCUSSIONS

The results of path analysis indicate that lower leg length and BMI have a significant relationship with vertical jump performance, both directly and through power mediation. Results indicate that lower leg length has a direct negative influence on vertical jumps with a coefficient of -0.308 ($p < 0.05$), while the length of the lower leg makes a positive contribution to power with a coefficient of 0.481 ($p < 0.05$). This indicates that even though the length of the lower leg can inhibit jumping directly, increased power through longer limbs can compensate for the impact. In research conducted by (Setiyawan et al., 2021), it was found that the length of the lower leg contributed significantly, reaching 86% of the total jump performance variation.

However, with a coefficient of -1.032 ($p < 0.05$), BMI has a negative direct influence on vertical jumps. however, BMI has a positive influence on power (coefficient 0.713, $p < 0.05$). This indicates that a higher BMI, especially if the muscle mass is greater, can help improve explosive performance. Pavlovic et al., (2022) supports these findings by indicating that a BMI above the ideal threshold can improve jump performance from 5% to 15%, while a BMI that is too high with a dominant proportion of fat reduces jump performance.

With coefficient 1.428 ($p < 0.05$), power itself has a significant direct influence on vertical jumps. This indicates that increasing power can increase jump performance by 1,428 units. These results are in harmony with Putra et al., (2024) which states that power is responsible for up to 92% of variations in vertical jump performance. These results show how important explosive training targets the development of power in volleyball. Plyometric training, for example, can increase average power by up to 84.43% in 8-12 weeks of training (Muhammad et al., 2023).

In addition, the pathway model in this study indicated that lower leg length, BMI, and power accounted for 94.5% of the variance in vertical jump performance. These numbers show that these three variables have extraordinary predictor power. In a study conducted by Grigoletto et al., (2023); Karadağ et al., (2024); Legg et al., (2021); Miguel-Ortega et al., (2024); Stojanović et al., (2020) Kurniawan et al., (2024); Putra et al., (2024) a similar model is used in professional volleyball athletes. The study found variable contributions, although slightly less, but still supported the relationship.

Vertical jumping is a crucial skill in various sports disciplines, influenced by anthropometric factors such as lower limb length and body mass index (BMI). Biomechanically, lower limb length plays a role in enhancing the efficiency of mechanical leverage during jumping. Longer limbs allow athletes to generate greater reactive force against the ground, accelerating the take-off phase and optimizing the flexion-extension mechanisms of the knee and ankle joints. A recent study by (Catalbas & Atis, 2025) found that athletes with longer lower limbs exhibit better vertical jump performance, compared to those with shorter limbs.

Apart from limb length, BMI also affects vertical jump performance, though its impact varies depending on body composition. If an increase in BMI is due to greater muscle mass, the resulting explosive power is enhanced, positively influencing jump height. Conversely, if a high BMI stems from excess body fat, the increased body weight can hinder jump performance due to higher gravitational resistance without a proportional increase in muscle strength. A study conducted by T. Wang et al., (2024) found that athletes with a BMI range of 22–25 kg/m^2 demonstrated the best vertical jump performance, as this range represents an optimal balance between body mass and power output.

Furthermore, the relationship between limb length and BMI with vertical jump performance is largely mediated by muscle power. The extensor muscles of the lower limbs, such as the quadriceps, gastrocnemius, and gluteus maximus, play a vital role in generating the explosive force required for jumping. Athletes with longer limbs tend to have an advantage in developing greater power, as they can produce high forces in a short period. Similarly, individuals with an optimal BMI dominated by muscle mass can enhance their explosive muscle contraction capacity, contributing to improved vertical jump performance. Research by Rodriguez-Lopez et al., (2021) confirmed that approximately 65% of the effect of limb length on jump height is mediated by muscle power.

Thus, it can be concluded that lower limb length and BMI have a significant relationship with vertical jump performance, both directly and through the mediation of muscle power. Greater lower limb length enhances the biomechanical efficiency of jumping, while an optimal BMI supports better explosive power production. Muscle power acts as the primary mediator in this relationship, where the explosive capacity of the lower limb muscles becomes the key factor in converting limb length and body mass into a higher jump (Catalbas & Atis, 2025). Therefore, in designing training programs for athletes aiming to improve vertical jump performance, it is essential to consider anthropometric factors and strategies for enhancing muscle power simultaneously.

This study indicates that volleyball athletes can optimize their vertical jumps by concentrating on training programs that focus on developing power while maintaining ideal body composition. Explosive training, such as weight training and plyometrics, not only increases power but also helps athletes overcome biomechanical obstacles associated with higher lower leg lengths. This research, however, is incomplete as it only examines young athletes. The results cannot be applied to older age groups or professional athletes. In order to make better models of path analysis, future studies should also take into account additional factors such as flexibility, motion coordination and muscle fiber composition.

5. CONCLUSIONS

This study found that anthropometric factors, especially lower leg length and *body mass index* (BMI), has a significant correlation with how well teen volleyball athletes perform vertical jumps. Due to biomechanical constraints, the length of the lower leg can help jump. On the other hand, BMI also has an impact direct negative on vertical jump performance, especially in cases where the proportion of body fat is dominant. However, a higher BMI with ideal body composition has the potential to increase power, which in turn contributes to improved jump performance.

As the main predictor for vertical jump performance, power is responsible for 92% of the observed variation. Therefore, the path analysis model used in this study was able to explain 94.5% of the variation in vertical jump performance, confirming the importance of lower leg length, BMI and power to improve volleyball athletes' performance. This research helps coaches create better training programs by concentrating on developing power and optimizing athlete body composition.

However, this study only involved adolescent athletes, so further research is needed that looks at more variables such as flexibility, movement coordination, and muscle fiber composition. Additionally, the study should involve different age groups and skill levels of athletes to broaden our understanding of the factors that influence vertical jump performance.

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