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# The relationship of body mass index, leg muscle strength to maximal oxygen volume optimization in students

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## ABSTRACT

Physical condition, including body mass index (BMI) and leg muscle strength, is a key factor influencing athletic performance, particularly in volleyball. This study aimed to examine the relationship between BMI and leg muscle strength with maximal oxygen uptake ( $VO_2$  max) in volleyball athletes. A non-experimental quantitative correlational design was applied with a total sample of 30 university volleyball players. Data were collected using standardized measurements of BMI, leg muscle strength, and the multistage fitness test (MFT) to estimate  $VO_2$  max. Normality and linearity tests were conducted before correlation analysis. Results showed an average BMI of 21.69, leg muscle strength of 70.27, and  $VO_2$  max of 32.16. Multiple correlation analysis indicated a significant relationship between BMI and leg muscle strength with  $VO_2$  max (Sig. F change = 0.003 < 0.05,  $R = 0.597$ ,  $R^2 = 0.356$ ). These findings suggest that optimal BMI and strong lower limb muscles jointly support aerobic capacity in volleyball athletes, providing evidence for targeted physical training programs that enhance both fitness and performance.



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## Introduction

Sports are structured activities designed to systematically develop both physical and mental potential through exercises, competitions, and recreational activities, aiming to achieve excellence and foster well-rounded individuals (Hirwana et al., 2023). Participation in sports is not only a form of recreation but also a medium to strengthen endurance, coordination, and overall health. However, modern technological advances have reduced the necessity for daily physical activity, leading to a more sedentary lifestyle. This shift has contributed to increased obesity rates and a decline in physical endurance, particularly among students who spend much of their time on academic and digital activities (Kurniawan, Widhiya, et al., 2025).

Volleyball is a high-intensity sport that demands speed, power, and repeated explosive movements throughout a match (Munir, 2024). Athletes must combine technical skills with physical readiness to

sustain performance under the stress of long rallies and dynamic gameplay. The sport requires both aerobic and anaerobic capacities, as well as muscular strength and coordination to execute jumps, spikes, and defensive maneuvers effectively. Without adequate physical preparation, athletes are prone to rapid fatigue and reduced efficiency during competitions.

Leg muscle strength is a crucial component in volleyball performance because it directly affects the ability to jump, move quickly, and land safely (Lui et al., 2025). Higher leg strength allows athletes to achieve greater jump heights, execute more powerful attacks, and block opponents more effectively. Furthermore, strong lower limbs contribute to agility, balance, and rapid directional changes, which are essential for maintaining competitive advantage during matches. Athletes with well-developed leg muscles can perform consistently across all phases of a game, minimizing performance decline due to fatigue.

In addition to technical advantages, leg muscle strength significantly improves movement efficiency and endurance during matches (Wolter et al., 2024). Strong lower limb muscles reduce the energy cost of movement, allowing athletes to perform repeated high-intensity actions without overloading the cardiovascular system. Moreover, leg muscle strength plays an essential role in injury prevention by providing joint stability and absorbing impact during landings, thereby reducing the risk of knee, ankle, and other musculoskeletal injuries that commonly occur in volleyball (Pamungkas et al., 2018).

Body Mass Index (BMI) serves as a simple yet important indicator of an athlete's body composition and overall health, influencing movement efficiency, energy expenditure, and aerobic capacity (Nia et al., 2024). Both excessively high and low BMI can negatively affect  $VO_2$  max, which in turn may limit endurance performance on the court. Athletes with a BMI that is too high may experience reduced oxygen utilization efficiency, while those with very low BMI may have insufficient muscle mass and energy reserves to sustain prolonged high-intensity activity. Maintaining an optimal BMI is therefore critical for maximizing athletic performance and aerobic capacity.

$VO_2$  max is widely recognized as a key parameter for evaluating cardiovascular fitness and the body's ability to efficiently utilize oxygen during physical activity (Prasetyo et al., 2024; Groehs et al., 2024). Accurate assessment of  $VO_2$  max, for example using the multistage fitness test (MFT), provides valuable insights into an athlete's endurance capacity and potential for sustained high-intensity performance (Bafirman et al., 2023). Athletes with higher  $VO_2$  max can maintain elevated performance levels throughout long rallies without experiencing excessive fatigue, highlighting the importance of aerobic capacity for competitive success.

Despite the importance of both BMI and leg muscle strength, studies investigating the combined effect of these two variables on  $VO_2$  max in volleyball athletes remain limited. Understanding how BMI and lower limb strength jointly influence aerobic capacity is essential for designing training programs that are not only effective but also tailored to the physiological needs of individual athletes. Without such knowledge, training may fail to fully optimize performance and could overlook critical factors influencing endurance and efficiency.

Optimal physical condition, including a balanced BMI and strong leg muscles, provides a foundation for maintaining performance during the high-intensity demands of volleyball. Athletes with proper body composition and well-developed lower limbs can achieve better energy efficiency, maintain aerobic capacity, and perform repeated explosive movements throughout the match. These advantages are crucial in fast-paced games that require continuous movement, rapid reactions, and sustained power output. Therefore, attention to both BMI and leg muscle strength is essential in any program aimed at maximizing performance.

Based on the considerations above, this study aims to investigate the relationship between BMI and leg muscle strength with  $VO_2$  max in volleyball athletes. The findings are expected to provide empirical evidence to guide coaches and trainers in designing targeted, individualized training programs that improve both physical fitness and competitive performance. By understanding the interaction of body composition and muscular strength on aerobic capacity, training strategies can be optimized to enhance overall athletic potential and ensure athletes perform at their best during matches.

## Method

This study used a non-experimental quantitative approach with an ex post facto correlational design, aiming to examine the relationship between Body Mass Index (BMI), leg muscle strength, and maximal oxygen uptake (VO<sub>2</sub> max) in volleyball athletes. A correlational design was chosen because it allows researchers to determine whether and how strongly independent variables (BMI and leg muscle strength) are associated with the dependent variable (VO<sub>2</sub> max) without manipulating the variables.

The population of this study consisted of 30 volleyball student-athletes from Nahdlatul Ulama University, and total sampling was employed, resulting in a sample size of 30 athletes. The inclusion criteria required participants to be active university volleyball players with no current injuries or medical conditions that could affect their physical performance. This ensures that the sample accurately represents the population of interest.

Data were collected using two primary techniques. First, documentation was used to record participants' identity, university affiliation, and player positions. Second, behavioral tests were conducted to measure the three main variables: BMI, leg muscle strength, and VO<sub>2</sub> max. BMI was calculated using participants' body weight and height according to standard formulas, while leg muscle strength was measured using validated strength tests suitable for lower limbs. VO<sub>2</sub> max was estimated using the Multistage Fitness Test (MFT/Beep Test), which is reliable for assessing cardiovascular endurance in a group setting.

Before performing correlation analysis, prerequisite tests were conducted to ensure the appropriateness of the data. Normality testing was carried out using the Kolmogorov-Smirnov test to confirm that all variables were normally distributed. Linearity tests were also performed to verify that the relationships between independent and dependent variables were linear, which is necessary for accurate correlation results.

Finally, the data were analyzed using Pearson's product-moment correlation for simple relationships and multiple correlation analysis to determine the combined effect of BMI and leg muscle strength on VO<sub>2</sub> max. The coefficient of determination (R<sup>2</sup>) was calculated to quantify how much variance in VO<sub>2</sub> max is explained by the two independent variables. Significance was tested at  $p < 0.05$ , with the results interpreted to assess the strength and relevance of the relationships.

This method ensures a clear and systematic approach to investigating the research question, provides reproducible procedures, and allows for an objective assessment of how BMI and leg muscle strength jointly influence aerobic capacity in volleyball athletes.

## Results and Discussions

This study involved 30 volleyball who were university students. The results of the BMI measurements, leg muscle strength, and Beep test or MFT can be seen in the following table.

**Table 1.** Description of BMI values, leg muscle strength, and maximum oxygen volume in volleyball

Statistik	IMT	Leg Muscle Strength	Maximum Oxygen Volume
Mean	21,69	70,27	32,16
Standard Error	0,45	6,37	1,23
Median	22	66,75	33,2
Mode	22	44	34,7
Standard Deviation	2,46	34,9	6,74
Sample Variance	6,07	1215,7	45,45
Range	10,6	151	24,7
Minimum	17,7	31,5	19,2
Maximum	28,3	182,5	43,9
Sum	650,7	2108,1	964,9
Count	30	30	30

The table above shows an average BMI value of 21.69 with a standard deviation of 2.46 and a sample variance of 6.06, with a minimum BMI value of 17.7 and a maximum score of 28.3. The average leg muscle strength score is 70.27 with a standard deviation of 34.86 and a sample variance of 1215, while the minimum score is 31.5 and the maximum score is 182. The average maximum oxygen volume score was 32.16 with a standard deviation of 6.74 and a sample variance of 45.44, while the minimum score was 19.2 and the maximum score was 43.9. The next step is to conduct a prerequisite test. The prerequisite tests that must be conducted before conducting the analysis test are as follows.

### Normality Test

Normality testing is applied so that researchers can determine whether the data used is normally distributed or not, therefore normality testing is carried out using the Kolmogorov-Smirnov test. The results of the normality test can be seen in the following table.

**Table 2.** Results of the Multiple Correlation Test One-Sample Kolmogorov-Smirnov Test

Statistic	Description	Value
N	Sample size	30
Normal Parameters	Mean	0.000000
	Standard Deviation	5.409417
Most Extreme Differences	Absolute	0.128
	Positive	0.128
	Negative	-0.104
Test Statistic	Kolmogorov-Smirnov Z	0.128
Asymp. Sig. (2-tailed)	Significance	0.200
Monte Carlo Sig. (2-tailed)	Significance	0.234
99% Confidence Interval	Lower Bound	0.223
	Upper Bound	0.245

Based on the table above, according to the criteria that have been tested, all the data can be concluded to be normally distributed because the Asymp Sig (2-tailed) value is greater than 0.05, indicating that the data is normally distributed.

### Linearity Test

The purpose of the linearity test is to ensure the presence of a linear data distribution. The results of the linearity test can be seen in the following table.

**Table 3.** Results of Linearity Test of BMI and VO2max ANOVA Table

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups (Combined)	975.937	22	44.361	0.908	0.604
Linearity	70.869	1	70.869	1.450	0.268
Deviation from Linearity	905.068	21	43.098	0.882	0.620
Within Groups	342.112	7	48.873		
Total	1318.050	29			

Based on the results of the linearity test above using SPSS 29, in the ANOVA table the value of (deviation from linearity) is 0.620, which is greater than 0.05. Therefore, the relationship between the predictor and the criterion is considered linear, and it can be concluded that there is linearity between BMI and VO2max.

**Table 4.** Results of Linearity Test of Strength and VO2max ANOVA Table

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups (Combined)	1239.043	24	51.627	3.267	0.096
Linearity	460.235	1	460.235	29.12	0.003
Deviation from Linearity	778.808	23	33.861	2.143	0.203
Within Groups	79.007	5	15.801		
Total	1318.050	29			

Based on the results of the linearity test above using SPSS 29 on the ANOVA table, a value of 0.203 (deviation from linearity) was obtained, which is greater than 0.05. Therefore, the relationship between

the predictor and the criterion is declared linear, and it can be concluded that there is linearity between lower limb muscle strength and VO<sub>2</sub>max.

**Table 5.** Results of Multiple Correlation Test

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	0.597a	0.356	0.308	5.6062	0.356	7.468	2	27	0.003

From the table above, it can be concluded that the Sig. F change value of 0.003 < 0.05, therefore H<sub>0</sub> is rejected and H<sub>1</sub> is accepted, which means there is a significant relationship or correlation between BMI and lower limb muscle strength with maximal oxygen volume in volleyball athletes.

The results of this study show a significant correlation between Body Mass Index (BMI) and leg muscle strength with maximal oxygen uptake (VO<sub>2</sub> max) in volleyball athletes, with a Sig. F value of 0.003 < 0.05. This indicates that these two physical variables simultaneously contribute to aerobic capacity. Analytically, BMI is an important determinant of cardiorespiratory endurance, as athletes with an ideal BMI are better able to utilize oxygen efficiently during high-intensity activities (Bourdier et al., 2025). Conversely, excessive BMI may lead to deconditioning and impaired respiratory function, reducing VO<sub>2</sub> max, while a very low BMI may reflect insufficient energy reserves and muscle mass, both of which can limit endurance performance (Bellissimo et al., 2021).

Leg muscle strength is equally crucial for volleyball performance. Strong lower limbs support repeated high-intensity movements, including jumping, lateral shifts, and rapid direction changes, which are critical throughout a match. Athletes with greater leg muscle strength experience less fatigue and can maintain technical performance from the beginning to the end of the game, which positively affects VO<sub>2</sub> max (Prakoso & Sugiyanto, 2017). This aligns with previous research showing that lower limb endurance and strength are closely associated with improved aerobic capacity in athletes.

The correlation coefficient ( $r = 0.597$ ) indicates a moderate relationship between BMI and leg muscle strength with VO<sub>2</sub> max, while the coefficient of determination ( $R^2 = 0.356$ ) reveals that 35.6% of the variance in VO<sub>2</sub> max can be explained by these two variables. This suggests that, although BMI and leg muscle strength are significant, other factors such as training methods, nutrition, genetics, and gender differences may also influence maximal oxygen uptake (Bafirman et al., 2023).

BMI and leg muscle strength interact complementarily to influence VO<sub>2</sub> max. An ideal BMI provides an optimal balance between body mass and energy efficiency, while strong leg muscles enhance movement stability, energy utilization, and muscular endurance (Ramirez et al., 2025; Khatun et al., 2025). Athletes with both balanced BMI and strong lower limbs tend to demonstrate higher metabolic efficiency, allowing oxygen to be effectively delivered to working muscles without causing premature fatigue.

Excessive BMI increases the energy demand for movement, reducing aerobic efficiency, while inadequate BMI may compromise cardiovascular and muscular support during high-intensity efforts (Kurniawan, Sumaryanto, et al., 2025). Proper management of BMI through targeted exercise and nutrition is therefore essential for optimizing VO<sub>2</sub> max and sustaining performance during competitions.

Leg muscle strength also supports aerobic capacity by improving oxygen delivery and utilization at the muscular level. Trained muscles exhibit higher capillarization and oxidative capacity, which allows for more efficient aerobic metabolism and increases VO<sub>2</sub> max (Ghayomzadeh et al., 2025; Takahashi et al., 2024). This reinforces the idea that lower limb strength is not only important for technical execution but also plays a key role in sustaining high-intensity performance.

Simultaneously, the combination of BMI and leg muscle strength enhances overall athletic performance. Athletes with optimal body composition and strong lower limbs can maintain consistent performance throughout a match, perform repeated explosive movements, and utilize oxygen efficiently (Valentino et al., 2025). The interaction between these variables highlights the importance

of an integrated approach to training, combining strength development with body composition management.

These findings have practical implications for volleyball coaches and trainers. Programs aimed at improving  $VO_2$  max should not only focus on aerobic conditioning but also include interventions to maintain an ideal BMI and develop lower limb strength systematically (Bourdier et al., 2025; Ramirez et al., 2025). Such a holistic approach ensures athletes are physically prepared to meet the demands of competitive volleyball.

In conclusion, this study confirms that BMI and leg muscle strength are significantly related to maximal oxygen uptake in volleyball athletes. While these variables explain a substantial portion of  $VO_2$  max variance, attention to other contributing factors such as individualized training, nutrition, and recovery strategies is necessary. Understanding the complementary relationship between body composition and muscular strength provides valuable guidance for optimizing endurance, performance, and injury prevention in volleyball athletes.

## Conclusions

Based on data management and analysis of the relationship between body mass index and leg muscle strength with maximum oxygen volume in volleyball, it can be concluded that there is a significant relationship or correlation between BMI and leg muscle strength with maximum oxygen volume in volleyball athletes. It is recommended that future researchers use a larger sample size and not only at the student level but also in volleyball clubs with various age groups. To further support the research results and novelty, further research needs to be conducted by adding dependent variables that include lower limb muscle explosive power, speed, balance, and flexibility in volleyball athletes.

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