

RELATIONSHIP BETWEEN ANTHROPOMETRIC PARAMETERS AND VERTICAL JUMP PERFORMANCE IN CADET VOLLEYBALL SELECTION ¹

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Abstract: Volleyball is a team sport played by two teams on a court divided by a net. It is an intense sport that combines vertical and horizontal movements, involving anaerobic energy systems with short recovery periods. The anthropometric characteristics of athletes are a significant prerequisite for successful engagement in a specific sport, influencing athletic performance and being essential for achieving elite sports skills. The aim of this study is to determine the relationship between anthropometric parameters and vertical jump performance in female volleyball cadets. A research study was conducted to assess motor abilities and physical characteristics of 40 female volleyball players. Anthropometric parameters, including body height, body mass, body fat percentage, muscle mass percentage, and body mass index, as well as arm span, were measured using appropriate instruments. Motor abilities were evaluated through a vertical jump test using the Opto-Jump system. Pearson correlation coefficients revealed significant positive correlations between countermovement jump (CMJ) and muscle mass percentage ($r=0.588$, $p<0.001$), arm span ($r=0.515$, $p<0.001$), body height ($r=0.502$, $p=0.001$), and body mass ($r=0.342$, $p=0.031$). Muscle mass percentage was identified as a statistically significant predictor ($B=1.488$, $p=0.004$), while arm span also showed a significant positive association with CMJ ($B=0.095$, $p=0.002$). Conversely, body mass ($B=0.233$, $p=0.146$) and body height ($B=-0.238$, $p=0.447$) were not statistically significant predictors in this model. The multiple regression analysis results indicate the statistical significance of the model ($F=6.667$, $p<0.001$), with a multiple correlation coefficient $R=0.660$. The findings of this study emphasize the need for a multidimensional approach in training processes, which should include not only physical conditioning but also biomechanical and technical factors.

Keywords: *volleyball, vertical jump, anthropometry, anthropometric parameters, plyometric training, jumps*

INTRODUCTION

Volleyball is a team sport played by two teams on a court divided by a net. It is an intense sport that combines vertical and horizontal movements, involving anaerobic energy systems with short recovery periods (Polglaze & Dawson, 1992; Gabbett & Georgieff, 2007; Sheppard et al., 2009). Most coaches and researchers agree that plyometric training (PT) is a method used to improve vertical jump ability and leg muscle strength (Ebben & Blackard, 2001; Ebben et al., 2004; Markovic et al., 2007; Simenz, et al., 2005).

When speed and agility are combined with maximum strength, the result is power (Saeed, 2013). For the lower limbs, PT involves performing various types of jumps using body weight, such as drop jumps, squat jumps,

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countermovement jumps (CMJ), alternating jumps, and other plyometric exercises involving stretch-shortening cycles (Fleck & Kraemer, 2004). PT is characterized by the use of stretch-shortening cycles (SSC), which occur during the transition from rapid eccentric muscle contraction (deceleration phase) to rapid concentric muscle contraction (acceleration phase) (Sole et al., 2022). SSC movements harness the elastic properties of connective tissues and muscle fibers, allowing muscles to store elastic energy during the deceleration phase and release it during the acceleration phase to increase muscle strength and force production (Morio, 2011; Davies et al., 2015).

Furthermore, PT induces numerous beneficial adaptations in the musculoskeletal and nervous systems, muscle function, and overall performance in healthy individuals. By enhancing SSC and related neuromechanical mechanisms, PT can potentially improve human athletic performance. Vertical jump is a fundamental component of attacking, blocking, and serving in volleyball. In top-level volleyball, jumping is also utilized when setting the ball, as it reduces the time the ball spends in the air, speeds up attacks, and complicates the opponent's first line of defense – their block to predict the attacking opponent's options.

The assessment of vertical jump performance in volleyball is an essential part of training and testing (Ziv & Lidor, 2010). In a five-set volleyball match, players from different positions perform between 65 and 136 jumps. On average, setters perform the greatest number of jumps, followed by middle blockers, opposite hitters, and outside hitters (Fontani et al., 2000). Additionally, scoring actions (e.g., serves, spikes, and blocks) are jump-dependent, with a typical team (~12 players) executing around 120,000 jumps during a season (Garcia-de-Alcaraz, 2020). According to the principle of training specificity, female volleyball players should systematically incorporate jump-based training programs.

Anthropometric characteristics of athletes are important prerequisites for successful competition in the sport, affecting athletic performance and being necessary for achieving exceptional skills. The physical attributes of volleyball players are mainly assessed by measuring anthropometric parameters such as height, body mass index, and other physical factors related to performance, including jumping ability, agility, strength, and endurance (Bayios et al., 2006; Ibrahim, 2010; Duncan, et al., 2006). In female athletes, the onset of pubertal growth spurt occurs around the age of 10, with adult height generally reached by the age of 14–15 (Malina et al., 2004). Pubertal growth in girls is accompanied by increased body fat, which can negatively impact sports performance (Rogol et al., 2002; Lidor & Ziv, 2010). Successful female volleyball players tend to have lower body fat percentages, as evidenced by differences in adiposity between first and second league players (Malousaris et al., 2008).

A frequently overlooked form of exercise is plyometric training (PT), which involves jumping exercises utilizing stretch-shortening cycles (Chen et al., 2023). Plyometric loading is especially effective for children and adolescents during periods of bone growth. Previous research has shown that plyometric training positively influences growth and development in adolescents (Kryeziu et al., 2023). Plyometric training can significantly improve jump capacity in adolescents (Coşkun et al., 2022), which is crucial for athletic success and overall health.

Lower limb strength and vertical jumps are key indicators of volleyball players' success (Stec & Smulsky, 2007). The average height of today's volleyball players has increased compared to previous periods and ranges between 195 and 200 cm (Ercolessi, 1999).

The aim of this study is to examine the relationship between anthropometric parameters and vertical jump performance in female cadet volleyball players. This information may provide valuable insight and reference values for talent identification and the evaluation of applied training programs. Participants

METHOD

Participants

This study was conducted with the aim of assessing the motor skills and physical characteristics of 40 female volleyball players aged 12 to 15, who trained four times per week and had an average of three years of experience playing volleyball. All participants were enrolled in the volleyball school "DIF." Standard training sessions lasted 90 minutes and included athletes with an average training history of 3 years (± 6 months) within the school. The sessions covered technical elements such as jumping, serving, receiving, and attacking, as well as strength training. Strength exercises targeted both the upper and lower body and were performed in 3–4 sets of 10–15 repetitions, with 1-minute resting intervals. The primary focus was on the development of and learning technique. Only athletes

without any injuries that could affect performance were included in the study. Anthropometric characteristics such as body height, body weight, body fat percentage, muscle mass percentage, and body mass index were measured using appropriate instruments – the Martin anthropometer and the Tanita body composition scale. Arm span was measured using a tape measure. These anthropometric parameters were selected as predictors of vertical jump performance due to their direct or indirect influence on the biomechanics and energy efficiency of jumping, while arm span may offer an advantage during the run-up and arm swing phases.

The testing was completed in a single day. Anthropometric measurements were taken first, prior to the assessment of motor skills. The measurements were carried out as follows:

- The Martin Anthropometer: Used to measure body height. The anthropometer is 2 meters long and marked in millimeters and centimeters. It was placed vertically behind the participant's back, ensuring contact at minimum one point. The examiner held the anthropometer with the right hand, adjusting the sliding ring with the thumb and the index finger, while the left hand positioned the horizontal bar at the crown of the participant's head.
- The Tanita Scale: This device uses a revolutionary bioelectrical impedance analysis method. It automatically measures body weight and fat percentage and uses a mathematical model to estimate deviations from ideal weight based on gender and age.
- Arm Span (AS): Measured by asking participants to extend their arms horizontally to the sides at maximum reach. The measurement was taken from behind using a tape measure.

Motor skill performance was evaluated using vertical jump tests on the OptoJump system.

Countermovement Jump (CMJ) (Figure 1): The jump was initiated from a squat position. No specific instructions were given regarding the depth or speed of the movement. The intra-class correlation coefficient (ICC) for test reliability and the typical measurement error for the vertical jump test were 0.96 and 2.9%, respectively.

Figure 1. Graphical Representation of the Countermovement Jump (CMJ) Test



The OptoJump system (Microgate, Italy) was used to assess the countermovement jump (CMJ). The OptoJump system consists of two portable bars equipped with 33 optical LED sensors spaced 3.125 cm apart along the transmitting bar. These LEDs continuously communicate with sensors on the receiving bar. The system detects any interruption in this communication and calculates its duration. This allows for precise measurement of flight and contact times during a series of jumps, with an accuracy of up to 1/1,000th of a second.

The collected data were analyzed using descriptive statistics. All measurements were presented using mean values, standard deviations, minimum and maximum values, correlation coefficients, and regression analysis. Microsoft Excel, ANOVA, and statistical software programs were used for data preparation and analysis. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Descriptive statistical analysis (Table 1) provides an overview of the sample of 40 participants for selected variables. The average body height (BH) was 155.6 cm, with a standard deviation of 10.4 cm, ranging from 134.9 cm to 176.9 cm. The average arm span (AS) was 156.4 cm (SD = 12.1 cm), with a range from 134.4 cm to 184.0 cm.

The average body mass (BM) was 48.8 kg, with a standard deviation of 11.8 kg. Minimum and maximum values were 30.5 kg and 72.3 kg, respectively. The average body mass index (BMI) was 19.9 kg/m² (SD = 3.1), with values ranging from 14.2 to 25.7 kg/m².

The average body fat percentage (BF%) was 20.9%, with a standard deviation of 6.9%, ranging from 7.7% to 33.9%. The average muscle mass percentage (MM%) was 34.8% (SD = 2.5%), with a minimum of 29.6% and a maximum of 39.4%.

Finally, the average countermovement jump height (CMJ) was 22.4 cm (SD = 5.7 cm), with the lowest recorded value at 9.8 cm and the highest at 34.0 cm.

Table 1. Descriptive Statistics Results

	<i>BH</i>	<i>AS</i>	<i>BM</i>	<i>BMI</i>	<i>BF</i>	<i>%M</i>	<i>CMJ</i>
<i>N</i>	40	40	40	40	40	40	40
<i>M</i>	155.6	156.4	48.8	19.9	20.9	34.8	22.4
<i>Max</i>	176.9	184.0	72.3	25.7	33.9	39.4	34.0
<i>Min</i>	134.9	134.4	30.5	14.2	7.7	29.6	9.8
<i>SD</i>	10.4	12.1	11.8	3.1	6.9	2.5	5.7

BH – body height; *AS* – arm span; *BM* – body mass; *BMI* – body mass index; *BF* – body fat percentage; *MM* – muscle mass percentage; *CMJ* – countermovement jump; *N* – number of participants; *SD* – standard deviation; *Min* – minimum; *Max* – maximum

Table 2 presents the Pearson correlation coefficients between the CMJ height and selected anthropometric variables, including body mass, muscle mass percentage, arm span, and body height. Significant positive correlations were observed between CMJ and muscle mass percentage ($r = 0.588$, $p < 0.001$), arm span ($r = 0.515$, $p < 0.001$), body height ($r = 0.502$, $p = 0.001$), and body mass ($r = 0.342$, $p = 0.031$). These results suggest that a higher muscle mass percentage, larger body dimensions, and greater body mass are associated with better jumping performance.

Table 2. Pearson Correlation Between CMJ and Selected Anthropometric Variables

<i>Variables</i>	<i>Correlation(r)</i>	<i>p-value</i>
<i>Body mass (kg)</i>	0.342	0.031
<i>Muscle mass (%)</i>	0.588	<0.001
<i>Arm span (cm)</i>	0.515	<0.001
<i>Body height (cm)</i>	0.502	0.001

Table 3 summarizes the results of the multiple regression analysis conducted to explore the relationship between the CMJ height (dependent variable) and body mass, muscle mass percentage, arm span, and body height (predictors).

The ANOVA results indicate that the model was statistically significant ($p < 0.001$). Muscle mass percentage was a statistically significant predictor ($B = 1.488$, $p = 0.004$), suggesting that a higher percentage of muscle mass is associated with greater CMJ height.

Arm span also showed a significant positive association with CMJ ($B = 0.095$, $p = 0.002$), indicating that individuals with greater arm span tend to achieve higher jumps.

Body mass ($B = 0.233$, $p = 0.146$) and body height ($B = -0.238$, $p = 0.447$) were not statistically significant predictors in this model, suggesting that their individual contributions become minimal when other variables are controlled.

The lack of statistical significance for body mass and body height in the regression model is likely due to the strong explanatory power of muscle mass percentage, which may have masked their effects.

Table 3. Multiple Regression Analysis

<i>Predictor</i>	<i>B</i>	<i>Std. Error</i>	<i>Beta</i>	<i>t</i>	<i>p-value</i>
<i>Body mass (kg)</i>	0.233	0.157	0.182	1.487	0.146
<i>Muscle mass (%)</i>	1.488	0.480	0.558	3.100	0.004
<i>Arm span (cm)</i>	0.095	0.031	0.310	3.100	0.002
<i>Body height (cm)</i>	-0.238	0.435	-0.076	-0.769	0.447

B – regression coefficient; *Std. Error* – standard error of estimate; *Beta* – standardized coefficient; *t* – t-value; *p-value* – level of significance

$$R=0.660 \quad R^2=0.436 \quad F=6.667$$

R – multiple correlation coefficient; **R²** – coefficient of determination; **F** – F-test for the relationship between the dependent variable and the set of independent variables

DISCUSSION

This study was designed with the aim of determining the relationship between selected anthropometric variables and vertical jump performance in female volleyball players. Understanding the differences in selected anthropometric variables is crucial for implementing training strategies and enhancing performance in volleyball. The study's findings were also considered when evaluating factors for player selection, including training experience, fitness, and more. These results can be utilized by coaches when selecting players for matches and designing training programs, keeping in mind the tactical plan for each athlete.

In modern volleyball, every team strives to achieve higher jumps, as actions like blocking and attacking become more complex for opponents when executed at greater heights. Therefore, more attention must be given to offensive actions such as attack, block, and serve, since the majority of points are gained through these actions. Moreover, the probability of winning increases with effective blocking, strengthening the team in these key actions.

In this study, we aimed to examine the impact of various anthropometric variables – body mass, muscle mass percentage, arm span, and body height – on the height of vertical jump. The results of Pearson's correlation coefficient revealed significant associations between these variables and jump height.

Body mass (BM) showed a significant correlation, where higher body mass may negatively affect jumping performance. However, our analysis did not reveal a strong negative correlation, likely due to the height and specific body structure of the participants. The correlation between body mass and CMJ was lower, indicating that body mass is not as critical as muscle mass in explaining jumping performance.

Muscle mass percentage (%M) showed a significant positive correlation with jump height. This can be explained by the fact that greater muscle mass contributes to increased muscle strength, which is essential for explosive vertical movements such as jumping (Bobbert & van Ingen Schenau, 1988). Greater muscle mass enables faster muscle contractions, thereby improving jumping performance.

Body height (BH) can be considered the most important physical attribute. However, a high jumping capacity can help compensate for a player's lack of height (Marques et al., 2009).

Arm span (AS) also showed a significant positive correlation. This can be linked to the biomechanics of movement, where a greater arm span allows for a more efficient use of arm swing during jumping. In another study (Reeves et al., 2008), it was hypothesized that a longer arm generates additional vertical acceleration due to a lon-

ger lever created by the arm swing. This explains the significant correlation between arm span and vertical jump observed in our research. The arm swing during a CMJ can increase take-off velocity by at least 6% compared to a jump without arm swing and increase jump height by 15% or more (Vaverka et al., 2016).

In a study by Pandey et al. (2016), the correlation coefficient between height and volleyball performance was significant at the 0.05 level, while the correlation between body mass and performance was not significant. In our study, the results of multiple regression indicate that body mass and height are not statistically significant predictors of vertical jump height when considered together with other variables. However, Pearson's test shows that body mass and height have significant individual effects. This suggests that their direct contribution is limited when other variables are controlled. This change implies that the relationship between height and vertical jump may be mediated or overshadowed by the combined effects of body mass and muscle mass. The lack of statistical significance may also indicate that body height and muscle mass are interrelated, where muscle mass is a more direct determinant of jump height, while height may play an indirect role.

The multiple regression results show that the model is statistically significant ($F=6.667$, $p<0.001$), with a multiple correlation coefficient $R=0.660$. The coefficient of determination ($R^2=0.436$) indicates that the proposed model explains 43.6% of the variability in CMJ height. The findings of this study are consistent with previous research (Stojanović et al., 2020), which also reported no significant association between body mass and vertical jump performance in adolescents. Our results align with those of earlier studies (Pérez-López et al., 2015; Davis et al., 2003), which also demonstrated that body mass does not have a significant impact on vertical jump. This is further supported by the findings of Marković and Jarić, who found that body mass is independent with vertical jump height.

Our results indicate that there is no significant association between body height and vertical jump performance in CMJ tests, in line with studies by Stojanović et al. (2020), Aslan et al. (2011) and Aragón-Vargas & Gross (1997).

CONCLUSION

Modern volleyball, due to the shorter duration of plays and increased game intensity, requires greater reliance on alactic anaerobic energy metabolism. This means there is a growing demand for athletes with improved fitness, who are also fast and capable of performing high jumps.

In this study, we aimed to explore the influence of different anthropometric variables – body mass, muscle mass percentage, arm span, and body height – on vertical jump height. Pearson's correlation coefficients revealed significant associations between these variables and vertical jump. However, the multiple regression results indicate that body mass and height are not statistically significant predictors of vertical jump height when considered alongside other variables.

Beyond the findings presented in this study, the results can be practically applied in the design of specific training programs aimed at improving vertical jump performance in volleyball players. These programs should primarily focus on increasing muscle strength and explosive power, rather than solely on body mass or height, as these variables did not demonstrate statistically significant roles as predictors.

This study has certain limitations, including a relatively small sample size and other potentially influential factors such as neuromuscular coordination and jumping technique. Future research should further investigate these aspects and consider a broader range of anthropometric and motor variables to provide a more comprehensive understanding of the determinants of vertical jump performance.

The results of this study highlight the need for a multidimensional training approach that includes not only physical conditioning but also biomechanical and technical factors. Such an approach can help optimize performance and reduce injury risk in modern volleyball, where athletes are expected to perform jumps with increasing intensity and precision.

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