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RELATIONSHIP BETWEEN BODY COMPOSITION AND VERTICAL JUMP PERFORMANCE AMONG ADOLESCENTS

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With the aim to investigate the relationship between the body composition of adolescents and their vertical jump performance, this research was carried out on a sample of seventh grade elementary school students (47 male students). The sample of measuring instruments for body composition assessment included: body height, body mass, sum of five skinfolds thicknesses (biceps, triceps, subscapularis, suprailiac, and calf), body fat percentage, and muscle mass percentage. The SJ and CMJ tests were used for the assessment of vertical jump performance. At the multivariate level the results showed that body composition, as a predictor system, explained 44% (p = .000) of the variance of SJ and 41% (p = .000) of the variance of CMJ. At the univariate level of it was noted that the sum of five skinfolds had a high influence on the predictor system for SJ (t = -3.77; p = .001) and also a high influence on CMJ (t = -2.98; p = .005). The sum of five skinfolds had a negative impact on SJ and CMJ tests for vertical jump performance assessment. It could be concluded that the relationship between body composition components and vertical jump performance was clearly demonstrated in adolescents.

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Key words: *relationship, body composition, vertical jump, adolescents*

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Introduction

Vertical jump performance is an important factor in many sports, and the increasing vertical displacement of an athlete can positively affect achievement in sports (1). Also, vertical jump performance is very often used for talent identification and prediction of future success in sports, especially among adolescents in sensitive periods, when growth and development occur very dynamically (2, 3).

Beside physiological and biomechanical factors, vertical jump performance is affected by various anthropometric characteristics (4, 5). Most of the studies report that well-developed muscle mass and low percentage of subcutaneous adipose tissue are predictors of good sport performance (6-8).

Body composition has been described as a confounding factor in vertical jump performance, and several studies have attempted to categorize those body composition variables which better explain jump ability during childhood and adolescence (9), and tried to determine the nature of the relationship between anthropometric factors and vertical jump performance (4, 5, 10-14).

Two studies have identified a significant negative relationship between the sum of skinfold thickness and vertical jump among karate athletes (12) and hockey and cycling athletes (5). Researchers have also suggested lower skinfold thickness is preferable as it indicates lesser fat mass which generates no power but has to be carried vertically while jumping. Similar results were found among recreational athletes (10), where body fat percentage is negatively related to vertical jump height. Marković and Jarić (11) investigate the relationship between vertical jump height and body mass, and the results show that body mass is independent of vertical jump height. Previous studies found no significant relationship between body height relative to vertical jump performance (10, 13, 15).

Anthropometry is considered a simple, inexpensive and easy-to-use method in epidemiological studies. Skinfold measurements provide excess weight information, and the sum of skinfolds indicates body fat distribution (16).

A reliable and valid approach for estimation of human body composition parameters is a technique known as bioelectrical impedance (BIA). This method is noninvasive, safe, provides rapid measurements, requires little operator skills and subject cooperation, and is portable (17).

The most commonly used tests for assessing explosive strength of the legs and jumping ability are the squad jump (SJ) and countermovement jump (CMJ). The SJ and CMJ tests are a simple, practical, valid, and very reliable measure of the lower body power compared to other jumping ability tests. The SJ is commonly used to test the concentric strength of the leg extensors, whereas the CMJ is used to measure the reactive strength of the lower body (18).

The aim

The aim of this study was to investigate the associations between body composition, the vertical jump performance of adolescents, and ability to predict SJ and CMJ from body composition variables.

Materials and methods

The sample of this study consisted of 47 7th grade elementary school male students, aged 13 years ± 6 months (BH: 165.44 ± 8.69 cm; BM: 56.62 ± 10.29 kg). The sample included every student who volunteered to participate in the research with the consent of their parents. An additional requirement was that students were clinically healthy during the testing.

All experimental procedures and possible risks and benefits were explained to each student. Signed consent was obtained from their parents prior to the onset of participation and approval to conduct the study was granted by school principals. The study protects the children's privacy by allowing for anonymity and was designed in compliance with the recommendations for clinical research of the Declaration of Helsinki (2013) of the World Medical Association. This study was also reviewed and approved by the Ethics Committee of the Faculty of Sport and Physical Education, University of Niš.

Body height (BH) was measured using the Martin anthropometer GPM 101 (GPM GmbH Switzerland), following standard procedures (19). Values of BH were measured and recorded in millimeters (mm). Body mass (BM) was measured with an accuracy of 0.1 kg with an electronic body weight scale Omron BF511 (Omron Healthcare Co, Kyoto, Japan). Skinfold thickness was measured using GPM 6100 (GPM GmbH Switzerland), with an accuracy of 0.2 mm at the biceps, triceps, subscapular, suprailiac and calf sites, according to the methodology recommended by the International Biological Program (20). A GPM caliper provides a constant pressure of 10g/mm^2. The measurement results were evaluated 2 seconds after the grip was caught on the skin. All five sites of skinfold thicknesses were summed up to provide the sum of skinfolds (SUM5). Body composition components, body fat percent (BF%), and muscle mass percent (MM%) were assessed using the BIA electronic scale Omron BF511. The participants were asked to avoid the following procedures before body composition measurement, as described by Rech et al. (21), not to perform any physical exercises 12 hours before testing, not to eat or drink anything during the four hours before the evaluation, to urinate at least 30 minutes before the evaluation, not to take any diuretics during the seven days prior to the test, and not to consume alcohol during 48 hours preceding the test.

Optojump (Microgate, Italy) is used for SJ and CMJ assessment. The Optojump system consists of 2 transmitting and receiving bars equipped with 33 optical Light-Emitting Diods (LEDs) fitted in the transmitting bar at 3,125 cm intervals. The LEDs on the transmitting bar communicate continuously with those on the receiving bar. The system detects any interruptions in communication between the bars and calculates their duration. This makes it possible to measure flight and contact times during the performance of a series of jumps with an accuracy of 1/1,000 of a second.

For the Sqaut Jump (SJ), the participants started from an upright standing position with their hands on their hips; they were then instructed to flex their knees and hold a predetermined knee position (~90^{O}) for a count of 3 s. At that point, the participants were instructed to jump as high as possible without performing any countermovement phase. For the Countermovement Jump (CMJ), the participants started from an upright standing position with their hands on their hips (i.e., without an arm swing); they were then instructed to flex their knees (~90^{O}) as quickly as possible, and then jump as high as possible in the ensuing concentric phase (22).

Statistical analyses

Descriptive statistics, the Kolmogorov–Smirnov (normality of the distribution), and Levene's (homogeneity of variance) tests were calculated for all experimental data before inferential testing. Pearson simple and partial correlation coefficients were used to determine the correlation between the predictor variables (BH, BM, SUM5, BF%, MM%) and criterion variables (SJ, CMJ). For the further investigation of the association and explanatory power of the predictor variables for criterion variable, a multiple linear regression analysis was used. Statistical procedures were performed using STATISTICA 10 (StatSoft Inc, Tulsa OK, USA) and the level of significance was set at $p \leq 0.05$.

Results

The Kolmogorov-Smirnov test showed that the data were normally distributed and no violation of homogeneity of variance was found using Levene's test. With the normal distribution of the results of BC, SJ, and CMJ assessment, it is possible to apply parametric statistical procedures. For determining the explanatory power of the predictor variables on the criterion variable, multiple linear regression analyses were applied. Selected BC predictor variables (BH, BM, SUM5, BF%, MM%) were included for building the initial regression models for prediction of SJ and CMJ as the criterion variables. The initial models were tested for assumptions for multicollinearity among predictor variables. The first step was the observation of the correlation matrix between the predictor variables. The correlation matrix showed that the variable BF% was in a high significant correlation with most of the predictor variables (BH, r =- 0.46; SUM5, r = 0.87; MM%, r = -0.96). The next step in the confirmation of the presence of multicollinearity was the observation of the variance inflation factor (VIF). After observation, the VIF value was high for BF% (VIF = 30.11); therefore, the presence of multicollinearity was confirmed for BF%. In the final step, BF% was excluded from the initial regression models due to multicollinearity with other variables from the predictor system. The remaining variables were included in the final regression models for further analysis. The results of this analysis are given in Table 1 for SJ, and Table 2 for CMJ.

Table 1 presents the results from the final regression model for SJ as a criterion. A statistically significant simple negative correlation was found between SUM5 and SJ, and a positive correlation between MM% and SJ. Furthermore, the analysis of partial correlation coefficients showed a statistically significant negative correlation between SUM5 and SJ. The multiple linear regression identified that BC components provided good explanatory power for SJ 44% (p = .000). The BC component with the highest explanatory power in the regression model for SJ was SUM5 (p = 0.001).

Table 1. Descriptive statistics, correlation coefficients and multiple regression model results for SJ

	Mean	SD	Min.	Max.	Beta	Part r	r	t(33)	p-level
BH (cm)	165.44	8.69	147.20	190.60	0.04	0.02	0.27	0.15	0.882
BM (kg)	56.62	10.29	38.70	78.00	0.31	0.18	-0.06	1.21	0.234
SUM5 (mm)	57.44	17.57	29.60	104.60	**-0.92**	**-0.50**	**-0.61**	**-3.77**	**0.001**
MM% (k%)	38.50	2.92	32.80	43.60	-0.23	-0.14	**0.50**	-0.89	0.378
SJ [cm]	22.70	4.86	8.90	30.90					
R = .66 R^2 = .44 F(4;42) = 8.26 SEE = 3.807 p = **.000***									

Legend: Mean - arithmetic mean; SD - standard deviation; Beta – standardized regression coefficient; Part r - partial correlation coefficient; r – simple correlation coefficient; R - coefficient of multiple correlation; R^2 - coefficient of multiple determination; F – F-test of the relationship between the dependent variable and the set of independent variables; SEE - standard error of estimate; p – coefficient of statistical significance of multiple regression.

Table 2. Descriptive statistics, correlation coefficients and multiple regression model results for CMJ

	Mean	SD	Min.	Max.	Beta	Part r	r	t(33)	p-level
BH (cm)	165.44	8.69	147.20	190.60	-0.07	-0.04	**0.30**	-0.25	0.804
BM (kg)	56.62	10.29	38.70	78.00	0.36	0.21	-0.02	1.38	0.176
SUM5 (mm)	57.44	17.57	29.60	104.60	**-0.75**	**-0.42**	**-0.58**	**-2.98**	**0.005**
MM% (k%)	38.50	2.92	32.80	43.60	0.01	0.00	**0.53**	0.03	0.976
CMJ [cm]	24.03	4.73	11.30	32.80					
R = .64 R^2 = .41 F(4;42) = 7.29 SEE = 3.806 p = **.000***									

Legend: Mean - arithmetic mean; SD - standard deviation; Beta – standardized regression coefficient; Part r - partial correlation coefficient; r – simple correlation coefficient; R - coefficient of multiple correlation; R^2 - coefficient of multiple determination; F – F-test of the relationship between the dependent variable and the set of independent variables; SEE - standard error of estimate; p – coefficient of statistical significance of multiple regression.

Similar results are presented in Table 2, where CMJ was the criterion variable. Statistically significant simple positive correlations were found between BH and MM% from the predictor system and CMJ, and a negative correlation between SUM5 and CMJ. Partial correlation analysis coefficients showed a statistically significant negative correlation only between SUM5 and CMJ. The multiple linear regression identified that BC components provided good explanatory power for CMJ 41% (p = .000). The BC component with the highest explanatory power in the regression model for CMJ was SUM5 (p = 0.005).

Discussion

The results of anthropometric measures obtained from our sample showed that the average age, BH, and BM were similar to the values obtained in similar studies (3, 5, 9, 23).

The purpose of this study was to examine the relationship between body composition components and the vertical jump performance of 13-year-old boys. The SJ and CMJ have widely been accepted as a criterion for the assessment of vertical jump performance.

The results obtained from simple correlation coefficients for SJ indicate a significant negative correlation between SUM5 and SJ (r = -0.61), and a significant positive correlation between MM% and SJ (r = 0.50). The results from the simple correlation coefficients for CMJ are very similar with the previously outlined results for SJ in Table 1. A significant negative correlation was found between SUM5 and CMJ (r = -0.58), and significant positive correlations were found between MM% and CMJ (r = 0.53), and BH and CMJ (r = 0.30). These results were expected and support the findings of many previous studies which found similar correlation coefficients between body fat, muscle mass, and vertical jump performance (3-5, 9, 10, 12, 15, 23-26).

After the exclusion of BF% due to multicollinearity, all other body composition components were analyzed in order to explain the SJ and CMJ variation of adolescents included in this study.

At the multivariate level, the results showed that body composition, as a predictor system, explained 44% (p = .000) of the variance of SJ and 41% (p = .000) of the variance of CMJ. At the univariate level it was noticed that the sum of five skinfolds (biceps, triceps, subscapular, suprailiac and calf), with a significant negative partial correlation (SJ: Part. r = -0.50; CMJ: Part. r = -0.42) and a strong beta coefficient (SJ: Beta = -0.92; CMJ: Beta = -0.75), had a high influence on the predictor system for SJ (Table 1: t = -3.77; p = .001), and also a high influence on CMJ (Table 2: t = -2.98; p = .005). The sum of five skinfolds had a negative impact on SJ and CMJ tests for vertical jump performance assessment and represents a body composition marker that had the highest predictive power for SJ and CMJ.

The best explanatory power of SUM5 for predicting SJ and CMJ may indicate that using the sum of five sites of the skinfolds is more accurate for estimating the influence of total body fat on vertical jump performance, as fat distribution does not occur in a similar way for individuals. These results can be explained by the fact that body fat percentage is a good indicator of the total amount of adipose tissue in the body, but not the distribution of adipose tissue, while anthropometric measures of skinfolds are good indicators of body fat distribution in the body (27). When using the sum of these skinfolds, it is possible to clearly see the trend of global accumulation of body fat (16). Our data indicate that the participants have much more subcutaneous adipose tissue on their abdominal region (suprailiac skinfold) than the others skinfold sites.

The participants with lower body fat demonstrated the highest vertical jump performance, especially in SJ, in accordance with higher negative simple and partial correlation coefficients between SUM5 and SJ, as compared to SUM5 and CMJ. That can be explained by the difference in vertical jump techniques that are not biomechanically similar for SJ and CMJ (28). Hip extension velocity and trunk angular displacement are essential for jump height during the propulsive phase of the CMJ test (29). According to Piucco and Santos (25), excess body fat induces an increase in body mass which results in a loss of athletic performance in movements that involve speed and explosive power, such as jumps, since acceleration is equal to force divided by mass (30). It can be stated that lower subcutaneous adipose tissue, especially in the trunk region, is a desirable body composition component, since it means less ballast mass (fat) which generates no power. Thus it provides a lighter body mass to be carried and allows a higher vertical velocity to be achieved during jump performance (12).

The results of this study suggest that there is no significant relationship between body mass and vertical jump performance among adolescents. Our findings are similar to those of previous studies (4, 9, 10), which also showed that body mass has no significant bearing on the vertical jump. This is supported by the findings of Marković and Jarić (11), who studied the relationship between vertical jump height and body mass, where the result showed that body mass is independent of vertical jump height.

Our results indicate no significant relationship between body height relative to vertical jump performance on the SJ and CMJ tests, in accordance with previous studies (10, 13, 15), except a weak but still significant simple correlation that was found between BH and CMJ. Based on the conclusions of Maćkala et al. (31), that the highest correlation exists between body height and trunk length (r = 0.93), our assumption leads us again to propulsive phase of the CMJ test where trunk angular displacement is crucial for jump height (29).

Conclusion

From the obtained results it could be concluded that the relationship between body composition components and vertical jump performance was clearly demonstrated among the adolescents. With the exception of BH, BM, and MM%, the remaining predictor, SUM5, was able to explain the SJ and CMJ variation among the adolescents in this study. The sum of biceps, triceps, subscapularis, suprailiac, and calf skinfolds showed the best power to explain vertical jump performance with a negative impact on SJ and CMJ values among the adolescents. However, this study has some limitations which have to be pointed out. The sample included only seventh grade students, and only field tests were used to estimate body composition. Future studies should be conducted including the same and other samples by using direct measures of body composition, such as computed tomography and magnetic resonance imaging, in order to develop more accurate regression models. Also, we must consider that the participants in this study were adolescents in sensitive periods, when growth and motor skill development occur very dynamically, so the obtained results are valid only for the same age groups. Future studies can be done to evaluate further influence of each skinfold site on vertical jump performance, to obtain more accurate information.

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RELACIJE IZMEĐU TELESNE KOMPOZICIJE I VISINE VERTIKALNOG SKOKA KOD ADOLESCENATA

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Sa ciljem da se utvrde relacije između telesne kompozicije i visine vertikalnog skoka kod adolescenata, sprovedeno je istraživanje na uzorku učenika sedmog razreda (47 dečaka). Uzorak mernih instrumenata za procenu telesne kompozicije je bio sačinjen od: telesne visine, telesne mase, sume pet kožnih nabora (tricepsa, bicepsa, leđa, trbuha i potkolenice), procenta masnog tkiva i procenta mišićnog tkiva, kao sistem prediktorskih varijabli. Kao kriterijumske varijable, visina skoka iz čučnja (SJ) i visina skoka iz čučnja sa pripremom (CMJ) primenjeni su za procenu visine vertikalnog skoka. Na multivarijantnom nivou, rezultati su pokazali da komponente telesne kompozicije, kao prediktorski sistem, objašnjavaju 44% (p = ,000) varijanse SJ i 41% (p = ,000) varijanse CMJ, kao kriterijuma. Na univarijantnom nivou uočeno je da suma kožnih nabora ima najveći uticaj u prediktorskom sistemu za kriterijum SJ (t = -3,77; p = ,001), kao i za kriterijum CMJ (t = -2,98; p = ,005). Suma kožnih nabora ima negativan uticaj na visinu vertikalnog skoka SJ i CMJ. Može se zaključiti da postoje značajne relacije između komponenti telesne kompozicije, kao prediktora, i visine vertikalnog skoka, kao kriterijuma, kod adolescenata.

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Ključne reči: *relacije, telesna kompozicija, vertikalni skok, adolescenti*