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THE INTERDEPENDENT INFLUENCE OF BIA WITH KINEMATIC AND KINETIC VERTICAL JUMPING PARAMETERS

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Abstract: The aim of this study was to examine the relationship of various bioelectrical impedance analysis (BIA) body composition variables with kinematic and kinetic variables that were measured in vertical jumping task, in students of faculty of sport and physical education. The sample included 7 participants (6 males and 1 female, age 24.25±3.97 years, height 183.4±12.48 cm, weight 77.9± 13.36 kg, body mass index 23.0±1.46 kg/m2). BIA body composition variables (intra-celular water-ICW, extra-celular water-ECW, proteins-PRT, minerals-MIN, body fat mass-BFM, skeletal muscle mass-SMM, visceral fat are-VFA) were measured via InBody 720, while kinematic and kinetic variables (maximal jump force-Fmax, maximal jump power-Pmax, maximal jump velocity-Vmax, concentric action jump time-T) were measured on force plates. Pearson correlation analysis revealed that significant association was established between: Fmax with BH, BM, ICW, ECW, PRT, and MIN, and Pmax with BH, BM, ICW, ECW, PRT, MIN, and SMM, while Vmax and T failed to made im-pact on BIA variables. Backward regression analysis (r2) identified BM as the most important deter-minants of Fmax (r2=0.878), and Pmax (r2=0.951), and BH and BMI as the most important dete-rminants of Vmax and T (Vmax:r2 0.564, T:r2=0.348). The present results suggest two important findings: 1) body mass plays crucial role in jumping maximal force and power manifestation; 2) body height and body mass index are the best BIA determinants of jumping velocity and time characteristics.

Keywords: body mass, body fat mass, skeletal muscle mass, force, power

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Introduction

Body composition is vital in sport training science, especially for athletes, as its various parameters play a crucial role in optimizing performance and evaluating the effects of training process (Santos et al., 2020). Precise measurement of these parameters enables athletes and coaches to adapt training process and nutrition strategies effectively, which affects training and competition performance. Body composition parameters plays a significant role in understanding the physiological adaptations during sport training (Nunes et al., 2019).

Generally, there are several methods of morphology measurement and data collection. The most widely used are body height and mass, and body mass index; while also widely used are morphology measures derived from bioelectrical impedance analysis (BIA) — body fat mass and percentage, muscle mass and percentage, free fat mass, and other measures such as skinfold measures (de Andrade Goncalves et al., 2017). As above-mentioned, InBody 270 multi-frequency body composition analyzer is widely used, very practical and precise instrument. BIA devices, which use electrical impedance to measure body composition, are often marketed as reliable. This is happened by sending a low-frequency electrical current through the body, and the resistance encountered by this current is used to predict the amount of body fat. They use certain proprietary algorithms to measure total body fat and lean tissue mass (muscles, bones, and other tissues), offering simplicity and practicality for athletes and related professionals (Aanstad et al., 2014). Even though it is a safe, non-invasive, cost-effective, and easily transportable technique, this method is not perfect, as it has its own flaws. It has been shown that is affected by the body's hydration level, as this can make impact on electrical conductivity of biological tissues (McLester, 2020).

The vertical jump (VJ) is considered as a motor performance that involves all lower limb joints in various recreational activities, sports modalities, and training programs (Arakawa et al., 2013). This task is considered a method of testing power and other kinetic and kinematic variables that affects muscular performance in lower limbs (Gutiérrez dávila et al. 2014). Among several jump technique variations (i.e., squat jump, horizontal jump, ballistic jump, etc.), the more commonly utilized due to his association with specific sports movements and easy familiarization is countermovement Jump (CMJ). CMJ start position is considered by a upright stance position with hand on the hips, followed by flexion (eccentric phase) and extension (concentric phase) of the knees and hips (Gheller et al., 2014). The main representative of this jump is the transfer of elastic energy through the eccentric-concentric cycle and eliciting superior activation of muscle spindle that allows more power in the CMJ (Dowling & Vamos, 1993). To evaluate the coordination and intervenient factors related to VJ, different kinetic and kinematic components have been used. Variables as maximal and mean power, force, velocity and time, along with rate of force development are used in describing jumping performance (Moura & Okazaki, 2022).

In available literature there is no much data concerning analyzing possible relations of BIA derived morphology variables and VJ variables. The available literature has shown that VJ performance (Pmax and Hmax) was correlated with lean body mass, fascicle length, and type II fiber cross-sectional area (Methenitis et al., 2015). Some other researches have found associations between lean body mass and maximal force and power (Legg et al., 2021), and between jump height and body composition, in vertical jumping (Perez-Lopez et al., 2015). This means that there is a lack of researches that have been analyzing relationships among BIA (i.e., intra-cellular water, extra-cellular water, proteins, minerals, body fat mass, skeletal muscle mass, visceral fat area) and VJ (i.e., maximal force, power and velocity) parameters.

In accordance with the above shortcomings, the aim of this study was to examine the relationship of various BIA body composition variables with kinematic and kinetic variables that were measured in vertical jumping task, in students of faculty of sport and physical education. This study seeks to provide clearer insights of influence of body composition on VJ performance.

Methods

Participants

This study hired a cross-sectional research design. The sample consisted of 7 participants (6 males and 1 female). The participants had an age of 24.25 ± 3.97 years, body height (BH) of 1.84 ± 0.06 m, body mass (BM) of 82.54 ± 6.51 kg, and body mass index (BMI) of 24.43 ± 1.73 kg/m^2. All participants were recruited voluntarily and were provided with comprehensive information about the study's purpose, procedures, and potential risks. The written informed consent, a cornerstone of ethical research, was obtained from each individual, ensuring that the study adhered to the highest ethical standards.

Experimental design

This study, of a cross-sectional design, explored the relationship of different BIA body composition measures with kinetic and kinematic measures in vertical jumping task. The participants attended one familiarization session followed by four one experimental sessions with at least 3 days of rest before experimental session.

Procedures

All measurements were conducted in the morning during the spring of year 2021. The experiment was conducted in the spring between 9 a.m. and 14 p.m. in the laboratory facility that was maintained at the air temperature between 18 and 22 °C. The participants were asked to refrain from strenuous activity for five days before and after each experimental session. They were also performed in the morning under fasting conditions to minimize the potential influence of recent food intake and hydration status on the outcomes. Participants were instructed to refrain from consuming alcohol or caffeine and engaging in any vigorous physical activity for at least 24 hours before the assessment to ensure optimal standardization and accuracy of the collected data.

Familiarization session. The familiarization session was designed to collect standard anthropometric measures and to inform the participants about the procedures (i.e., type of exercise performed). Anthropometric measures were taken by the same experimenter according to the standard procedures recommended by the International Society for the Advancement of Kinanthropometry (Norton, et al., 2000). Body height and body mass were measured to the nearest 0.5 cm and 0.1 kg, respectively. Thereafter, body mass index (BMI) was also calculated. On this session from participant were also collected body composition measures from the BIA InBody 270 analyzer, which provides various body composition measurements for study aim examination.

Experimental session. Prior to experimental session, 15-minute warm-up was executed (i.e., 5-minute bicycle-ergometer riding, 5-minute dynamic stretching, and 5-minute individual preparation). This was followed with 15 CM with 10 seconds of rest between them. Then, participants were allowed a 5-minute rest before performing 3 consecutive CMJ, from which kinetic and kinematic variables were calculated. In experimental session, this VJ have performed in a way that for every jump is granted for 3 seconds to perform eccentric phase, concentric phase, jump phase, landing phase, and then returning to initial phase. CMJs were performed through specific procedures described elsewhere (Arsenijević et al., 2023).

Data analysis

Equipment and instruments. We measured body composition using BIA with InBody 270 device that used Tetapolar 5 points by tactical electrodes system with DSM-BIA (Direct Segmental Multifrequency Bioelectrical Impedance Analysis) (Biospace Co, Ltd., Seoul, Korea). Inbody 270 device demonstrated high test-retest reliability and accuracy (ICC 0.9995). It is regarded to be highly statistically reliable and valid for measuring both overall and segmental body composition in female and male athletes (Dopsaj et al., 2020). The kinetic and kinematic data were collected via two force plates (dimensions 0.4 x 0.6 m, INC., Newton MA, USA) on which participants performed CMJs following the guidelines provided by Vanrenterghem, De Clercq, and Van Cleven (2001). Signals were collected with ground reaction forces frequency at 1 kHz. Raw data were processed using LabVIEW custom designed program for this experiment (LabVIEW version 18.0, National Instruments Corporation, Austin, TX, USA), by which corresponding kinetic and kinematic variables were calculated.

Body composition variables. BH—body height, cm; BM—body mass, kg; BMI—body mass index: BM (body mass, kg)/BH2 (body height, m), kg Body mass·m−2; ICW – intra-cellular water, l; ECW – extra-cellular water, l; PRT – proteins, kg; MIN – minerals, kg; BFM—body fat mass, kg; SMM — skeletal muscle mass, kg; VFA – visceral fat area, cm^2.

Kinetic and kinematic variables (KKV). We assessed kinetic and kinematic variables during concentric jump phases and calculated maximal force (Fmax), maximal power (Pmax), and maximal velocity (Vmax). From 3 performed CMJs were determined KKV, and their average value was used for further analysis and calculation for all of three variables (i.e., Fmax, Pmax and Vmax) (Moreno et al., 2014).

Statistical Analysis

Descriptive statistics were calculated for all measured variables, including average value (Mean), standard deviation (SD), minimum (Min) and maximum values (Max), and coefficient of variation (cV%).

Correlation coefficient (r) was used to establish associations between body composition variables and each KKV. Statistical significance was set at $p < 0.05$. Coefficient of determination (r^2) and its equation were also reported on scatter plots to express the proportion of shared variance between devices. A backward multiple regression was performed to determine the best fitting model for each KKV. Prior to regression analysis, multicollinearity was examined using a variance inflation factor (VIF), and any variable that had a VIF of 5 or higher was excluded from the model (Kojic et al., 2023).

The strength of the correlation coefficients was interpreted following the classification proposed by Hopkins et al. (2015): trivial (< 0.1), small (0.1), moderate (0.3), high (0.5), and extremely high (0.9).

Results

Table 1. Descriptive statistic of body composition and kinetic and kinematic variables

	Mean	SD	Min	Max	cV%
BH (cm)	183.4	12.5	164.0	201.5	6.8
BM (kg)	77.9	13.4	54.2	94.5	17.2
BMI (kg/m2)	23.0	1.5	20.2	24.9	6.4
ICW (l)	32.4	7.1	19.5	41.1	21.7
ECW (l)	19.0	4.0	11.8	24.2	21.2
PRT (kg)	14.0	3.0	8.5	17.7	21.5
MIN (kg)	4.8	1.0	3.1	6.2	21.0
BFM (kg)	7.6	2.5	5.1	11.3	32.3
SMM (kg)	40.3	9.2	23.5	51.6	22.7
VFA (cm2)	26.5	13.6	11.2	43.6	51.3
Fmax (N)	1834.3	441.2	1037.4	2350.8	24.1
Pmax (W)	3753.1	972.4	2112.1	4844.2	25.9
Vmax (m/s)	2.6	0.3	2.3	3.0	9.9

BH - body height; BM - body mass; BMI - body mass index; ICW - intra cellular water; ECW - extra cellular water; PRT - proteins; MIN - minerals; BFM - body fat mass; SMM - skeletal muscle mass; VFA - visceral fat area; Fmax - maximal jump force; Pmax - maximal jump power; Vmax - maximal jump velocity

Descriptive statistics parameters (Mean, SD, Min, Max, and cV%) for body composition variables (BH, BM, BMI, ICW, ECW, PRT, MIN, BFM, SMM VFA) and KKV variables (Fmax, Pmax and Vmax) are displayed in Table 1. Correlation matrix information's are displayed in Table 2. Along with values of r, also significance values (p) provided.

Table 2. Correlation matrix of morphological characteristic BIA variables with kinematic and kinetic variables

		BH (cm)	BM (kg)	BMI (kg/m²)	ICW (l)	ECW (l)	PRT (kg)	MIN (kg)	BFM (kg)	SMM (kg)	VFA (cm²)
Fmax (N)	*r*	0.883	0.937	0.790	0.919	0.909	0.922	0.902	-0.530	0.918	-0.437
	p	0.008	0.001	0.034	0.003	0.004	0.003	0.005	0.220	0.004	0.327
Pmax (W)	*r*	0.942	0.975	0.745	0.960	0.964	0.962	0.953	-0.599	0.959	-0.503
	p	0.001	0.000	0.054	0.000	0.000	0.000	0.001	0.155	0.001	0.245
Vmax (m/s)	*r*	0.693	0.743	0.634	0.714	0.716	0.720	0.690	-0.343	0.712	-0.268
	p	0.085	0.056	0.125	0.072	0.070	0.068	0.086	0.451	0.073	0.562

BIA - bioelectrical impedance analysis; BH - body height; BM - body mass; BMI - body mass index; ICW - intra cellular water; ECW - extra cellular water; PRT - proteins; MIN - minerals; BFM - body fat mass; SMM - skeletal muscle mass; VFA - visceral fat area; Fmax - maximal jump force; Pmax - maximal jump power; Vmax - maximal jump velocity; T - concentric action jump time

Additional regression analysis (backward regression model), have revealed the best-fitting model with BM, as independent variable, in describing Fmax as dependent variable. This model has explained about 88% of the named dependent test (BMI: p=0.002), and equation and r2 value are shown in on Figure 1. When it comes to the best fitting model on Pmax as dependent variable, backward regression analysis has singled out BM as the variable that has explained approximately 95% of the named variable (BH: p = 0.000). The equation of this model and r2 value have been shown on Figure 2. In the case of the Vmax, as dependent variable, in this model BH and BMI variables fitted with describing around 56% of variance (BH and BMI: p > 0.05). This model equation and r2 value are presented on Figure 3.

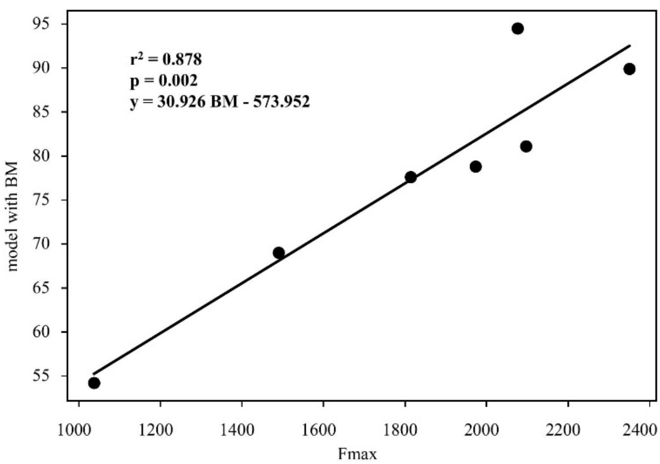

Figure 1. Best-fit regression models with body mass (BM - expressed in kg), predicting maximal force (Fmax - expressed in newton (N)), in vertical jumping task

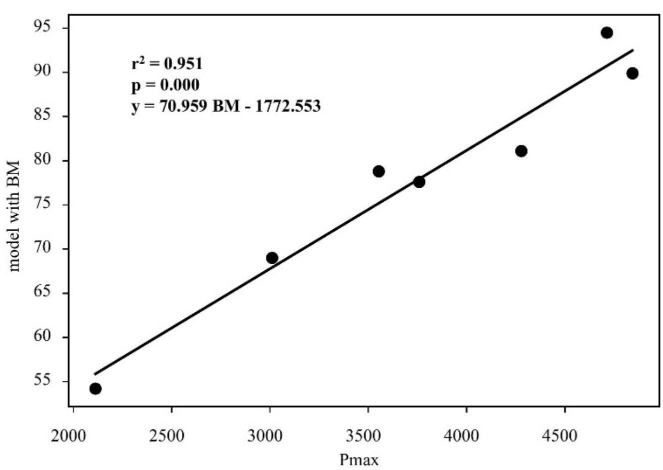

Figure 2. Best-fit regression models with body mass (BM - expressed in kg) predicting maximal power (Pmax - expressed in watts (W)), in vertical jumping task

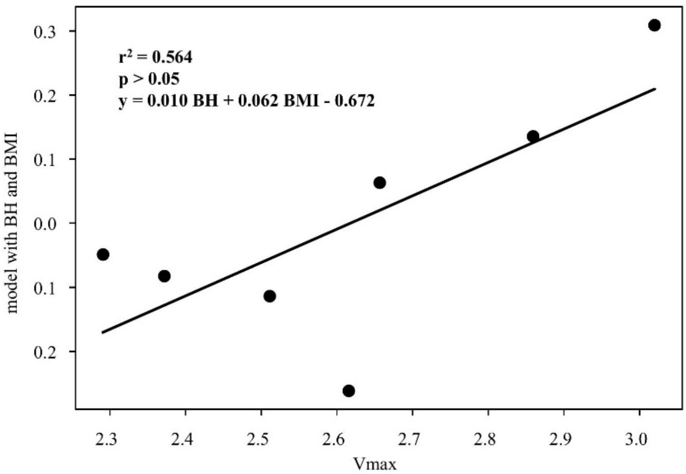

Figure 3.

Best-fit regression models with body height (BH – expressed in cm) and body mass index (BMI – expressed in kg/m2) predicting maximal power (Pmax - expressed in watts (W)), in vertical jumping task

Discussion

This research aimed to assess the relationship of various BIA body composition variables with kinematic and kinetic variables that were administered in vertical jumping task, in students of faculty of sport and physical education. Generally speaking, it was expected that present findings will provide insights into the influence of body composition variables on kinetic and kinematic variables measured in performing vertical jumping task (i.e., counter-movement jump). The results have showed that there in case of Fmax and Pmax variables, all body composition variables, except of VFA and BFM were significantly correlated ($p < 0.05$), and in a case of Vmax all body composition variables stayed out of significance ($p > 0.05$).

Initially, variable Fmax (i.e., maximal force) have showed extremely high association with most of body composition variables BM, ICW, ECW, PRT, MIN and SMM. Further, the same variable accomplished high correlation with BH, BMI and BFM and moderate with VFM. It is worth of mentioning that all variables, but BFM and VFA (i.e., which were negatively correlated), made positive relations with Fmax (i.e., BH, BM, BMI, ICW, ECW, PRT, MIN and SMM). Subsequent backward regression analysis demonstrated that BM is the best determinant of Fmax in vertical jumping task in measured students of Faculty of Sport and Physical Education population. In previous findings there is data of relationships of body composition variables with jump height in vertical jump task (Perez-Lopez et al., 2015), and only one research has found where relationship between Fmax with some of body composition have been examined (Legg et al., 2021). In mentioned research total lean mass showed highest relationship with Fmax (i.e., r =

0.68). Concerning Fmax in context of relationship with body composition results of the present study unequivocally indicate that body composition influence on the maximal force in vertical jump performance, or more specifically in a highest share of body mass, extra and intra-cellular water, protein, mineral and skeletal muscle mass.

From the perspective of maximal power (i.e., Pmax variable), results of conducted correlation analysis have showed an extremely high association of Pmax with BH. BM, ICW, ECW, PRT, MIN and SMM. High correlations were observed in Pmax with BMI, BFM and VFA. Studies that have examined relationship between Pmax and body composition variables showed similar (Legg et al., 2021). Like in findings in Fmax, total lean mass was the highest determinant of Pmax in vertical jump demand. In accordance with exposed findings, it can be said that maximal power in vertical jumping is on the highest level influenced by body height and mass, intra and extra-cellular water, proteins, minerals and skeletal muscle mass.

Regarding maximal velocity (i.e., Vmax) measure, high associations were found with BH, BM, BMI, ICW, ECW, PRT, MIN and SMM, while moderate and negative were with BFM, and small and also negative with VFA. Unfortunately, we failed to find any data in available research that have examined relationship between maximal velocity and body composition variables in vertical jumping task or testing. Overall, maximal velocity in vertical jumping is the most connected with body height and mass, body mass index, extra- and intra-cellular water, proteins, minerals and skeletal muscle mass.

The present study provides important theoretical implications, since our findings suggest that vertical jump performance is greatly influenced by body composition. As it was expected and already found in available literature (Perez-Lopez et al., 2015; Legg et al., 2021), majority of variables were positively corelated with kinetic and kinematic measures, except for variables that estimates fat mass (i.e., BFA and VFA), which were negatively associated. This was anticipated as more fat mass negatively influence vertical jump task performance. Another thing that is debatable is lack of significant correlations between maximal velocity and body composition variables. This could be explained by small sample in this study, and more participants would probably change this picture. Unavailability of other studies that compared Vmax with body composition does not allow us to make comparation with other studies in this case Moreover, this is the first study that explored and confirmed potential dependence of body composition on maximal force, power and velocity, as body composition affects every sport performance that request performing power. Regarding the study limitations, its fair to say that we had a small sample of subjects, and more subject and possible elite sport population could strengthen the research data.

Conclusions

To conclusion, our study emphasizes the importance of body composition on kinetic and kinematic variables in performance of vertical jumping task (i.e., counter-movement jump), since the obtained findings unequivocally suggest that the most off body composition measures significantly influenced maximal force and power. This cannot be claimed for maximal velocity as there was no significant correlation established. Namely, the most of the used body composition measures were positively corelated with kinetic and kinematic variables, and only body fat mass and visceral fat area were negatively corelated. Therefore, it appears that the structure of the body has a great implication when vertical jump task is performed, and the present study provides important findings about measures derived from BIA and these findings can serve practitioners for analyzing the advantages for performance of vertical jumping.

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