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Original

RELACIÓN ENTRE CARACTERÍSTICAS MORFOLÓGICAS Y HABILIDADES FUNCIONALES EN ESTUDIANTES FÍSICAMENTE ACTIVOS

THE RELATIONSHIP BETWEEN MORPHOLOGICAL CHARACTERISTICS AND FUNCTIONAL ABILITIES IN PHYSICALLY ACTIVE STUDENTS

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RESUMEN

El objetivo de este estudio fue determinar la relación entre las características morfológicas y el consumo máximo de oxígeno (VO_2max) de estudiantes físicamente activos. La muestra incluye 90 hombres (20,91±2,11 años) y 20 mujeres (20,51±1,57 años) estudiantes de la Universidad de Belgrado. La composición corporal fue medida empleando InBody72, con 9 variables usadas para definir el estatus morfológico y el test de Course-Navette para estimar el consumo máximo de oxígeno. Se realizaron análisis estadísticos en SPSS 21.0, mientras que análisis de regresión múltiple (MRA) fue usado para definir modelos multivariante entre la variable criterio (VO_2max) y el conjunto de variables morfológicas predictivas. Los varones mostraron un VO_2max más alto en comparación con las hembras (48,33 vs. 38,54 mlO_2/kg/min, $p<0,05$). Se encontró una pequeña correlación significativa entre la masa corporal y VO_2max ($r \sim 0,3$, $p < 0,01$) en varones, mientras que en hembras la altura corporal mostró una correlación media con VO_2max. En ambas muestras, variables de grasa corporal mostraron una correlación significativa con VO_2max en el rango de r = 0,261 a 0,545 ($p < 0,05$). Además, el porcentaje da masa muscular también mostró una correlación con VO_2max en ambas muestras, mientras que la masa muscular esquelética no mostró una correlación significativa. El modelo predictivo de regresión fue más preciso en hembras que en varones. Nuestros resultados sugieren que la mayoría de las características morfológicas no afectan al sistema cardiorespiratorio y no tienen un gran impacto en el valor de VO_2max.

Palabras clave: Composición corporal, Course-Navette, consumo máximo de oxígeno, actividad física, test

ABSTRACT

The aim of this study was to determine the relationship between morphological characteristics and maximal oxygen consumption (VO_2max) in physically active students. The sample included 90 male (20,91±2,11 years) and 20 female (20,51±1,57 years) University students from the first to the fourth year of undergraduate studies. Body composition was measured using InBody720, with 9 variables used to define the morphological status and a Shuttle run test used to estimate maximal oxygen uptake. Statistical analyses were performed in SPSS 21.0, while multiple regression analysis (MRA) was used for defining multivariate models between the criterion variable (VO_2max) and a set of predictive morphological variables. The males showed higher VO_2max compared to females (48,33 vs. 38,54 mlO_2/kg/min, $p<0,05$). Small significant correlation was found between body mass variables and VO_2max ($r \sim 0,3$, $p < 0,01$) in the male sample, while in the female sample body height showed medium correlation with VO_2max. In both samples, body fat variables showed significant correlation with VO_2max in range from r = 0,261 to 0,545 ($p < 0,05$). Furthermore, the percent of muscle mass also showed correlation with VO_2max in both samples, while skeletal muscle mass showed no significant correlation. Predictive regression model was more accurate in females than in males. Our results suggest that the majority of morphological characteristics do not affect the cardiorespiratory system and do not have a large impact on the value of VO_2max.

Keywords: Body composition, shuttle run, maximal oxygen uptake, physical activity, test

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INTRODUCTION

Cardiorespiratory fitness represents the ability to perform large-muscle, dynamic, moderate- to high-intensity exercise for prolonged periods of time (Pate et al., 1995), while maximum oxygen uptake or VO_2max is a globally accepted parameter for the evaluation of an individual's cardiorespiratory fitness (Bandyopadhyay & Chatterjee, 2003). On the other hand, individual characteristics of endogenous and exogenous factors largely determine a person's morphological characteristics (Malkogeorgos et al. 2010). At a macro level, the human body is composed of four large measurable components (fat, water, minerals and protein). The relationship between VO_2max and the different components of body composition has been reported by many scientists over the last few decades (Buskirk & Taylor, 1957; Parízková et al., 1971; Novak et al., 1978; Sharp et al., 1992; Watanabe et al., 1994).

The status of body composition can be determined by applying direct and indirect methods of measuring (Heymsfield et al., 2005; Röthlingshöfer et al., 2011; Koley et al., 2012). Bioelectrical impedance analysis is a simple, fast and non-invasive method for evaluation of body composition (Ling et al., 2011; Dopsaj et al., 2015). The procedure involves a flow of safe, low-level electric current (800 µamp) through a human body. The results obtained through this procedure represent a measure of impedance or resistance of electric current as it travels through the water found in muscles and fat. Biospace InBody720 Body Composition Analyzer has previously been shown to have high test-pretest reliability and accuracy (ICC 0.9995) (Gibson et al. 2008).

University students represent a unique group of young people in the final phase of biological, social and professional maturation (Tarnus & Bourdon, 2006; Wardle et al., 2006). Nowadays, students are increasingly faced with pressure and stress, but it has been found that physical activity reduces stress and depression among this group (Shashank et al., 2013). Most European countries still recommend adults to have "at least 30 minutes of physical activity 5 days a week", while some countries recommend even longer durations (Kahlmeier et al., 2015).

Despite recommendations and warnings from the World Health Organisation, the situation regarding physical activity does not seem to change, especially among University students. The results of a recent study support this claim. Namely, Dopsaj et al, (2019) concluded that 91,2% of female students are physically non-active, which leads to the occurrence of body fat surplus and muscle mass deficit. Novak et al. (2015), also point out the difference between Croatian and Lithuanian students. The results of their research show that Croatian students have higher body mass and BMI values compared to Lithuanian students who have better scores on tests of explosive power and muscle endurance (Novak et al., 2015). In a recent study of Dopsaj (Dopsaj et al., 2020), a total of 15,6% of a large sample was categorized as obese, based on their body fat percent. On the other hand, when it comes to the physically active students in Belgrade, almost 90% of students of both genders can be classified in normal ranges of body fat percent, which can be brought into connection with a higher level of physical activity (Dopsaj et al., 2015).

There are only a few studies found in the region, which deal with body composition in students (Novak et al., 2015; Dopsaj et al., 2015; Dopsaj et al., 2019; Dopsaj et al., 2020). To this day, there is a lack of scientifically valid general data about physically active students' body composition characteristics. Moreover, no studies have been found to examine the relationship between body composition and functional abilities in physically active students.

In connection with the previous observations, the aim of this study was to assess the relationship between morphological characteristics and maximal oxygen uptake in a sample of healthy, physically active students.

METHODS

Participants

Students of the Faculty of Sport and Physical Education (N = 110) voluntarily participated in this study. They were randomly divided into 11 groups of 10 each, regardless of semester or their academic major. The sample included both males (N = 90, 20,91 ± 2,11 years) and females (N = 20, 20,51 ± 1,57 years) who were actively studying at the time. All participants had 3 to 5 classes of physical activity per week depending on their field of study. Prior to participation, all subjects were asked to sign a written informed consent containing the explanation of all measurement procedures, goals, and potential risks

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related to the study. The study was conducted in accordance with the Helsinki Declaration and it was approved by the Institutional Ethics Committee.

Procedures

A cross-sectional study design was adopted where participants attended two testing sessions performed in the laboratory and in the gym. The first session was held in the period between 8.00 a.m. and 11.00 a.m. and its goal was to collect basic anthropometric and body composition data on the InBody 720 scale. The second session was used to estimate individual maximal oxygen uptake (VO_2max) in the standardized 20m Shuttle Run test (Ramsbottom et al., 1988).

Primarily, participants were instructed to maintain consistent dietary and sleeping patterns, to avoid alcohol consumption for 24 hours before testing and to consume adequate water prior to arrival. Body composition was measured using the bioelectrical impedance method (Bioelectrical Impedance Analysis – BIA) with a professional instrument of the latest generation – InBody 720 Tetrapolar 8-Point Tactile Electrode System (Biospace, Co., Ltd) based on DSM-BIA method (Direct Segmental Multi - frequency Bioelectrical Impedance Analysis). The sample of variables included general morphological variables: body height (BH), body mass (BM), BMI, skeletal muscle mass (SMM), body fat mass (BFM); variables scaled to body weight: percent of skeletal muscle mass (PSMM), percent of body fat (PBF); variables scaled to body height: skeletal muscle mass index ($SMMI=SMM/BH^2$) and body fat index (BFM/BH^2) and variables of functional abilities (VO_2max). In addition to those mentioned, among collected data was also the type and frequency of physical activity that students were engaged in, apart from their faculty classes.

The testing of functional abilities was conducted in indoor stadium, with hardwood floor during the afternoon. Audio sound for Shuttle Run test was played via Logitech 2.1 Multimedia Speaker System, with 120W peak power (Logitech International S.A., Lausanne, Switzerland). Each group was consisted of 10 participants running at the same time. For each participant, starting and ending line were marked with cones, placed 1 m from each other. Throughout the testing of each of the groups, five researchers, with previous experience, and five assistants were assigned to monitor the regularity of the test. Five of them were placed on the starting line and other five were placed on the ending line so that each researcher would monitor only 2 participants. For each participant, gender, age, weight, level and shuttle were noted and the same formula (Ramirez et al., 2008) was used to calculate the value of VO_2max.

Statistical analyses

All statistical analyses were performed in SPSS 21.0 (IBM Corporation). The results are presented as Mean ± SD. The normality of data was confirmed by the Kolmogorov-Smirnov test. The correlation between VO_2max and body composition variables was assessed using the Pearson test. The Pearson correlation coefficient represents a well-established measure of correlation with range of +1 (perfect correlation) to −1 (perfect but negative correlation), where 0 is designating the absence of a relationship (Adler & Parmryd, 2010). Multiple regression analysis (MRA) was used to define multivariate models between the criterion variable (VO_2max) and a set of predictive morphological variables. All p-values less than 0,05 were considered significant, for 95% level of probability.

RESULTS

Basic descriptive statistics of the sample are presented in Table 1.

Table 1. Mean values and standard deviation of included variables for both male and female sample.

Variable / Sample	MALES	FEMALES
	MEAN ± SD	MEAN ± SD
VO_2max (ml/kg/min)	48,33 ± 5,98	38,54 ± 5,46
BH (cm)	181,79 ± 6,34	166,55 ± 6,78
BM (kg)	77,28 ± 9,03	59,76 ± 9,31
BMI (kg/m²)	23,39 ± 2,67	21,40 ± 2,06
SMM (kg)	39,25 ± 4,78	26,57 ± 3,90
BFM (kg)	8,67 ± 4,44	11,80 ± 3,52
PSMM (%)	50,86 ± 2,96	44,54 ± 1,88
PBF (%)	10,98 ± 4,64	19,48 ± 3,25
SMMI (kg/m²)	11,87 ± 1,23	9,52 ± 0,81
BFMI (kg/m²)	2,65 ± 1,41	4,21 ± 1,06

VO_2max – estimated maximal oxygen consumption; **BH** – body height; **BM** – body mass; **BMI** – body mass index; **SMM** – skeletal muscle mass; **BFM** – body fat mass; **PSMM** – percent of

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skeletal muscle mass; **PBF** – percent of body fat; **SMMI** – skeletal muscle mass index; **BFMI** – body fat mass index

The average value of VO_2max was 48,33 $mlO_2/kg/min$ for males, and 38,54 $mlO_2/kg/min$ for females. Furthermore, males showed higher basic anthropometric characteristics (body height = 181,79 cm; body mass = 77,28 kg; BMI = 23,39 kg/m^2) and values of skeletal muscle mass (39,25 kg). The average height in female sample was 166,55 cm, the average body mass was 59,76 kg, and the average BMI was 21,40 kg/m^2. On the other hand, as expected, females showed higher values of body fat mass (11,80 kg) and a higher percent of body fat (19,48 %), while mean values in male sample were 8,67 kg and 10,98 %. Correlations between VO_2max and morphological variables are presented in Table 2.

Table 2. Correlation between VO_2max and morphological variables

Body composition variable	VO_2max Males r	VO_2max Females r
BH	-0,003	**-0,512***
BM	**-0,313****	-0,409
BMI	**-0,321****	-0,244
SMM	-0,176	-0,271
BFM	**-0,413****	**-0,520***
PSMM	**0,261***	**0,545***
PBF	**-0,396****	**-0,551***
SMMI	-0,199	0,002
BFMI	**-0,404****	**-0,460***

VO_2max – estimated maximal oxygen consumption; **BH** – body height; **BM** – body mass; **BMI** – body mass index; **SMM** – skeletal muscle mass; **BFM** – body fat mass; **PSMM** – percent of skeletal muscle mass; **PBF** – percent of body fat; **SMMI** – skeletal muscle mass index; **BFMI** – body fat mass index; ** p < 0,01, * p < 0,05

In the male sample, small significant correlation (r ~ 0,3, p < 0,01) was found between body mass parameters (BM and BMI) and VO_2max. In the female sample, body height showed medium correlation with VO_2max, while body mass parameters showed correlation on the border of significance (p = 0,073). In both samples, body fat parameters (body fat mass, percent of body fat and body fat index) showed significant correlation with VO_2max in range from r = 0,261 to 0,545 (p < 0,05). Moreover, percent of muscle mass showed correlation with VO_2max in both samples, while skeletal muscle mass showed no significant correlation. Average correlation of all significant variables and VO_2max was 0,351 for males and 0,518 for females.

Table 3. Predictive regression model

Model No.	r	R^2	Adjusted R^2	Std. Error of the Estimate	F	Sig.
Predictive regression model – male sample					ANOVA of regression	
4	0,502	0,252	0,198	5,357	4,661	0,000
6	0,466	0,217	0,180	5,416	5,884	0,000
Predictive regression model – female sample						
6	0,834	0,696	0 ,639	3,281	12,228	0,000
4. Predictors Males: (Constant), BFMI, SMM, BH, PSMM, PBF, BM						
6. Predictors Males: (Constant), BFMI, SMM, PSMM, BM						
6. Predictors Females: (Constant), BFMI, PSMM, SMM						

BH – body height; **BM** – body mass; **SMM** – skeletal muscle mass; **PSMM** – percent of skeletal muscle mass; **PBF** – percent of body fat; **BFMI** – body fat mass index

Based on predictive regression model, we can calculate two formulas for the estimation of VO_2max for males and one for females:

VO_2_Males = -265,31 - (BH*0,339) + (BM*4,424) - (SMM*8,213) + (PBF*2,419) + (PSMM*7,031) - (BFMI*10,703)

VO_2_Males = -92,859 + (BM*1,834) - (SMM*3,751) + (PSMM*2,9877) - (BFMI*1,785)

VO_2_Females = -297,901 - (SMM*2,124) + (PSMM*7,616) + (BFI*12,738)

DISCUSSION

The present study is among the first ones to investigate the relationship between morphological characteristics and maximal oxygen uptake in a sample of physically active students. The results of this study demonstrate that there are different anthropometric variables which correlate with VO_2max in male and in female students, whereas when speaking of body composition, variables related to VO_2max are mostly similar for both groups. Significant inverse relation was found for body fat mass and VO_2max, as well as for percent of body fat and VO_2max, in both samples. Unexpectedly, no significant relation was found between skeletal muscle mass, skeletal muscle mass

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index and VO_2max. Our results suggest that variables with statistically significant correlation to oxygen consumption are related to body mass and body fat, while variables related to muscle mass have no significant influence on VO_2max.

VO_2max

VO_2max represents the functional limit of the body's ability to deliver and extract oxygen with the aim of meeting the metabolic demands of exercise (Hawkins & Wiswell, 2003), and it is recognized as the reference standard for physical fitness (Shephard et al., 1968). The findings in other studies and our findings have shown similar values of VO_2max in a sample of students, where authors have reported VO_2max ranging from 36,80 to 51,80 ml/kg/min (Welch et al., 1958; Kitagawa et al., 1977; Verma et al., 1979; George et al., 1997; Nabi et al., 2015; Bestard et al., 2017). The comparison of these results suggests that endurance of students at the Faculty of Sport and Physical Education in Belgrade is not on the higher level than that of other university students.

Body composition and VO_2max

The importance of body composition values is well-known, since body composition is one of the key components of human health (Wells & Fewtrell, 2006). In our study, mean values of BMI were categorized as normal range. Dopsaj et al. reported an average BMI of 24,54kg/m^2 and 21,71kg/m^2 in a sample of 250 physically active students (Dopsaj et al., 2015). Galloway, Farrow and Martz (2010) reported an average BMI of 24,2 kg/m^2 and 25,1 kg/m^2 in female and male students. The study conducted at the Lebanese American University on the sample of 220 students reported 23,6 kg/m^2 as the average value of BMI (Yahia, Achkar, Abdallah & Rizk, 2008). Majeed (2015) investigated BMI and physical activity in female medical students, where the measurement of BMI indicated that the majority of students 63,7% had normal weight. The results of the two aforementioned studies showed similar values in a sample of physically non-active females, where BMI was 21,61kg/m^2 and 22,02kg/m^2 (Dopsaj et al., 2019; Dopsaj et al., 2020). The results of body fat parameters were similar to the values of physically active students (PBF=10,98% males, PBF=19,48% females vs PBF=12,91% males, PBF=23,80% females), while non-active females at the University of Belgrade had significantly larger values of PBF, i.e. 26,14% and 25,34% (Dopsaj et al., 2020).

When it comes to the relationship between body mass and body fat parameters and VO_2max, there are many studies which support our results. Berthoin et al. have found significant negative correlation between body mass and maximal aerobic speed in a sample of females, while body height showed no correlation (Berthoin et al., 1995). In a similar study, the results have shown that body fat affects lower values of VO2max (Bandyopadhyay & Chatterjee, 2003). Umamaheswari et al. (2017) investigated the relation between BMI, PBF and VO_2max in overweight adults. Results showed that there was an inverse correlation between BMI ($p<0,001$) and a positive correlation between lean body mass and VO_2max ($p<0,001$) in the sample of obese adults aged 19 to 30. The findings of Watanabe et al. supported the claim that obesity accentuates exercise intolerance and low VO_2max (Watanabe et al., 1994). Huttunen observed that weight reduction among obese and non-obese children increased their VO_2max value, while Sharp also reported that VO_2max was positively correlated with fat-free mass and negatively correlated with adiposity (Huttunen et al., 1986; Sharp et al., 1992).

The findings obtained from a sample of professional athletes are in line with the abovementioned results, since Ilic et al. reported that high level of body fat had negative influence on maximal oxygen consumption, the mean value being only 39,98 ml/kg/min in Serbian U20 handball team (Ilic et al., 2015). These results lead us to the conclusion that body mass variables have a highly negative influence on the oxygen transport system and aerobic power.

Contrary to our expectations, results have shown that muscle mass had no correlation with VO_2max both in male and in female sample. Hickson et al. reported no change in VO_2max after traditional strength training program was performed for 10 consecutive weeks by young and middle-aged men (Hickson et al., 1980). Also, Hurley et al. found no change in treadmill VO_2max in middle-aged men after 15 weeks of Nautilus strength training (Hurley et al., 1984). Since both muscle and fat parameters, expressed in percents, correlate with VO_2max, we may conclude, despite our results, that relative values of those parameters have more influence on VO_2max.

Regression predictive model

Many studies are trying to find the right parameters and formulas to predict, as closely as possible, the accurate value of VO_2max. In the study of Jetté et al. (1976) the formula showed that VO_2max could be predicted with high accuracy (R=0,905). In the abovementioned study of George et al. (1997), the questionnaire-based N-EX regression model exceeded the accuracy of previously developed N-EX regression models (R=0,85). The results of Bradshaw et al. showed the correlation coefficient between the predicted and the actual VO_2max 0,74 Pearson r (Bradshaw et al., 2005). Wier (2006) found three models, developed by multiple regression, to estimate VO_2max with correlation coefficient ranging between 0,80 and 0,82. In 2008, the multiple regression analysis produced a model resulting in an R^2=0,867 (Akalan et al., 2008).

Our predictive regression model, based on InBody scale parameters, showed different formulas and parameters for estimating VO_2max for male and female samples. The predictive model in the male sample was imprecise, while the predictive model designed for the female sample showed more accuracy. The male sample was consisted of students involved in different sports and physical activities (e.g. weightlifting, basketball, soccer, wrestling, cycling), hence significant differences in body composition and motor skills were evident. The occurrence of those differences could explain why the predictive model showed less than 20% of the variance for males. On the other hand, only 20 females were tested and there were no significant exceptions. It is possible that this is because the female sample was homogeneous and that the formula is valuable only for female students of the Faculty of Sport and Physical Education at the University of Belgrade. It is clear that more research is needed to determine valid predictive regression model for University students.

CONCLUSIONS

We may be able to conclude that certain morphological characteristics do have a significant correlation with maximal oxygen consumption. Predictive regression model based on morphological parameters showed lack of accuracy in the male sample. Most morphological characteristics do not affect the cardiorespiratory system significantly enough to make a large impact on the value of VO_2max. We need to point out that our sample consisted of a homogeneous group of students, which might conceal certain relationships between the parameters used and VO_2max. Therefore, future research should include a more heterogeneous sample of students for further understanding of this relation.

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