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RELATIONSHIPS BETWEEN PHYSICAL FITNESS AND MORPHOLOGICAL CHARACTERISTICS IN OBESE EIGHT-YEAR-OLD CHILDREN: A CROSS-SECTIONAL STUDY

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Abstract
The objective of this study was to investigate the association between Physical Fitness (PF) parameters and morphological features in eight-year-old obese children. The sample consisted of 273 obese second-grade students from Niš, Serbia (104 girls and 169 boys; mean age 8.26 ± 0.40 for girls and 8.34 ± 0.43 for boys). The assessed PF parameters included Resting Heart Rate (RHR), Exercise Heart Rate (EHR), maximal oxygen uptake (VO_2max), and a battery of tests measuring strength, flexibility and speed. Morphological characteristics were evaluated using 13 variables encompassing longitudinal, transversal, and volumetric dimensions, as well as skinfold thickness measurements. Canonical correlation analysis was conducted to examine the relationships between sets of fitness-related and morphological variables. The results revealed three statistically significant canonical functions, reflecting complex interrelationships between PF parameters and body structure. The first canonical function (Sig.= .00) demonstrated negative correlation between VO_2max and obesity-related parameters. The second function (Sig.= .00) reflects the relationship between longitudinal body dimensions and the ability to perform fast, alternating upper limb movements. The third function (Sig.= .04) suggested that children with more pronounced longitudinal body dimensions, but also with higher levels of subcutaneous fat, tend to achieve better results in tests of explosive strength and flexibility. These findings emphasize the complex and multidimensional relationship between physical fitness and morphological characteristics in eight-year-old children. They underscore the importance of early identification and the implementation of targeted, school-based interventions aimed at promoting health and supporting optimal physical development in young children.
Keywords: children, morphological characteristics, physical fitness, obesity, canonical correlation analysis

INTRODUCTION

Previous research indicates that the motor development of overweight and obese children differs from that of children with normal weight (Mota, Santos, Guerra, Ribeiro, & Duaret, 2002; Graf, Koch, Dordel, Schindler-Marlow, Graf, Koch, Kretschmann-Kandel, Falkowski, Christ, Coburger, & Predel, 2004). Research results confirm that excess body fat in children poses an obstacle to the development of fitness abilities as well as the formation of motor skills (Bala & Popović, 2007). Increased body mass in children is associated with decreased health-related fitness parameters (Cadenas-Sánchez, Artero, Concha, Leyton, & Kain, 2015; Thivel, Ring-Dimitriou, Weghuber, Frelut, & O'Malley, 2016), as well as diminished skill-related fitness parameters (Delaš, Tudor, Ružić, & Šestan, 2008).
Over the past few decades, a decline or stagnation in motor skills has been observed, accompanied by an increase in body mass index (BMI) (Kopecký & Přidalová, 2008). One explanation for this complex phenomenon is the decreased level of physical activity among children. An insufficient number of motor experiences and opportunities for participation in motor activities can slow down both the motor and intellectual development of a child (Humphrey, 1991).

Physical fitness, particularly cardiorespiratory and muscular fitness during childhood and adolescence, is a significant predictor of future health (Ortega, Ruiz, Castillo, & Sjöström, 2008; Ruiz, Castro-Piñero, Artero, Ortega, Sjöström, Suni, & Castillo, 2009). Despite the positive effects on health, secular trends in PF show an annual decline of approximately 0.4% in cardiorespiratory fitness (Tomkinson, Leger, Olds, & Cazorla, 2003) and about 2.0% in muscular fitness (Cadenas-Sánchez, et al., 2015). Cardiorespiratory fitness is negatively correlated with BMI, suggesting that the decline in cardiorespiratory fitness is partly due to increased obesity among children (Mota, et al., 2006; Stratton, Canoy, Boddy, Taylor, Hackett, & Buchan, 2007). Literature states that obesity is one of the main factors contributing to the declining trend in aerobic capacity among children (Macfarlane & Tomkinson, 2007). Study results show that obese children have lower maximal oxygen consumption, relative to body weight (Berndtsson, Mattsson, Marcus, & Larsson, 2007), and thus lower cardiorespiratory fitness than their normal-weight peers (Marinov, Kostianev, & Turnovska, 2002).
Although cardiorespiratory fitness has long been considered the most important parameter of health-related fitness, recent literature highlights muscular fitness as a key component related to overall health preservation (Thivel, et al., 2016).

Smith, Eather, Morgan, Plotnikoff, Faigenbaum, et al. (2014) report that high levels of muscular fitness have numerous positive health effects for children and adolescents. Their findings show that muscular fitness is inversely related to both abdominal and overall obesity, as well as to cardiovascular and metabolic diseases. Moreover, muscular fitness is essential for performing a large number of daily activities (Thivel et al., 2016). Previous studies confirm that obesity in childhood negatively affects speed, endurance, agility, and lower limb strength but does not impact upper limb strength, handgrip strength, or flexibility (Ceschia, Giacomini, Santarossa, Rugo, Salvadego, et al., 2016). Some studies show that flexibility is independent of nutritional status (Tokmakidis, Kasambalis, & Christodoulos, 2006; Leskošek, Strel, and Kovač, 2007), while other studies have shown that flexibility is negatively correlated with BMI (Kim, Must, Fitzmaurice, Gillman, Chomitz, et al., 2005) and skinfold thickness (Matton, Thomis, Wijndaele, Duvigneaud, Beunen, et al., 2006).

Given the fact that obesity is a major public health issue with far-reaching consequences on the overall psychophysical status of a child, and later in adulthood, there is a clear need for research into obesity and its relationship with various FPs. Previous studies on these relationships have yielded highly variable or even contradictory results. This particularly applies to research on the relationship between muscle strength, cardiorespiratory fitness, or flexibility and the nutritional status of children. Although adiposity rebound typically occurs around age six, research shows it can also appear as late as age eight, making this a critical period for monitoring the development of obesity in children (Doi, Williams, & Frank, 2016). This research aims to contribute to clarifying the relationship between PF parameters and the morphological characteristics of obese eight-year-old children.

METHODS

The sample of participants consisted of 273 obese children (104 girls and 169 boys), second grade students (mean age 8,26±0,40 for girls and 8,34 ±0,43 for boys) of elementary schools in Nis, Serbia. The following fitness parameters were measured: Exercise Heart Rate (EHR), VO_2max (ml), Resting Heart Rate (RHR), bend forward - bend backward – throw test (BFBBT), hand tapping, 20-meter dash initiated from a standing start, “Abalakov” test and forward bend on the bench test. Morphological characteristics were determined by measuring 13 parameters of longitudinal and transversal dimensions of skeleton, volume and body weight, as well as subcutaneous fat tissue (body height, leg length, arm length, shoulder width, pelvic width, hip width, body mass, thorax volume, upper arm volume, thigh volume, upper arm skinfold, back skinfold and abdominal skinfold). For all variables, the mean and standard deviation (SD) were calculated. Canonical correlation analysis was applied to explore the associations between the set of variables representing PF and those representing morphological characteristics.

RESULTS

Table 1 presents the cross-correlation matrix of fitness parameters and morphological characteristics in eight-year-old obese children.

Canonical correlation analysis was used to determine the relationship between the set of fitness parameter variables and the set of morphological characteristic variables (Table 2). The analysis of the results indicates that the fitness parameters and morphological characteristics are associated through three pairs of statistically significant canonical factors. The significance levels of these canonical factors are .00, .00, and .04. The first pair of canonical factors explains 38% (R^2 = 0.38), the second 18% (R^2 = 0.18), while the third pair explains 15% (R^2 = 0.15) of the shared variance with a significance level of .05. The structures of the isolated canonical factors within the examined domains (FP and morphological characteristics) were defined to explain the structure of the canonical dimensions (Table 3).

The results indicate that the first isolated canonical factor loads most strongly on VO_2max (Sig. = 0.89) and several anthropometric and volume measurements. The second isolated canonical factor loads most strongly on the hand tapping test (Sig. = 0.66) and body height and leg length, while the third factor loads most strongly on the Abalakov test (Sig. = 0.74) and arm and leg length (Sig. = 0.47 and Sig. = 0.43, respectively) as well as beck skinfold (Sig. = 0.49) and BF% (Sig. = 0.49).

Table 1. Correlation table of fitness parameters and morphological characteristics in obese eight-year-old children

	EHR	VO_2max	RHR	BFBBT	Hand taping	20-meter dash	Abalakov	Forward bend
Body height	-0.02	-0.20**	-0.04	-0.00	0.14	-0.02	0.00	-0.03
BMI	0.29**	-0.45**	0.25**	-0.05	-0.06	0.03	-0.13	0.05
Leg length	-0.03	-0.20**	-0.07	0.00	0.19**	-0.04	0.05	0.04
Arm length	-0.06	-0.14*	-0.09	0.05	0.14*	-0.09	0.08	0.03
Shoulder width	0.05	-0.22**	-0.06	0.04	0.16*	-0.17*	0.05	0.03
Pelvic width	0.20**	-0.41**	0.10	-0.07	0.05	-0.05	-0.11	0.01
Hip width	0.10	-0.37**	0.17	-0.05	0.05	-0.02	-0.05	0.08
Body mass	0.15*	-0.39**	0.11	-0.03	0.07	0.02	-0.09	0.02
Thorax volume	0.19**	-0.39**	0.12	-0.02	-0.02	-0.04	-0.10	0.04
Upper arm volume	0.21**	-0.43**	0.16*	-0.03	-0.08	0.04	-0.15	0.11
Thigh volume	0.16*	-0.41**	0.12	-0.18**	-0.04	0.04	-0.03	0.11
Upper arm skinfold	0.21**	-0.39**	0.15*	-0.05	-0.01	0.12	-0.15	0.08
Beck skinfold	0.20**	-0.31**	0.13	-0.05	0.09	0.12	-0.20**	-0.13
Abdominal skinfold	0.19**	-0.32**	0.11	-0.03	0.07	0.05	-0.19**	-0.04
BF%	0.22**	-0.36**	0.14*	-0.05	0.03	0.14*	-0.21**	-0.05

*Legend: Statistical significance of the correlation ** $p < .01$; * $p < .05$*

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Table 2. Canonical correlation coefficients between fitness parameters and morphological characteristics in eight-year-old obese children

	R	R^2	Chi-sqr.	df	p
0	0.62	0.38	262.54	120	**0.00**
1	0.43	0.18	149.12	98	**0.00**
2	0.39	0.15	100.91	78	**0.04**
3	0.34	0.12	61.44	60	0.42
4	0.22	0.05	32.33	44	0.90
5	0.20	0.04	20.39	30	0.91
6	0.17	0.03	10.75	18	0.91
7	0.12	0.02	3.61	8	0.89

Legend: R = canonical correlation coefficient; R^2 = coefficient of determination for the pair of canonical factors; Chi-Sqr. = Bartlett's χ^2 test; df = degrees of freedom; and p = statistical significance.

Table 3. Factor structure of fitness parameters and morphological characteristic in eight-year-old obese children

	Root 1	Root 2	Root 3
EHR	-0.43	-0.32	-0.47
VO_2max	**0.89**	0.06	0.09
RHR	-0.35	-0.17	-0.38
BFBBT	0.21	-0.03	0.04
Hand taping	0.11	**0.66**	0.21
20-meter dash	-0.05	0.30	-0.48
Abalakov	0.18	-0.05	**0.74**
Forward bend	-0.23	-0.32	0.55
Body height	-0.39	**0.53**	0.25
BMI	**-0.77**	-0.11	-0.28
Leg length	-0.39	**0.54**	**0.43**
Arm length	-0.26	0.37	**0.47**
Shoulder width	-0.36	0.19	0.38
Pelvic width	**-0.72**	0.15	-0.05
Hip width	**-0.74**	0.26	0.12
Body mass	**-0.69**	0.32	-0.01
Thorax volume	**-0.70**	0.02	-0.03
Upper arm volume	**-0.78**	-0.06	-0.09
Thigh volume	**-0.77**	0.13	0.15
Upper arm skinfold	**-0.70**	0.16	-0.18
Beck skinfold	-0.50	0.44	**-0.49**
Abdominal skinfold	-0.56	0.27	-0.34
BF%	-0.62	0.31	**-0.43**

DISCUSSION

The results presented in the cross-correlation table indicate a statistically significant association between fitness parameters and morphological characteristics in eight-year-old children. Analysis of the matrix reveals that cardiorespiratory fitness parameters are strongly correlated with morphological variables.

First canonical factor: Association between cardiorespiratory fitness and nutritional status

The first isolated canonical factor shows the highest projections for VO_2max, exercise heart rate (EHR), and resting heart rate (RHR). On the other hand, from the domain of morphological characteristics, the most strongly projected variables include upper arm circumference, BMI, thigh circumference, hip width, pelvic width, chest circumference, and upper arm skinfold thickness—all with negative coefficients. This negative correlation between VO_2max and obesity-related parameters confirms previous findings indicating that higher body fat percentages adversely affect aerobic capacity (Ortega et al., 2008; Vandendriessche et al., 2011). However, some recent studies suggest that obese children with lower circular dimensions, body mass, and subcutaneous fat may exhibit higher maximal oxygen consumption (Đošić et al., 2020). This can be explained by the fact that even if an obese child has lower body volume or mass, it does not necessarily imply reduced cardiovascular function, as specific factors such as physical activity levels, aerobic capacity, and genetics often play a more significant role. It is also worth noting that in the study by Đošić et al. (2020), both overweight and obese children were examined, while the current research focuses exclusively on obese children.

Interestingly, a decrease in HR and RHR was observed with the increase of certain morphological dimensions, which does not entirely align with previous research suggesting a positive relationship between resting heart rate and obesity in children (Peters et al., 2013). A higher body fat percentage is typically associated with elevated resting heart rate (RHR) and higher heart rate under exertion (exercise HR), values which generally reflect lower cardiovascular efficiency, as the heart must work harder to deliver oxygen throughout the body. These results may be influenced by the developmental stage of eight-year-old children, as well as by differences in motor activity levels among participants (Tomkinson et al., 2019).

Second Canonical Factor: Speed of Movement Execution and Longitudinal Dimensions

The second canonical factor is most influenced, within the domain of fitness parameters, by the hand tapping test, followed by exercise heart rate (HR), the bench trunk flexion test, and the 20-meter sprint. From the morphological space, the variables with the highest projections include leg length, body height, back skinfold thickness, body mass, and body fat percentage. This factor reflects the relationship between longitudinal body dimensions and the ability to perform fast, alternating upper limb movements.

A similar positive correlation between body height, body mass, and the frequency of movement was observed by Malacko, Pejčić, and Tomljenović (2014), who emphasized that larger body dimensions may enable more efficient biomechanics of movement. However, an increased fat percentage negatively affects flexibility, which aligns with the findings of Matton et al. (2006) who demonstrated that the accumulation of adipose tissue in the abdominal region is a significant limiting factor in flexibility tests.

Third Canonical Factor: Explosive Strength and Longitudinal Structure

The third canonical factor shows the highest projections within the fitness domain for the Abalakov jump test, followed by the bench trunk flexion test, the 20-meter sprint, exercise heart rate (HR), and resting heart rate (RHR). From the morphological domain, the most prominent projections include arm length, leg length, and shoulder width, along with negative projections for skinfold thickness and body fat percentage.

This combination suggests that children with more pronounced longitudinal body dimensions, along with higher levels of subcutaneous fat, tend to perform better in tests of explosive strength and flexibility. Despite a higher fat mass, it is possible that the length of the limbs enables more efficient biomechanical execution of jumping and sprinting tasks. These findings require further analysis, as they may vary depending on sex, physical activity level, and pubertal status (Riddoch et al., 2009).

Scientific studies confirm that longitudinal structure significantly influences biomechanical performance during childhood development. For instance, Malina et al. (2004) reported that children with longer legs generally perform better in jumping and running activities due to a greater range of motion and improved take-off efficiency. Similarly, Vandendriessche et al. (2011) found that longitudinal body dimensions, together with factors such as body mass and strength, can positively affect explosive strength, although it is also important to monitor how these dimensions evolve across different stages of physical growth and puberty.

CONCLUSION

This study found strong links between physical fitness and body structure in eight-year-old children, identifying three key patterns. Higher body mass, fat percentage, and larger girths (such as arm, pelvis, and chest circumference) are associated with lower cardiorespiratory fitness, reflected in reduced VO_2max and elevated heart rates. This confirms that obesity negatively impacts physical fitness. Additionally, taller children with longer limbs tend to perform better in speed and flexibility tests, although excess body fat may reduce flexibility. This suggests a complex relationship where larger body dimensions can enhance movement efficiency, while excess fat can hinder it. Finally, children with longer arms, legs, and broader shoulders often show better results in explosive strength activities, even if they have higher body fat. This may be due to biomechanical advantages of longer limbs, but further research is needed to better understand this in the context of growth and puberty.

Overall, results highlight the intricate and multifaceted connection between physical fitness and body morphology in eight-year-old children, underlining the importance of considering both body structure and body fat percentage when assessing physical abilities and planning interventions.

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