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ORIGINAL SCIENTIFIC ARTICLE

HEALTH-RELATED PHYSICAL FITNESS IS ASSOCIATED WITH TOTAL AND CENTRAL BODY FAT IN CHILDREN AGED 6 TO 10 YEARS

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Abstract

Study purpose. This study purpose was to investigate whether health-related physical fitness is associated with total and central body fat in school children aged 6-10 years.

Materials and methods. A total of 2197 Macedonian children aged 6-10 years (1096 boys and 1101 girls) participated in the study. Health-related physical fitness was measured by the modified EUROFIT test battery: the 20 m shuttle run test (cardiorespiratory fitness); the handgrip strength test, the standing long jump and the 30 s sit-ups tests (muscular strength); the 4×10 m shuttle run test (motor fitness) and the sit and reach test (flexibility). Body mass index, body fat percentage and waist circumference were used as markers of total and central body fat, respectively.

Results. The standing long jump, the 30 s sit-ups, the 4×10 m shuttle run and the 20 m shuttle run tests were negatively associated with all markers of total and central body fat in boys and girls after controlling for age ($p<0.01$). The handgrip strength test was positively associated with all markers of total and central body fat ($p<0.01$). No statistically significant correlation was established between the markers of total and central body fat and the sit and reach test.

Conclusions. The present study broadens previous findings in children and adolescents which demonstrate correlations between the health-related physical fitness components, chiefly the muscle strength, the agility and cardiorespiratory fitness and total central adiposity. Fitness assessment should be introduced in future epidemiological and intervention studies in school children because it seems to be an important factor determining health.

Keywords: cardiorespiratory fitness, muscular strength, motor fitness, children, obesity.

Introduction

The Obesity among children and adolescents is a serious problem in the 21st century children's health (Reilly, 2006). Overweight and obesity during the childhood, and especially in adolescence, linger on in the adulthood. Former studies' results indicate that one out of four children at the age of 6 to 14 is affected by overweight (Kotani et al. 1997; Kain et al., 2002). Obesity is a multifactorial problem which is a product of a variety of causes, including those of heredity, social status, lifestyle, eating habits, and physical activity level (National Institutes of Health of USA, 2000). Physical fitness has proved to be an additional significant subject from a public-health perspective concerning adults (Myers et al., 2007) as well as children and adolescents (Ortega et al., 2008). Those studies which examine the correlation between the status of weigh and health-related physical fitness in young people have frequently reported a decrease of fitness in the course of obesity-increase (Haerens, et al., 2007; Brunet, et al., 2007; Martinez-Tellez, et al., 2016; Fogelholm, et al., 2008; Gontarev & Ruzdija, 2014).

Understanding the relation between physical fitness (including cardiorespiratory fitness, muscular strength and motor fitness) and obesity-related effects among children of the age from 6 to 10 years would make it possible to derive additional information about the question whether physical fitness is to be or not introduced as a health-marker as early

as at the mentioned ages. Wehypothesize that the physical fitness levels are associated with markers of adiposity. The goal of the present study is to examine how health-related physical fitness corresponds with the body mass index (BMI), body fat percentage and waist circumference (WC) in Macedonian children at the age of 6 to 10 years.

Materials & methods

Study participants

The research was conducted on a sample of 2197 children from 19 primary schools in the Republic of North Macedonia, 11 of which are in urban areas and 8 in rural areas. The sample was divided into two sub-samples according to the gender: 1096 male respondents and 1101 female respondents. The average age of the respondents was 8.63 ± 2.34 years. The respondents were treated in accordance with the Helsinki Declaration of 1961 (revision of Edinburgh 2013). The measurements were conducted in March, April and May 2019. The measuring was performed by experts of Kinesiology and Medicine.

Anthropometric measurements

Applying standardized procedures, the measurements of weight, height, and WC were carried out at school; all the instruments were verified before measuring each subject. Weight was measured in underwear and without shoes, with a medical decimal weight scales, to thenearest 0.1 kg, and height was measured barefoot in the Frankfort horizontal plane with a telescopic height measuring instrument (Martin's anthropometry) to the nearest 0.1 cm. Body mass index was calculated as bodyweight in kilograms divided by the square of height in meters. Waist circumferences were measured twice using inextensible anthropometric tape with the children standing erect and relaxed, with arms at the sides and feet positioned close together. Waist circumference was measured midway between the lowest border of the rib cage and the upper border of the iliac crest, at the end of normal expiration.

Components of the body composition have been determined by the method of bioelectrical impedance (measuring of the electric conductivity – Bioelectrical Impedance Analysis - BIA). The measuring was realized by a Body Composition Monitor, model "OMRON - BF511". In order to provide better precision of the results obtained from the estimation of the body composition, prior to each measuring, we ensured that the preconditions recommended by Heyward & Gibson (2014) had been fulfilled.

Evaluation of Physical Fitness

Six tests, forming part of the EUROFIT battery, validated and standardized by the European Council, were applied in the following order:

Sit and Reach test, Hand Grip test, Standing long jump test, Sit-ups 30 sek, Shuttle run: 4×10 meters, 20 meter shuttle run test.

Statistical analysis

Characteristics of the study sample are described as mean and standard deviation. Gender differences were assessed by one-way analysis of variance. To study the association of health-related physical fitness (i.e. the handgrip strength, standing long jump, 4×10m shuttle run, one-leg stance and 20m shuttle run tests) with BMI, body fat percentage and WC, we conducted linear regression analysis inserting the health-related physical fitness variable as independent variables and BMI, body fat percentage and WC as dependent variables. All these relationships were analysed in separate regression models (one for each fitness test and dependent variable) using age as covariate. The analysis were further adjusted by height when WC was the outcome variable. Since we observed a significant interaction effect between sex and most fitness components, all analyses were performed separately for male and female participants. All the analyses were performed using the Statistical Package for Social Sciences software (SPSS, v. 26.0 for Windows; SPSS Inc., Chicago, IL, USA).

Results

The characteristics by gender of the examined population are presented in Table 1. The analysis of the table shows that the male respondents have greater body weight, waist circumference, higher body mass index values, (BMI), and a greater percentage of body fat in comparison with those of the female respondents ($p \leq 0.010$). Further, the male respondents, compared to the female ones, show better results in all health-related physical fitness tests ($p<0.001$), except for the test 'sit-and-reach' ($p<0.001$).

Table 2 presents the relation between the health-related physical fitness and BMI, after adjusting according to the age, in the male respondents. There was an association between all health-related physical fitness and BMI (all $p< 0.001$), except for Sit-and-reach test ($p = 0.759$).

Table 3 shows the correlation between the health-related physical fitness and BMI after adjusting for age in female respondents. The inspection of the table shows that most of the health-related fitness tests associate with BMI (all $p < 0.000$), except for the fitness tests 'sit-and-reach' (β =-0.005 ± 0.017, $p = 0.450$) and 4×10-m shuttle run test (β =0.100 ± 0.053, $p = 0.058$).

The association between health-related physical fitness and body fat percentageare shown in Tables 4 and 5 aboutmale and female participants, respectively. There was an association between all health-related physical fitness tests and body fat percentagein male and female participants (all $p < 0.001$), except for the Sit-and-reach test (male $p = 0.715$; female $p = 0.067$).

Tables 6 and 7 show the association between health-related physical fitness and WC after adjusting to theage and height for male and female participants, respectively.There wasan association between all health-related physical fitness tests and WC (all $p < 0.001$), except for the Sit-and-reach test (male $\beta = 0.028\pm 0.035$, $p = 0.418$; female β = -0.009 ± 0.034, $p = 0.797$).

Since in both male and female respondents an interaction between the age and all the health-related physical fitness tests, on one hand, and the percentage of body mass index, on the other hand, was established, we repeated the analysis due to the age groups (6, 7, 8, 9 and 10 years of age) for male and female individually. With the male respondents, a statistically significant correlation between the

Table 1. Characteristics of the study participants by gender

Indicators	All (n = 2197)		Boys (n = 1096)		Girls (n = 1101)		F	Sig.
	Mean	SD	Mean	SD	Mean	SD		
Age (years)	8.63	2.34	8.59	1.32	8.66	3.03	0.54	0.462
Height (cm)	132.73	9.95	133.02	9.72	132.45	10.16	1.80	0.180
Weight (kg)	33.03	9.93	33.58	10.29	32.49	9.53	6.60	0.010
WC (cm)	60.29	8.70	61.39	9.06	59.20	8.19	34.88	0.000
BMI (kg/m^2)	18.41	3.49	18.64	3.66	18.18	3.30	9.51	0.002
Body fat %	23.33	8.04	23.78	7.85	22.88	8.19	6.42	0.011
Sitand reachtest (cm)	15.94	6.40	14.37	6.38	17.50	6.04	138.77	0.000
Handgrip strength (kg)*	12.95	3.66	13.61	3.67	12.30	3.54	72.30	0.000
Standing long jump (cm)	106.38	24.13	112.93	24.34	99.87	22.08	173.05	0.000
30 sec sit ups (n)	12.32	5.59	13.59	5.52	11.04	5.37	120.44	0.000
4×10m shuttle run test (sec)	15.35	2.04	14.90	2.02	15.79	1.96	110.45	0.000
20 m SRT (VO_2max)	48.47	3.32	49.25	3.59	47.69	2.81	128.08	0.000

Values are presented as mean and standard deviation. *Values are the mean of right hand and left hand. BMI - body mass index; 20 m SRT, 20 m shuttle run test; WC - waist circumference.

Table 2. Association between health-related physical fitness and body mass index in male children, after adjusting for age

Predictors	β	SE	R^2	P
Sitand reachtest (cm)	-0.005	0.017	0.099	0.759
Handgrip strength (kg)	0.443	0.034	0.221	0.000
Standing long jump (cm)	-0.043	0.004	0.171	0.000
30 sec sit ups (n)	-0.159	0.020	0.149	0.000
4×10m shuttle run test (sec)*	0.436	0.057	0.145	0.000
20 m SRT (VO_2max)	-0.458	0.028	0.282	0.000

β – unstandardized beta coefficient; SE – standard error; R^2 – coefficient of determination. *In the 4×10-m shuttle run test, the greater the score (sec) the worse the performance.

Table 3. Association between health-related physical fitness and body mass index in female children. after adjusting for age

Predictors	β	SE	R^2	P
Sitand reachtest (cm)	-0.012	0.016	0.017	0.450
Handgrip strength (kg)	0.418	0.027	0.200	0.000
Standing long jump (cm)	-0.022	0.005	0.038	0.000
30 sec sit ups (n)	-0.081	0.019	0.034	0.000
4×10m shuttle run test (sec)*	0.100	0.053	0.020	0.058
20 m SRT (VO_2max)	-0.524	0.035	0.188	0.000

β – unstandardized beta coefficient; SE – standard error; R^2 – coefficient of determination. *In the 4×10-m shuttle run test. the greater the score (sec) the worse the performance.

4×10-m shuttle run fitness test and the Body Mass Index percentage was not established with the boys at the age of 6 (p = 0.485); with the female respondents, though, a statistically significant correlation was not established between the Standing-long -jump test and the Body Mass Index percentage in the 6-year-old girls (p = 0.051), and with the 8-year-old girls it was the test 4×10-m shuttle run (p = 0.507).

Since with the male respondents an interaction was established with relation to the age, the Standing-long-jump fitness test and WC, we repeated the analysis for each of the

Table 4. Association between health-related physical fitness and body fat percentage in male children, after adjusting for age

Predictors	β	SE	R2	P
Sitand reachtest (cm)	-0.014	0.039	0.008	0.715
Handgrip strength (kg)	0.627	0.083	0.061	0.000
Standing long jump (cm)	-0.121	0.010	0.132	0.000
30 sec sit ups (n)	-0.428	0.046	0.085	0.000
4×10m shuttle run test (sec)*	1.221	0.132	0.085	0.000
20 m SRT (VO_2max)	-1.073	0.063	0.228	0.000

β – unstandardized beta coefficient; SE – standard error; R^2 – coefficient of determination. *In the 4×10-m shuttle run test. the greater the score (sec) the worse the performance.

Table 5. Association between health-related physical fitness and body fat percentage in female children, after adjusting for age

Predictors	β	SE	R^2	P
Sitand reachtest (cm)	-0.078	0.043	0.008	0.067
Handgrip strength (kg)	0.579	0.074	0.062	0.000
Standing long jump (cm)	-0.102	0.011	0.079	0.000
30 sec sit ups (n)	-0.368	0.047	0.062	0.000
4×10m shuttle run test (sec)*	0.775	0.132	0.037	0.000

Table 6. Association between health-related physical fitness and waist circumferencein male children, after adjusting for age andheight

Predictors	β	SE	R^2	P
Sitand reachtest (cm)	0.028	0.035	0.393	0.418
Handgrip strength (kg)	0.358	0.086	0.405	0.000
Standing long jump (cm)	-0.096	0.009	0.452	0.000
30 sec sit ups (n)	-0.350	0.040	0.432	0.000
4×10m shuttle run test (sec)*	1.111	0.114	0.439	0.000
20 m SRT (VO_2max)	-0.934	0.057	0.514	0.000

β – unstandardized beta coefficient; SE – standard error; R^2 – coefficient of determination. *In the 4×10-m shuttle run test, the greater the score (sec) the worse the performance.

Table 7. Association between health-related physical fitness and waist circumferencein female children, after adjusting for age andheight

Predictors	β	SE	R^2	P
Sitand reachtest (cm)	-0.009	0.034	0.316	0.797
Handgrip strength (kg)	0.380	0.090	0.328	0.000
Standing long jump (cm)	-0.078	0.010	0.357	0.000
30 sec sit ups (n)	-0.314	0.040	0.355	0.000
4×10m shuttle run test (sec)*	0.919	0.112	0.358	0.000
20 m SRT (VO_2max)	-0.823	0.082	0.376	0.000

β – unstandardized beta coefficient; SE - standard error; R^2 - coefficient of determination. *In the 4×10-m shuttle run test, the greater the score (sec) the worse the performance.

age groups (6, 7, 8, 9 and 10 years). No significant correlation was observed between the Standing long jump and WC in 6-year-old children (p = 0.183; respectively). After excluding age from the analyses conducted and the results persisted, we repeated all the analysis (data not shown).

Discussion

The present study results suggest that the health-related physical fitness, estimated through the tests 'Handgrip strength', 'Standing long jump', '30sec sit up', '4×10m shuttle run test', '20m shuttle run test' (VO2 max) are associated with the measures of 'total and central body fat' in boys and girls at the age from 6 to 10 years, after adjusting for the age. The study results correspond with former studies which have been conducted on children and adolescents, and which indicate an association between the health-related physical fitness components, chiefly those of the muscle strength, agility, the percentage of 4×10-m shuttle run test and cardiorespiratory fitness with the total and central Body fat in the children aged from 6 to 10 (Ruiz et al., 2011; Artero et al., 2010). The excess of body fat is an additional load that is very possible to have a negative impact on the fitness performances, especially in the fitness tests where the body is moving in the space or the weight of some body part is to be overcome. However, fit children are possible to possess higher levels of lean body mass in comparison with their unfit counterparts. In most cases, when the individual is physically inactive, the largest component of total energy expenditure is the resting energy expenditure. This may partially explain why fit children have less fat mass than those who are unfit.

In the present study, just as it is in other studies, the correlation between the health-related components and body fat markers is somewhat lower in the female respondents as compared to the male respondents (Gutin et al., 2004; Artero et al., 2010). The most consistent correlations were established for the '20-m Shuttle run test' in both male and female respondents. The results were fairly consistent regardless of the methodology that was used to assess the body fat mass. However, the correlations were stronger when the body fat markers were measured by bioelectrical impedance. Having an excess of body fat can affect to a greater extent the movements which require for body to move in a vertical axis compared to the body moving in a horizontal axis (Artero et al., 2010).

The further results of the study indicate an inverse correlation between the muscular strength and weight-bearing tests, and between the total and central adiposity, which is in accordance with earlier research works (Okely et al., 2004; Ara et al., 2004; Deforche, et al., 2003; Xu, et al. 2020). The present study shows a negative relation between Standing-long -jump test and the total adiposity in the respondents of both genders.

Studies of earlier research also indicate that the greater body weight is a barrier in doing fitness tests (Gontarev, et al., 2018). In addition, the research results point at the presence of a negative connection of the Sit-ups test with the total and central adiposity in the respondents of both genders.

It is also important to emphasize that the results show a positive connection of the Handgrip strength test with the total and central body fat (Malina et al., 1995; Casajús et al., 2007; Prista et al., 2003).The suggestion is that, in cases of excessive adiposity, the increases of fat-free mass fail due to the necessity of supporting this extra load (Forbes, 1964; Artero et al., 2010; Elezi et al., 2021). This finding indicates that individuals of excessive fat can acquire better results in tests which do not imply conquering a body weight as well as a particular body part (such as the Handgrip strength test, for example), which is relevant to some late study works (Artero et al., 2010; Elezi et al., 2021).

The exercises which aim at improving the muscle strength are recommended by a greater number of health organizations because of their effect on improving the muscle vigour, power, hypertrophy, muscle stamina, agility, coordination as well as prevention of a number of diseases (Pollock et al., 2000; Kell, et al., 2001; Stump et al., 2006; Wolfe, 2006). The results of longitudinal research works suggest that there is a negative correlation between the changes of muscle strength during the childhood-to-adolescence period and the change of the total adiposity; but the correlation between the muscle strength and the changes in the central adiposity is less explicit (Ruiz et al., 2009).

The present study indicates a negative correlation of the cardiorespiratory fitness with the total and central adiposity, which corresponds with previous research works where a sophisticated methodology used to be applied in assessing the body composition of children aged 8 to 11 (Gutin et al., 2004). Lee and Arslanian (2007) have established that the cardiorespiratory fitness is related to the lower values of visceral and abdominal fat, measured by DEXA in 113 American adolescents at the age of 8 to 17 years. The mentioned findings were alike when the anthropometric methods of assessing the total and central adiposity were used (Ortega et al., 2007). Ruiz et al. (2006) established that the cardiorespiratory fitness is inversely associated to the total body mass that is assessed through the sum of five skinfolds with Swedish and Estonian children at the age of 9 to 10 years. In this direction, they also noted that the cardiorespiratory fitness was associated in inversive way with WC in Spanish children (Ortega, et al., 2007) and Swedish ones (Ortega, Ruiz & Sjöström, 2007). Ortega et al. (2007) established that the Spanish adolescents who possessed higher levels of a cardiorespiratory fitness had also a lower abdominal adiposity (assessed with WC). In addition, the studies of longitudinal research point that, regardless of the initial level of cardiorespiratory fitness, its improvements are associated with a lower risk of developing an excessive obesity/fat during the period of adolescence (Ortega et al., 2011).

The correlation observed between agility (i.e. 4 × 10 m shuttle run test) and the total and central adiposity corre-

sponds with the results obtained in earlier research studies with children and adolescents (Ruiz, et al., 2011; Yamborisut, et al., 2011). The data obtained from our study suggests that the excess of body fat in children appears to be the cause of a lower performance in all tests that require a driving force for lifting the body mass both in children and adolescents (Artero et al., 2010).

When it comes to the correlation between the flexibility assessed by the Sit-and-reach test and the total central obesity, the results of former research works are contradictory. In other studies, however, no correlation was established between the flexibility, when assessed through Sit-and-reach test, and the measures of total and central adiposity, and that corresponds with the results obtained in our study (Ceschia et al., 2016; Sacchetti, et al., 2012; Tokmakidis, et al., 2006; Dumith et al., 2010; Malina, et al., 2011).

The present study's results should be considered with a certain degree of precaution. As with any transversal research work, the direction of association cannot be stated; undoubtedly, a reciprocal association between the fitness and obesity might be found. We, though, cannot be absolutely positive that unmeasured confounder factors, such as the diet, physical activity or genetic factor, have no impact on the obtained results. The confirmation of the present study's findings and, consequently, their ruling out with a representative sample of children require further research studies.

This study broadens the findings of earlier research works with children and adolescents which used to show the correlation of health-related physical fitness components, chiefly the muscular strength, agility and cardiorespiratory fitness with the total and central adiposity in children at the age of 6 to 10 years. The fitness assessment should be introduced concerning future epidemiological and intervention studies of children of the mentioned age, since it appears to be an important factor that predetermines future health and wellbeing.

Conclusions

The present study broadens previous findings in children and adolescents which demonstrate correlations between the health-related physical fitness components, chiefly the muscle strength, the agility and cardiorespiratory fitness and total central adiposity. Fitness assessment should be introduced in future epidemiological and intervention studies in school children because it seems to be an important factor determining health.

Conflict of interest

The authors state no conflict of interest.

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ФІЗИЧНА ПІДГОТОВЛЕНІСТЬ ЗА СТАНОМ ЗДОРОВ'Я ПОВ'ЯЗАНА ІЗ ЗАГАЛЬНИМ УМІСТОМ ЖИРУ В ОРГАНІЗМІ ТА В ЦЕНТРАЛЬНІЙ ЙОГО ЧАСТИНІ В ДІТЕЙ ВІКОМ ВІД 6 ДО 10 РОКІВ

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Мета дослідження. Метою дослідження було з'ясувати, чи пов'язана фізична підготовленість за станом здоров'я із загальним умістом жиру в організмі та в центральній його частині у школярів віком від 6 до 10 років.

Матеріали та методи. У дослідженні брали участь загалом 2197 македонських дітей віком від 6 до 10 років (1096 хлопців та 1101 дівчат). Вимірювання показників фізичної підготовленості за станом здоров'я здійснювали за допомогою модифікованого набору тестів EUROFIT: «Човниковий біг на 20 метрів» (кардіореспіраторна витривалість); «Міцність стискання руки», «Стрибки в довжину з місця» та «Піднімання тулуба в сід із положення лежачи за 30 секунд» (м'язова сила); «Човниковий біг 4×10 метрів» (рухова підготовленість) та «Нахили тулуба вперед із положення сидячи» (гнучкість). Як маркери загального вмісту жиру в організмі та в його центральній частині використовували індекс маси тіла, відсоток жиру в організмі та обвід талії, відповідно.

Результати. Тести «Стрибки в довжину з місця», «Піднімання тулуба в сід із положення лежачи за 30 секунд», «Човниковий біг 4×10 метрів» та «Човниковий біг на 20 метрів» були негативно пов'язані з усіма маркерами загального вмісту жиру в організмі та в його центральній частині у хлопчиків і дівчинок після врахування вікового фактора ($p<0,01$). Тест «Міцність стискання руки» був позитивно пов'язаний з усіма маркерами загального вмісту жиру в організмі та в його центральній частині ($p<0,01$). Статистично значущої кореляції між маркерами загального вмісту жиру в організмі та в його центральній частині та тестом «Нахили тулуба вперед із положення сидячи» установлено не було.

Висновки. Це дослідження розширює попередні результати в дітей і підлітків, які показують кореляції між складовими елементами фізичної підготовленості за станом здоров'я, переважно м'язовою силою, спритністю та кардіореспіраторною витривалістю, і загальним і центральним ожирінням. До майбутніх епідеміологічних та інтервенційних досліджень у школярів слід упровадити оцінку фізичної підготовленості, тому що вона здається важливим чинником, який визначає стан здоров'я.

Ключові слова: кардіореспіраторна витривалість, м'язова сила, рухова підготовленість, діти, ожиріння.

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