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ORIGINAL SCIENTIFIC PAPER

# Total and Abdominal Adiposity are Lower in Overweight and Obese Children with High Cardiorespiratory Fitness

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**Abstract**

The study goal was to determine the impact of cardiorespiratory fitness on the total and abdominal adiposity in a sample of children aged 6 to 10. It was hypothesised that high cardiorespiratory fitness would result in lower total and abdominal obesity. The research was conducted on a sample of 1432 respondents where 717 (50.1%) are boys, and 715 (49.9%) are girls aged 6 to 10. The average age of the respondents was 8.72±1.4 years. Three anthropometric measures (body height, body weight and waist circumference) were considered and the body composition was determined by BIA. Body mass index sex - and age-specific cut-off points were used for overweight and obesity definition and children were placed in two groups: overweight/obese and non overweight. Cardiorespiratory fitness (CRF) was assessed with the endurance shuttle-run test. Participants were grouped into high and low CRF based on age and sex distributions. The results were statistically analyzed by using t-tests and a $\chi^2$ test, analysis of covariance, Pearson correlation and hierarchical linear regression. On the basis of the obtained results, one can conclude that children who are overweight or obese and have a high level of cardiorespiratory fitness, have lower body mass index values, lower waist circumference, lower body fat percentage and a higher muscle mass percentage compared to children who are classified in the same BMI category, but have low values of cardiorespiratory fitness. The results of this study suggest that an appropriate level of cardiorespiratory fitness can reduce the threats of obesity among the pediatric population.

***Keywords:*** *central adiposity, fatness, fitness, obesity, children*

## Introduction

Theprevalence of paediatric obesity has been increased in USA and Europe over the pastyears (Wang, Monteiro, & Popkin, 2002; Lobstein & Frelut, 2003). It seems, however, that central and abdominal obesity increase at a faster rate than total body obesity in children (McCarthy, Ellis, & Cole, 2003). It has been shown that a lack of physical activity and a low cardiorespiratory fitness are associated with total obesity (Janssen et al., 2005; Katzmarzyk & Tremblay, 2007) and with abdominal obesity (Dencker et al., 2008; Yoon & So, 2009) in children.

Central adiposity is related to multiple risk factors for cardiovascular diseases in children (Freedman, Srinivasan, Harsha, Webber, & Berenson, 1989; Goran, Kaskoun, & Shuman, 1995) and adults (Bigaard et al., 2003). When it comes toboth men and women, there is strong evidence that physical activity and cardiorespiratory fitness (CRF) may protect against the adverse effects of obesity on health. Indeed, Blair et al. (1989) found twice lower relative risk of mortality of all causes in obese adults with moderate to

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high levels of cardiorespiratory fitness compared to obese adults with low levels of cardiorespiratory fitness. Ross and Katzmarzyk (2003) suggest that high levels of cardiorespiratory fitness are associated with lower levels of total and central obesity for an indicated body mass index (BMI) in 20-59 year-old men and women.

To the authors' best knowledge, there is no information in the literature on the effect of CRF on total and central obesity in children. Therefore, the aim of the present study was to examine the influence of CRF on total body and abdominal adiposity in a sample of young people.

## Methods

*Sample of respondents*

A total of 1432 healthy children (717 boys and 715girls) aged 6–10 years participated in this study. Subjects were living in Skopje, North Macedonia, and a signed consent was obtained from their parents.The respondents were treated in accordance with the Helsinki Declaration 1961 (revision of Edinburgh 2000). Measurements were realized in March, April and May 2019, in standard school conditions at regular classes of physical and health education. The measurement was realized by experts from the area of kinesiology and medicine, previously trained to perform functional tests and to take anthropometric measures.

*Anthropometric measures and body composition*

Anthropometric measurements were taken according to standard methodology of International Biological Program (IBP) and according to the recommendations of World Health Organization (WHO) and Weiner and Lurie (1981). Weight was measured in underwear and without shoes with an medical decimal weight scales, to thenearest 0.1 kg, and height was measured barefoot in the Frankfurt horizontal plane with a telescopic height measuring instrument (Martin's anthropometry) to the nearest 0.1 cm. Waist circumference was measured with a anthropometric tape positioned horizontally mid-way between the bottom of the rib cage and the iliac crest. A single measure was taken at the end of a normal expiration and recorded to the nearest 0.1 cm. Body mass index was calculated as bodyweight in kilograms divided by the square of height in meters.

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", by means of which we have measured the body weight, fat tissue percent and muscular mass percent. Prior to commencing the measurement we had entered the parameters of gender, years and body height of the respondent in the Body Composition Monitor. 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 American College of Sports Medicine (2005) and Heyward (2006) had been fulfilled.

*Definition of weight status*

Three weight status groups were established in this study: underweight/normal weight, overweight and obesity. Participants were categorized according to the international gender and age-specific BMI (kg/m$^2$) cut-off points (Cole, Bellizzi, Flegal, & Dietz, 2000; Cole, Flegal, Nicholls, & Jackson, 2007). These points have been particularly established for children and adolescents aged from 2 to 18 years, separately for males and females and for 0.5 year age groups. These cut off values are based on percentiles passing at age 18 years through BMI 18.5 kg/m$^2$ for underweight, 25 kg/m$^2$ for overweight and 30 kg/m$^2$ for obesity (Cole et al., 2000, 2007).

*Cardiorespiratory fitness*

The 20 meter shuttle run test (Leger & Lambert, 1982) was used to measure fitness. All testing was completed on a firm and level surface (concrete play area at each school). For this test, children were required to run back and forth between two lines placed 20 meters apart. A sound signal was emitted from a pre-recorded tape to dictate running speed. Frequency of the sound signals increased such that running speed increased by 0.5 km/hour each minute from the starting speed of 8.5 km/hour. The test ended when children could no longer keep pace with the sound signal. The last stage that children reached was used to predict maximal oxygen uptake ($VO_2$max) from the running speed corresponding to that stage ($VO_2$max=31.025+3.238 X–3.248 A+0.1536, where X=the final speed and A=age). Children were divided into quintiles based on age- and sex-specific distributions for CRF. Participants were classified as unfit (first and second quintile) or fit (fourth and fifth quintile). The middle quintile was not used in the analysis.

*Statistical analysis*

Descriptive statistical analyses were conducted to explore the characteristics of the data and to assess statistical assumptions. Independent samples t-tests were used to test for gender differences in the study variables. Normality of distribution was checked for all variables. Differences between fit and unfit children within each BMI category were assessed with one-way analysis of covariance with age and gender as covariate. The strength of the associations between variables was determined using Pearson correlation coefficients. Finally, hierarchical linear regression was used to determine the independent contributions of fitness on predicting the obesity measures. All the analyses were performed using the Statistical Package for Social Sciences software (SPSS, v. 22.0for WINDOWS; SPSS Inc., Chicago,IL, USA), and values of $p<0.05$ were considered statistically significant.

## Results

The research was conducted on a sample of 1432 respondents where 717 (50.1%) are boys, and 715 (49.9%) are girls at the age of 6 to 10 years. The average age of the respondents was 8.72±1.4 years.

The sample characteristics are presented in Table 1. The table overview shows the values of the arithmetic means, the standard deviations and the level of statistical significance, and it is observablethat there are statistically significant differences of the variables between male and female respondents: waist circumference, body mass index, body fat percentage, 20-m shuttle run test (shuttles) and 20-m shuttle run test ($VO_2$/kg/min).

The overview of the obtained results shows that the val-

**Table 1.** Descriptive statistics of each study variable presented separately for boys and girls

| Variables | Boys | | Girls | | T-test | Sig. |
|---|---|---|---|---|---|---|
| | Mean±SD | | Mean±SD | | | |
| Age (years) | 8.74±1.46 | | 8.71±1.42 | | 0.18 | 0.669 |
| Waist circumference (cm) | 61.24±8.63 | | 58.25±7.84 | | 46.82 | 0.000 |
| Body mass index (kg/m$^2$) | 18.76±3.82 | | 17.98±3.29 | | 17.03 | 0.000 |
| Body fat (%) | 23.66±7.99 | | 22.20±8.17 | | 10.94 | 0.001 |
| 20-m shuttle run test (shuttles) | 28.21±14.43 | | 21.71±9.61 | | 100.62 | 0.000 |
| 20-m shuttle run test (VO$_2$/kg/min) | 49.18±3.63 | | 47.73±3.04 | | 67.16 | 0.000 |
| Normal§ (% (n)) | 450 | 62.8% | 476 | 66.6% | χ2 | p |
| Overweight§ (% (n)) | 157 | 21.9% | 166 | 23.2% | 8.46 | 0.015 |
| Obese§ (% (n)) | 110 | 15.3% | 73 | 10.2% | | |

Legend: § - Determined through body mass index

ues of waist circumference are higher in boys, they also have higher body mass index, higher percentage of fat tissue, higher percentage of muscle mass, and they achieve better results in the 20 m. Shuttle Run Test and have higher maximum oxygen consumption.

The distribution of the overweight and obesity status in children, estimated by BMI, according to gender, is presented in Table 1. The table analysis and the overview of the $\chi^2$ test ($\chi^2$=8.46, p=0.015) suggest that there are statistically significant differences in regard to the degree of nutrition among boys and girls. The percentages show that a higher percentage of the girls have a moderate BMI, while a higher percentage of the boys have high BMI (obese).

The Pearson coefficients of correlation between cardiorespiratory fitness and obesity measures forthe respondents of both genders are displayed in Table 2. The table above shows that all obesity measures for the respondents of both genders show a statistically significant negative correlation (within the range r=-.53 to -.36) with the cardiorespiratory fitness. The associations between fitness and obesity measures (r=-.53 to -.47) were stronger in boys compared to girls (r=-.42 to -.36). The highest correlations in both boys and girls were found in the comparison between fitness and waist circumference.

Waist circumference, body fat percentage, and body mass index were significantly lower (p<0.01) in overweight/obese and fit children compared to unfit children at the same BMI category (Table 3), while the percentage of muscle mass showed statistically significant higher values in overweight/obese and fit children compared with unfit children at the same BMI category. Also, the values of waist circumference, body fat percentage and body mass index were significantly lower (p<0.01) in non overweight and fit children compared with unfit children at the same BMI category (Table 3), while the percentage of muscle mass showed statistically significant higher values in non overweight and fit children compared with unfit children at the same BMI category.

**Table 2.** Pearson correlations among study variables presented separately for boys and girls.

| Variables | Boys | | Girls | |
|---|---|---|---|---|
| | R | p | R | p |
| Fitness - Waist circumference | -.53 | .000 | -.42 | .000 |
| Fitness – BMI | -.49 | .000 | -.41 | .000 |
| Fitness - Body fat percentage | -.47 | .000 | -.36 | .000 |

**Table 3.** Anthropometric, body fat measures and physical characteristics between fit and unfit within the same BMI category

| Variables | Non overweighta | | Overweight/obesea | |
|---|---|---|---|---|
| | Unfit | Fit | Unfit | Fit |
| n | 279 | 497 | 305 | 110 |
| Waist circumference (cm) | 55.99±5.28 | 55.05±4.16* | 68.78±8.22 | 65.12±8.00* |
| Body mass index (kg/m$^2$) | 16.51±1.61 | 16.13±1.47* | 22.78±3.42 | 20.92±2.54* |
| Body fat (%) | 18.99±5.55 | 17.26±4.64* | 32.66±5.08 | 28.92±4.50* |
| Muscle mass (%) | 30.17±3.81 | 30.71±4.02* | 29.44±2.38 | 30.39±2.77* |
| 20-m shuttle run test (shuttles) | 16.31±4.76 | 35.50±12.03* | 14.43±4.61 | 31.34±10.13* |
| 20-m shuttle run test (VO$_2$/kg/min) | 45.95±2.30 | 51.36±2.63* | 45.40±2.26 | 50.44±2.14* |

Legend: a - Values are Means±SD; * - p<0.01 between fit and unfit within the same BMI category

Finally, hierarchical linear regression was used to determine the independent effects of fitness on the obesity measures. After controlling for age, gender, fitness accounted for 31% of the variance in waist circumference ($r^2$=0.313, p<.01), 32% of the variance in BMI ($r^2$=0.315, p<.01), and 34% of the variance in the body fat pecentage ($r^2$=0.340, p<.01).

## Discussion

On the basis of the obtained results, it can be concluded that cardiorespiratory fitness is negatively related to the measures of total (BMI, body fat percentage) and abdominal (waist circumference) obesity in this sample of 6-10 year-old Macedonian children. The regression model showed that cardiorespiratory fitness is a significant predictor that accounts for 31 to 34% of the variance in the obesity measures.

This is the first study in Macedonia to show the favorable effect of high CRF on body fat distribution in overweight and obese children. Although the respondents were not randomly selected, the prevalence of overweight and obesity was similar to representative samples of Macedonian children (36.4% of overweight children in representative samples; 35.5% in our study; Spiroski, 2016). The prevalence of overweight and obesity in the present study was also within the range reported for the countries surrounding the Mediterranean (27–36% for children aged 7–11 years; Lobstein & Frelut, 2003).

The cardiorespiratory fitness in this study is estimated indirectly. However, past studies suggest that the test is valid for estimating the maximum aerobic capacity in children (Leger & Lambert, 1982; Van Mechelen et al., 1986). Furthermore, our study was limited to the use of anthropometric indices and body composition was determined indirectly by the bioelectrical impedance method. The use of highly sophisticated methods, such as DEXA, computed tomography and magnetic resonance imaging, could provide more information about the role of cardiorespiratory fitness in the intra-abdominal fat in children. However, these methods are not suitable for large population studies.

The results of this study are in line with some previous studies involving adult men and women (Ross & Katzmarzyk, 2003). These authors showed that waist circumference, the sum of trunk skinfolds and the sum of the four skinfolds were lower at a given BMI in individuals with high cardiorespiratory fitness. The lower values of central obesity in the group with high values of cardiorespiratory fitness in this study also correspond to the previous studies which suggest that a reduction in waist circumference and intra-abdominal fat after exercise training, independently of BMI changes (Mourier et al., 1997; Ross et al., 2000).

The results from previous studies indicate that cardiorespiratory fitness is a strong predictor of health given that it is associated with overall obesity and abdominal obesity (Ortega, Ruiz, Castillo, & Sjostrom, 2008), which is consistent with the results obtained in this study.The strongest association observed was that of total adiposity, followed by abdominal adiposity and BMI. Because BMI does not measure fat mass or fat distribution directly, it can misclassify individuals (e.g., a mesomorphic child may be incorrectly classified as obese). Consequently, additional obesity indicators were used in the present study which provided better estimates of adiposity.

The study by McCarthy et al. (2003) suggests that central fat increases faster than total body fat in European children. The increased accumulation of adipose tissue in the abdominal or central region in children and adolescents is associated with adverse lipids and insulin concentrations. Namely, subscapular and truncal skinfold thickness and waist circumference are related to an increased level of fasting insulin, LDL cholesterol, total cholesterol and triglycerides levels (Freedman, Serdula, Srinivasan, & Berenson, 1999; Savva et al., 2000). These body composition indices are also associated with systolic and diastolic pressure (Savva et al., 2000; Maffeis et al., 2003) and a reduction of the HDL cholesterol concentration in children (Freedman et al., 1999).

Hussey, Bell, Bennett, O'Dwyer, and Gormley (2007) in a sample of 244 children from 7 to 10 years of age investigated the relationship between cardiorespiratory fitness and waist circumference, whereby a statistically significant correlation was found. Ekelund et al. (2001) found that fitness, measured by indirect calirometry, is statistically significantly related to body fat estimated through skinfold thickness in 82 adolescents between 14 and 15 years of age. Tell and Vellar (1988) found that cardiorespiratory fitness measured during submaximal bicycle exercise is correlated to BMI and triceps skinfold thickness in a sample of 413 boys and 372 girls, from 10 to 14 years of age. Liao et al. (2013) studies the associations between health-related physical fitness and obesity in the Taiwanese youth. The results of the research showed that cardiorespiratory fitness, lower body muscular fitness is also an important predictor of childhood and adolescent obesity. Wisnieski, Dalimonte-Merckling and Robbins (2019) studied whether CRF mediates the relationship between PA and OW/OB in adolescent girls. The results of the research showed that CRF is improved by increasing MVPA, and the improvement in CRF results in lower BMI and % BF among adolescent girls.

Although it is not possible to assess the impact of the results of this study on future health complications of obesity in children, the studies conducted with adult respondents suggest that fitmen with elevated central adiposity had almost 2.5 times lower mortality rate than unfit men in the same central adiposity category (Lee, Blair, & Jackson, 1999). Furthermore, fit men with high waist circumference had a rate of all-cause mortality similar to unfit men with low waist circumference both in a European sample (H. M. Lakka, T. A. Lakka, Tuomilehto, & Salomen, 2002) and in a USA sample (Lee et al., 1999). In another study, it was found that odds ratios for metabolic diseases were increased in overweight men and women with high abdominal adiposity compared with men and women with normal abdominal adiposity (Janssen, Katzmarzyk, & Ross, 2002). Finally, men and women who are overweight or obese and have high cardiorespiratory fitness, have a 2.5-times lower relative risk of mortality of all causes, compared to people of the same category of BMI who have low cardiorespiratory fitness (Blair et al., 1989).

The mechanism by which the high cardiorespiratory fitness reduces the risk of obesity is not clear. Cardiorespiratory fitness is inversely related to systolic and diastolic pressure, triglycerides, and total cholesterol concentration; it is also positively related tothe HDL cholesterol in children (Tell & Vellar, 1988). In adults, regular exercise is associated with improved muscle metabolism, and reduced metabolic risk as a result (Duncan et al., 2003; Goodpaster, Katsiaras, & Kelley, 2003).

## Conclusion

On the basis of the obtained results, one can conclude that children who are overweight or obese and have a high level of cardiorespiratory fitness, have lower body mass index values, lower waist circumference, lower body fat percentage and a higher muscle mass percentage compared to children who are classified in the same BMI category, but have low values of cardiorespiratory fitness. The beneficial impact of high CRF on body composition remained even after the values of body fatness were corrected for different BMI. The results of this study suggest that the appropriate level of cardiorespiratory fitness can reduce the threats of obesity in the pediatric population. They also highlight the limitation in examining health complications of obesity by studying BMI alone and suggest that percent fat, truncal adiposity and CRF should also be used in clinical practice. Future researches should be carried out on representative samples by using direct measures of body fat distribution, such as DEXA, computed tomography and magnetic resonance imaging. In addition, potential gender differences regarding the effect of fitness on overall and central obesity would be of great clinical relevance, however this question remains open for further research.

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**Conflict of Interest**
The authors declare that there is no conflict of interest.

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