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# Which Body Fat Anthropometric Indicators are Most Strongly Associated with Maximum Oxygen Uptake in Adolescents?

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## Abstract

**Background:** The relationship between maximum consumption of oxygen and indicators of body composition is important due in increasing the chance of developing cardiovascular risk factors. Therefore, the aim of this study was to investigate the association between body fat anthropometric indicators (BMI, WC, WHtR, CI, triceps skinfold, subscapular skinfold, suprailiac skinfold) with $VO_2$max and estimate the predictive ability of anthropometric indicators for the $VO_2$max variation in adolescents.
**Methods:** The study included 879 adolescents (14 - 19 years) and was carried out in southern Brazil. Aerobic fitness was assessed by the modified Canadian Aerobic Fitness test (mCAFT). Independent variables were: body mass index, waist circumference, waist /height ratio, conicity index (CI), triceps skinfold, subscapular skinfold, suprailiac skinfold, sum of triceps and subscapular skinfolds and sum of triceps, subscapularis and suprailiac skinfolds. Analyses were controlled for sociodemographic variables, physical activity and sexual maturation.
**Results:** With the exception of CI for girls, all anthropometric indicators were associated with $VO_2$max of adolescents in both sexes ($P < 0.01$). The sum of the three skinfolds obtained the highest explanatory power (21% and 23% for males and females, respectively).
**Conclusions:** Only CI for girls did not explain the $VO_2$max variation in adolescents, and the sum of the three skinfolds was the indicator that best predicted the $VO_2$max variation in adolescents.


*Keywords:* Association, Overweight, Lifestyle, Exercise, Adolescent Health

## 1. Background

International estimates have shown reduced aerobic fitness in adolescents from 1961 to 2002, and the decrease ranged from 0.36% to 1.83% per year (1). In Brazil, a study comparing data from 1978 to 2010 also confirmed this downward trend in aerobic fitness levels (2). These findings are alarming, as low aerobic fitness level is considered an independent risk factor for the development of diseases such as cardiovascular disease and a risk factor for premature mortality from all causes (3).

One of the parameters to identify aerobic fitness level is the assessment of maximum oxygen uptake ($VO_2$max). The relationship between $VO_2$max and body composition indicators has been investigated due to increased chance of the early development of cardiovascular risk factors and metabolic syndrome (4). This relationship between variables ($VO_2$max and body composition) is explained by the fact that overweight individuals tend to be less involved in sports and physical activity (due to limited mobility), which results in low aerobic fitness levels (5). In turn, a longitudinal study has identified the dose-response relationship between aerobic fitness and risk of overweightness, and as aerobic fitness decreased, the risk in overweight individuals with healthy weight increased (6).

The association between $VO_2$max and body composition remains independent of protocols used to estimate fat mass (7). Studies have found reduced $VO_2$max as body mass index values (BMI) increased (8). However, another study reported that it would not be excess weight or the amount of fat that interfered with $VO_2$max, but rather the amount of lean body mass (9).

Anthropometry is considered a simple, inexpensive and easy-to-use method in epidemiological studies (10). BMI and skinfolds provide excess weight information, but BMI indicates total body fat and the sum of skinfolds indicates body fat distribution (10). In turn, waist circumference (WC), waist/height ratio (WHtR) and conicity index (CI) are central adiposity indicators (10). In short, $VO_2$max is considered a strong health indicator for being associated to both total and central adiposity and to identify the magnitude of the relationship between each anthropometric indicator and $VO_2$max, and it is possible to plan effective interventions to reduce excess fat from improvements in $VO_2$max (6, 8). By analyzing different anthropometric indicators, it is possible to identify the best indicator for predicting aerobic fitness, and also assist in the physiological understanding of how certain fat distribution patterns influence $VO_2$max (6, 8).

Some studies have analyzed the relationship between $VO_2$max and anthropometric indicators in young populations (5, 7, 9, 11). The relationship between $VO_2$max and waist circumference (5, 7, 11), BMI (5, 9, 11), body mass (9), body fat percentage (4), triceps skinfold (12), subscapularis skinfold (13) and sum of skinfolds (4, 5) has been verified. The results of these studies have indicated that as the values of anthropometric indicators increased, $VO_2$max reduced, establishing an inverse relationship between these variables (5, 7, 10, 11). However, no studies using all six anthropometric indicators used this study (BMI, WC, WHtR, CI, triceps skinfold, subscapular skinfold, suprailiac skinfold) and with the aim of verifying the explanatory power of the indicators above for $VO_2$max have been found in literature. These data are relevant in comparing the effect of each anthropometric indicator on aerobic fitness and help choosing the most efficient parameters for prediction of this variable in future studies.

Thus, the aim of this study was to investigate the association between anthropometric indicators of general and central body fat (BMI, WC, WHtR, CI, triceps skinfold, subscapular skinfold, suprailiac skinfold) with $VO_2$max and estimate the explanation capacity of anthropometric indicators on the $VO_2$max variation in adolescents. The hypothesis is that anthropometric indicators show an inverse relationship with $VO_2$max values, and the increase in the values of indicators results in reduced $VO_2$max. Moreover, it is expected that indicators related to the sum of skinfolds would explain better the $VO_2$max variation than other indicators because they allow greater accuracy in distinguishing among body composition components (fat mass and lean body mass) (14).

## 2. Methods

### 2.1. Participants

This analytical school-based cross-sectional study is part of "Brazilian Guide to Evaluation of physical fitness related to Health and Life Habits - Stage I" macroproject. It was approved by the ethics committee on Human research of the federal university of Santa Catarina (CAAE Protocol: 33210414.3.0000.0121) and developed from August to November 2014.

The sample (N = 5182) was composed of students aged 14 - 19 years enrolled in public schools of Sao Jose, Santa Catarina, Brazil. Sao Jose has 209,804 inhabitants, has territorial extension of 114.94 $km^2$, Human Development Index of 0.809, percentage of young people (15 - 17 years) with complete primary education of 70.94%, expected schooling years of 10.52, life expectancy at birth of 77.81 years, per capita income of R$ 1,157.43, GINI index of 0.44, percentage of poor people of 1.36% and infant mortality rate of 10 (15).

The sampling process was determined in two stages: 1) stratified by public high schools (n = 11); 2) conglomerate of classes considering school shift and grade (n = 170 classes). In Stage 2, all students enrolled in high schools and who were present in classroom on the days of data collection were invited to participate in the study.

For sample calculation, unknown prevalence for the outcome (50%), tolerable error of five percentage points, 95% confidence level and design of effect 1.5 were adopted, adding 20% for losses and refusals and 20 % for the association study. Sample was estimated in 751 adolescents. However, due to cluster sampling, all students were invited to participate in the study, resulting in 1,132 students.

Students enrolled in state high schools, in the classroom on the day of data collection and being aged 14 - 19 years were defined as eligible. A student that did not want to participate was considered refusal and incomplete questionnaire or not performing one or more physical tests sample loss. Of the 1,132 students analyzed, 253 were excluded from the analysis for not performing the aerobic fitness test, totaling 879 students with mean age of 16.22 ± 1.14 years.

### 2.2. Measures

The dependent variable, VO2max, was estimated by the modified Canadian Aerobic Fitness test – mCAFT (16) validated in comparison with indirect calorimetry in men and women aged 15 - 69 years (17). To perform the test, adolescents had to complete one or more stages of three minutes each in which they should go up and down two steps of 20.3 cm each. The stage and the initial velocity were predetermined according to the sex and age of the subject. The pace for performing the steps within each stage of the tests was done by musical cadence, indicating the time when the participant should go up and down the step (16). The test was finished only when the participant reached 85% of maximum heart rate (determined by the formula 220 - age) (16), which was measured by Polar® frequency meter model H7 Bluetooth (Kempele, Finland). If the subject did not reach 85% of maximum heart rate in the current stage, a new stage was initiated soon after the completion of the last stage until maximum heart rate of 85% was achieved for the test completion. It was recorded as final test stage the stage in which the adolescent had completed. That is, if 85% of maximum heart rate was achieved during a certain stage, the stage prior to the one he was performing was recorded as the final stage.

The oxygen consumption during exercise and the reference values for the determination of the beneficial health zone for aerobic fitness are determined by the Canadian test battery (16). The equation of the aerobic fitness score determined by the Canadian battery is: score = 10 [17.2 + (29.1 x oxygen consumption) - (0.09 x weight in kg) - (0.18 x age in years).

The final score was divided by 10 to obtain the estimated value for $VO_2$max of adolescents (16, 18), which was continuously analyzed.

Independent variables were the anthropometric indicators BMI, WC, WHtR, CI, triceps skinfold, subscapular skinfold, suprailiac skinfold, sum of triceps and subscapular folds and sum of triceps, subscapular and suprailiac skinfolds.

Anthropometric data of body weight, height, waist circumference (WC) and skinfolds were measured according to procedures of the International Society for the Advancement of Kinanthropometry (ISAK) by a single evaluator certified with ISAK level-one and continuously analyzed. For skinfold measurements, a Cescorf® caliper (Porto Alegre, Brazil) with accuracy of 0.1mm was used.

WC was measured with Sanny® inelastic metal anthropometric tape with accuracy of 0.1 mm (São Paulo, Brazil), measured at the narrowest point between the last rib and the upper edge of the iliac crest. WHtR was assessed by the relationship between WC values (cm) and height (cm). BMI was calculated as the ratio of body weight (kg) to height in squared meters. CI was calculated by the following formula: CI = WC (m)/0.109 x $\sqrt{}$ body mass (kg)/height (m).

Sociodemographic variables were collected through self-administered questionnaire. Skin color was self-reported according to the Brazilian institute of geography and statistics (19) and dichotomized into "White" and "Brown/Black/Yellow/Indigenous". Age was categorized into "14 - 16 years" and "17 - 19 years." Socioeconomic level was identified by the questionnaire of the Brazilian association of research companies (20) and dichotomized into "high" ("A1", "A2", "B1", "B2") and "Low" ("C1", " C2 "," D "," E "). Maternal schooling was categorized into "$\geq$ 8 years of study" and "< 8 years of study."

The level of physical activity was assessed by the question: "During the past seven days, how many days were you physically active for at least 60 minutes a day?" Adolescents who practiced physical activity five or more days / week were classified as "physically active ($\geq$ 300 minutes per week)" and less than five days/week as "little physically active (< 300 minutes per week)" (21).

Sexual maturation was assessed according to the criteria proposed by Tanner (22) validated and reproducible for the Brazilian population (23). The indication of the stages was carried out by self-assessment (figures) of breast development (female) and genitals (male) after individual and previous explanation of the instrument by the researcher, always of the same sex as the adolescent. Due to the low number of adolescents in the pre-pubescent stage (0.2%), categories were "pre-pubescent/pubescent" and "post-pubescent." This variable was included in the multivariate analysis in a discrete and continuous way.

### 2.3. Statistical Analysis

In the descriptive analysis of variables, mean, standard deviation and frequency distribution were used. Data normality was verified by the asymmetry and kurtosis analysis. The highest asymmetry value was for variable BMI (asymmetry = 1.2) and the highest kurtosis value was for variable subscapular skinfold (kurtosis = 2.3). The other variables showed asymmetry and kurtosis values near zero. According to literature, such asymmetry and kurtosis values refer to normal data distribution (24, 25). Thus, the Student t test was used to verify differences between means according to sex. In addition, the effect size was calculated according to literature (26). The Pearson correlation was used to verify the relationship between $VO_2$max and anthropometric indicators (BMI, WC, WHtR, triceps skinfold, subscapular skinfold, suprailiac skinfold and CI) according to sex.

To identify the relationship between anthropometric indicators and $VO_2$max, simple and multiple linear regression were used. In both analyses, intercept measurements (B), standard error (SE), regression coefficient of predictor variables ($\beta$), t-test of parameters (t); determination coefficient ($R^2$); adjusted determination coefficient (Adj $R^2$) and analysis of variance with degrees of freedom (F (dfn, DFD)) were estimated. In addition, the effect size was calculated according to literature (26).

In the multiple linear regression, a model for each anthropometric indicator separately was built and adjusted for sociodemographic factors (skin color, age, school shift, maternal education and economic level), for level of physical activity and sexual maturation. That is, each model has been adjusted by an anthropometric indicator, as if models with more than one anthropometric indicator were built, the regression model would present multicollinearity (VIF $\geq$ 10) (27). Level of physical activity and sexual maturation were used in the regression models as control variables because oxygen uptake is influenced by growth and body development, responding differently in the different maturational stages, and adolescents in more advanced maturational stages feature advantage in oxygen uptake when compared to adolescents in early maturational stages (28). In addition, maximum oxygen uptake is directly related to the level of physical activity, considering that insufficient physical activity or low-intensity activities are insufficient to achieve necessary threshold for cardiovascular adaptations that increase maximum oxygen uptake to occur (29).

The Durbin-Watson test was used to check the assumption of independence of errors for each of the models. The results of the Durbin-Watson test for each model were from 1 to 3, which show independence of errors (27). The significance level was set at 5%. Analyses were performed using the statistical package for the social sciences (SPSS) version 22.0, considering the design effect and the sample weight and were presented stratified by sex.

## 3. Results

The average WC, CI and $VO_2$max values were significantly higher in boys. The average triceps, subscapular, suprailiac skinfold, sum of triceps and subscapular skinfold and sum of triceps, subscapular and suprailiac skinfold values were significantly higher in girls (Table 1). Most (62.4%) adolescents had white skin, were in the age group 14 - 16 years (57.6%), had high socioeconomic status (67.8%) and attended during the day (71.5%) (Table 2).

In the simple and multiple linear regression analysis, with the exception of CI in girls, all other anthropometric indicators were associated with $VO_2$max ($P < 0.01$). Thus, as BMI, WC, WHtR, sum of triceps and subscapularis skinfolds and sum of triceps, subscapular and suprailiac skinfold values increased, the $VO_2$max values of adolescents decreased, and the CI values for girls were not significant. The magnitude of decrease in $VO_2$max values can be verified in the regression coefficients of predictor variables (standardized $\beta$) (Table 3 and 4).

Multiple linear regression identified that regardless of sociodemographic factors (skin color, age, school shift, maternal education and economic level), level of physical activity and sexual maturation, BMI, WC, WHtR, sum of triceps and subscapularis skinfolds and sum of triceps, subscapular and suprailiac skinfold presented explanatory power for $VO_2$max above 10% (adjusted $R^2$) in both sexes. The anthropometric indicator with the highest explanatory power for $VO_2$max in both sexes was the sum of triceps, subscapular and suprailiac skinfolds, and the indicator with the lowest explanatory power was CI. The results showed that 21% and 23% of the $VO_2$max variance of females and males, respectively, was explained by the sum of the three skinfolds (triceps, subscapular and suprailiac) (Tables 3 and 4). All models showed VIF values close to one, indicating lack of multicollinearity among anthropometric indicators, sociodemographic factors and sexual maturation. Moreover, the Durbin-Watson test for each of the models ranged from 1 to 3, which shows the independence of errors in the regression model (data not shown) (Table 5).

## 4. Discussion

With the exception of CI, all other anthropometric indicators analyzed were able to explain the $VO_2$max variation of adolescents in this study. The sum of the three skinfolds (triceps, subscapular and supra-iliac) was the anthropometric marker that had the highest explanatory power ($R^2$) for $VO_2$max in both sexes.

The use of triceps skinfold alone is a way to estimate fat of body extremities (peripheral), while the subscapularis and suprailiac skinfolds provide information on fat concentrated in the trunk (14). However, as fat distribution does not occur in a similar way for individuals, when using the sum of these skinfolds, it is possible to clear see the trend of global accumulation of body fat (30). The sum of two and three skinfolds was the anthropometric indicators with greater explanatory power for $VO_2$max in adolescents, with differences between these indicators of only 1% in the determination coefficient ($R^2$). The best explanatory power of the sum of three skinfolds for predicting $VO_2$max may indicate that the analysis of different sites of fat accumulation results in increased accuracy to estimate total fat and consequently lean body mass in different individuals (14).

A review study showed that individuals with excess body fat had low aerobic fitness levels, regardless of protocol used to assess excess adiposity (BMI, body fat percentage, waist circumference, sum of skinfolds and CI) (31). Furthermore, it was found that large amounts of lean body mass was related to suitable aerobic fitness values due to the oxidative potential of muscle fibers (32). Especially in adolescence, changes in body composition occur abruptly, emphasizing the influence of these components (fat mass and lean body mass) on $VO_2$max (14).

In this study, adolescents with higher BMI, WC and WHtR had lower $VO_2$max values, corroborating other surveys (11). This fact is because overweight individuals are more likely to have difficulty moving around, resulting in greater economy of movement, increased energy expenditure and early fatigue in aerobic activities, reducing performance in physical tests (32). In addition, a systematic review showed that overweight adolescents tend to impose barriers to physical activity that involves individual factors such as shame of their body, interpersonal factors related

**Table 1.** Total Values and Stratified by Sex the Mean and Standard Deviation of Age, Anthropometric Indicators and Aerobic Score[a,b]

| Variables | Total Sample | Males | Females | P Value | Cohen's d |
|---|---|---|---|---|---|
| **Age, y** | 16.22 ± 1.14 | 16.28 ± 1.19 | 16.16 ± 1.10 | 0.15 | 0.10 |
| **BMI, kg/m$^2$** | 22.16 ± 3.72 | 21.89 ± 3.44 | 22.41 ± 3.95 | 0.25 | 0.14 |
| **WC, cm** | 71.48 ± 8.03 | 73.79 ± 7.71 | 69.41 ± 7.74 | < 0.01 | 0.57 |
| **WHtR** | 0.42 ± 0.04 | 0.42 ± 0.04 | 0.43 ± 0.04 | 0.51 | 0.25 |
| **TR SF, mm** | 14.94 ± 7.34 | 10.75 ± 5.13 | 18.70 ± 6.99 | < 0.01 | 1.29 |
| **SE SF, mm** | 13.32 ± 6.73 | 10.76 ± 4.86 | 15.60 ± 7.33 | < 0.01 | 0.77 |
| **SI SF, mm** | 16.25 ± 10.36 | 12.85 ± 8.45 | 19.22 ± 10.94 | < 0.01 | 0.65 |
| **ΣTR + SE, mm** | 28.26 ± 13.49 | 21.51 ± 9.53 | 34.30 ± 13.66 | < 0.01 | 1.08 |
| **ΣTR + SE+SI, mm** | 41.34 ± 25.29 | 32.25 ± 19.06 | 49.25 ± 27.33 | < 0.01 | 0.72 |
| **CI** | 0.95 ± 0.35 | 0.99 ± 0.33 | 0.91 ± 0.36 | < 0.01 | 0.23 |
| **$VO_2$max, mL/kg/min** | 38.80 ± 5.83 | 42.68 ± 5.34 | 35.33 ± 3.66 | < 0.01 | 1.60 |

Abbreviations: BMI, body mass index; CI, Conicity index; M, mean; SD, standard deviation; SE SF, subscapularis skinfold; SI SF: suprailiac skinfold; TR SF, triceps skinfold; $VO_2$max, maximum oxygen uptake; WC, Waist circumference; WHtR, Waist to height ratio; ΣTR + SE, sum of triceps and subscapularis skinfolds; ΣTR + SE + SI, sum of triceps, subscapular and suprailiac skinfolds.
[a]Values are expressed as mean ± SD.
[b]$P \leq 0.05$ (Student's t test).

**Table 2.** Distribution of the Total Sample and Stratified by Sex in Relation to Sociodemographic Factors[a]

| Variables | Total Sample | Males | Females |
|---|---|---|---|
| **Skin color** | | | |
| White | 541 (62.4) | 253 (62.2) | 288 (62.6) |
| Brown/Black/Yellow/Indigenous | 326 (37.6) | 154 (37.8) | 172 (37.4) |
| **Age, y** | | | |
| 14 - 16 | 506 (57.6) | 232 (55.9) | 274 (59.1) |
| 17 - 19 | 373 (42.4) | 183 (44.1) | 190 (40.9) |
| **School shift** | | | |
| Day | 623 (71.5) | 287 (70.0) | 336 (72.9) |
| Night | 248 (28.5) | 123 (30.0) | 125 (27.1) |
| **Maternal education** | | | |
| ≥ 8 years of schooling | 375 (43.2) | 183 (44.7) | 192 (41.8) |
| < 8 years of schooling | 493 (56.8) | 226 (55.3) | 267 (58.2) |
| **Socioeconomic level** | | | |
| High | 503 (67.8) | 255 (73.9) | 248 (62.5) |
| Low | 239 (32.2) | 90 (26.1) | 149 (37.5) |

[a]Values are expressed as No. (%).

**Table 3.** Pearson's Correlation Coefficient Between Body Fat Anthropometric Indicators and $VO_2$max of Adolescents

| Anthropometric Indicators | $VO_2$max | |
|---|---|---|
| | Males | Females |
| | r (CI95%) | r (CI95%) |
| **BMI** | -0.32 (-0.40; -0.24)[a] | -0.39 (-0.45; -0.31)[a] |
| **WC** | -0.32 (-0.40; -0.23)[a] | -0.39 (-0.46; -0.30)[a] |
| **WHtR** | -0.28(-0.35;-0.20)[a] | -0.29 (-0.36; -0.22)[a] |
| **TR SF, mm** | -0.42 (-0.48; -0.35)[a] | -0.42 (-0.48; -0.35)[a] |
| **SE SF, mm** | -0.42 (-0.48; -0.36)[a] | -0.42 (-0.48; -0.36)[a] |
| **SI SF, mm** | -0.44 (-0.50; -036)[a] | -0.41 (-0.49; -0.34)[a] |
| **ΣTR + SE, mm** | -0.44 (-0.49; -0.37)[a] | -0.44 (-0.50; -0.38)[a] |
| **ΣTR + SE + SI, mm** | -0.45 (-0.51; -0.38)[a] | -0.45 (-0.51; -0.38)[a] |
| **CI** | -0.14 (-0.22;-0.05)[a] | -0.06 (-0.20; -0.01) |

Abbreviations: BMI, body mass index; CI; 95%: 95% confidence interval; M, mean; r, Pearson's correlation; SD, standard deviation; SE SF, subscapularis skinfold; SI SF: suprailiac skinfold; TR SF, triceps skinfold; $VO_2$max, maximum oxygen uptake; WC, Waist circumference; WHtR, Waist to height ratio; ΣTR + SE, sum of triceps and subscapularis skinfolds; ΣTR + SE + SI, sum of triceps, subscapular and suprailiac skinfolds.
[a]$P < 0.01$.

to the prejudice they suffer due to excess weight, environmental factors such as lack of security in neighborhoods for physical activity, among others (33).

Boys with higher CI values of this study showed lower $VO_2$max values. No studies on CI compared to the $VO_2$max in adolescents were found in literature, only in adult women (34), making the comparison of results found in this study difficult. In addition, studies have shown that CI is an anthropometric indicator with low discriminatory power for health-related problems compared with other indicators (35).

The sample studied is from a city with Gini index of 0.44. This index is a measure commonly used to calculate inequalities in income distribution (15). To calculate this index, it is necessary to analyze the income of the population in the area under study. The Gini index expresses the difference between the incomes of the poorest and the richest. Numerically, it ranges from 0 to 1. Zero represents equality, which means that everyone has the same income, while 1 is the extreme opposite; i.e. a single person holds all wealth (15). The literature showed that adolescents from cities with high social inequality were less physically active in leisure time than adolescents from cities with low social inequality (36). This situation may reflect higher odds of obesity and lower levels of aerobic fitness in adolescents living in cities with high inequality in income distribution.

The fact that $VO_2$max was estimated by submaximal test may be considered a study limitation, considering that submaximal protocols to estimate $VO_2$max have lower accuracy compared to maximum protocols. However, submaximal tests are more practical to apply in population with high number of individuals (37). In addition, indirect submaximal tests using heart rate can be ways to assess $VO_2$max of adolescents with low physical fitness or those that do not bear the performance of maximum stress tests (38).

This study significantly contributes to this area because it presents seven different anthropometric indicators (BMI, WC, WHtR, CI, triceps skinfold, subscapular skinfold, suprailiac skinfold, sum of triceps and subscapular skinfolds and sum of triceps, subscapularis and suprailiac skinfolds), chosen in order to obtain a greater overview of the body fat distribution that could predict the $VO_2$max variation in adolescents. The use of regression models adjusted for sociodemographic factors, sexual maturation and physical activity, have identified that regardless of age, skin color, economic level, maternal education, maturational stage and level of physical activity among young people, anthropometric indicators can explain the aerobic fitness variation. Moreover, the association between $VO_2$max and anthropometric indicators enhances the need for effective intervention programs focused on maintaining satisfactory body fat and aerobic fitness levels, considering that both factors, when in inadequate levels, bring consequences and damage to health such as predisposition to cardiovascular diseases.

### *4.1. Conclusions*

It could be concluded that with the exception of CI for girls, all anthropometric indicators studied (BMI, WC, WHtR, sum of triceps and subscapular skinfolds and sum of triceps, subscapular and suprailiac skinfolds) were able to explain the $VO_2$max variation in adolescents of this study, and the sum of triceps, subscapularis and suprailiac skinfolds showed the best power to explain the aerobic performance of adolescents. The results of this research show that health professionals need to encourage adolescents to engage in physical activity programs in order to improve aerobic performance and reduce body fat.

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## Footnotes

**Conflicts of Interest:** Nothing to declare.

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## References

1. Tomkinson GR, Olds TS. Secular changes in aerobic fitness test performance of Australasian children and adolescents. *Med Sport Sci.* 2007;**50**:168–82. doi: 10.1159/0000101361. [PubMed: 17387257].
2. Moraes Ferrari GL, Bracco MM, Matsudo VK, Fisberg M. Cardiorespiratory fitness and nutritional status of schoolchildren: 30-year evolution. *J Pediatr (Rio J).* 2013;**89**(4):366–73. doi: 10.1016/j.jped.2012.12.006. [PubMed: 23791022].
3. Farrell SW, Finley CE, Haskell WL, Grundy SM. Is There a Gradient of Mortality Risk among Men with Low Cardiorespiratory Fitness? *Med Sci Sports Exerc.* 2015;**47**(9):1825–32. doi: 10.1249/MSS.0000000000000608. [PubMed: 25551401].
4. Eisenmann JC, Welk GJ, Ihmels M, Dollman J. Fatness, fitness, and cardiovascular disease risk factors in children and adolescents. *Med Sci Sports Exerc.* 2007;**39**(8):1251–6. doi: 10.1249/MSS.0b013e318064c8b0. [PubMed: 17762357].
5. Galaviz KI, Tremblay MS, Colley R, Jauregui E, Lopez y Taylor J, Janssen I. Associations between physical activity, cardiorespiratory fitness, and obesity in Mexican children. *Salud Publica Mex.* 2012;**54**(5):463–9. [PubMed: 23011497].
6. McGavock JM, Torrance BD, McGuire KA, Wozny PD, Lewanczuk RZ. Cardiorespiratory fitness and the risk of overweight in youth: the Healthy Hearts Longitudinal Study of Cardiometabolic Health. *Obesity (Silver Spring).* 2009;**17**(9):1802–7. doi: 10.1038/oby.2009.59. [PubMed: 19282826].
7. Lee SJ, Arslanian SA. Cardiorespiratory fitness and abdominal adiposity in youth. *Eur J Clin Nutr.* 2007;**61**(4):561–5. doi: 10.1038/sj.ejcn.1602541. [PubMed: 17021595].
8. Ortega FB, Ruiz JR, Castillo MJ, Sjostrom M. Physical fitness in childhood and adolescence: a powerful marker of health. *Int J Obes (Lond).* 2008;**32**(1):1–11. doi: 10.1038/sj.ijo.0803774. [PubMed: 18043605].
9. Goran M, Fields DA, Hunter GR, Herd SL, Weinsier RL. Total body fat does not influence maximal aerobic capacity. *Int J Obes Relat Metab Disord.* 2000;**24**(7):841–8. [PubMed: 10918530].
10. Gonzalez Jimenez E. [Body composition: assessment and clinical value]. *Endocrinol Nutr.* 2013;**60**(2):69–75. doi: 10.1016/j.endonu.2012.04.003. [PubMed: 22704270].

11. Arango CM, Parra DC, Gomez LF, Lema L, Lobelo F, Ekelund U. Screen time, cardiorespiratory fitness and adiposity among school-age children from Monteria, Colombia. *J Sci Med Sport.* 2014;**17**(5):491–5. doi: 10.1016/j.jsams.2013.09.010. [PubMed: 24211150].
12. Patkar KU, Joshi AS. Comparison of VO2max in obese and non-obese young Indian population. *Indian J Physiol Pharmacol.* 2011;**55**(2):188–92. [PubMed: 22319902].
13. Ronque ERV, Cyrino ES, Mortatti AL, Moreira A, Avelar A, Carvalho FO, et al. Relação entre aptidão cardiorrespiratória e indicadores de adiposidade corporal em adolescentes. *Revista Paulista de Pediatria.* 2010;**28**(3):296–302. doi: 10.1590/s0103-05822010000300007.
14. Cicek B, Ozturk A, Unalan D, Bayat M, Mazicioglu MM, Kurtoglu S. Four-site skinfolds and body fat percentage references in 6-to-17-year old Turkish children and adolescents. *J Pak Med Assoc.* 2014;**64**(10):1154–61. [PubMed: 25823156].
15. United Nations . Atlas de Desenvolvimento Humano do Brasil. ; 2016.
16. Canadian Society for Exercise Physiology . The Canadian Physical Activity, Fitness & Lifestyle Appraisal: CSEP's Plan for Healthy Living. Ottawa: Canadian Society for Exercise Physiology (CSEP); 1998.
17. Weller IM, Thomas SG, Gledhill N, Paterson D, Quinney A. A study to validate the modified Canadian Aerobic Fitness Test. *Can J Appl Physiol.* 1995;**20**(2):211–21. [PubMed: 7640647].
18. Brazilian Institute of Geography and Statistics . Pesquisa Nacional de Saneamento Basico. Rio de Janeiro: IBGE; 2010.
19. Brazilian Association of Research Companies . Criterio de classificacao economica Brasil. Sao Paulo: ABEP; 2010.
20. World Health Organization (WHO) . Global recommendations on physical activity for health. Geneve: World Health Organization; 2010.
21. Strong WB, Malina RM, Blimkie CJ, Daniels SR, Dishman RK, Gutin B, et al. Evidence based physical activity for school-age youth. *J Pediatr.* 2005;**146**(6):732–7. doi: 10.1016/j.jpeds.2005.01.055. [PubMed: 15973308].
22. Tanner JM. Growth at Adolescence'Blackwell Scientific Publications. Oxford; 1962.
23. Matsudo SMM, Matsudo VKR. Self-assessment and physician assessment of sexual maturation in Brazilian boys and girls: Concordance and reproducibility. *Am J Hum Biol.* 1994;**6**(4):451–5. doi: 10.1002/ajhb.1310060406. [PubMed: 28548259].
24. Kline RB. Principles and practice of structural equation modeling. Guilford publications; 2015.
25. Curran PJ, West SG, Finch JF. The robustness of test statistics to nonnormality and specification error in confirmatory factor analysis. *Psychol Methods.* 1996;**1**(1):16–29. doi: 10.1037/1082-989x.1.1.16.
26. Cohen J. Statistical power analysis for the behavioral sciences (revised ed.). New York: Academic Press; 1977.
27. Field A. Discovering statistics using SPSS. Sage publications; 2009.
28. Malina RM, Bouchard C, Bar-Or O. Physical activity as a factor in growth, maturation and performance. Champaign: Human Kinetics; 1991.
29. Armstrong N, Welsman JR. Assessment and interpretation of aerobic fitness in children and adolescents. *Exerc Sport Sci Rev.* 1994;**22**:435–76. [PubMed: 7925551].
30. Lohman TG. The Use of Skinfold to Estimate Body Fatness on Children and Youth. *J Phys Educ Recreat Dance.* 1987;**58**(9):98–103. doi: 10.1080/07303084.1987.10604383.
31. de Andrade Goncalves EC, Augusto Santos Silva D, Gimenes Nunes HE. Prevalence and Factors Associated With Low Aerobic Performance Levels in Adolescents: A Systematic Review. *Curr Pediatr Rev.* 2015;**11**(1):56–70. doi: 10.2174/1573396311666150501003435.
32. Yanek LR, Vaidya D, Kral BG, Dobrosielski DA, Moy TF, Stewart KJ, et al. Lean Mass and Fat Mass as Contributors to Physical Fitness in an Overweight and Obese African American Population. *Ethn Dis.* 2015;**25**(2):214–9. [PubMed: 26118151].
33. Stankov I, Olds T, Cargo M. Overweight and obese adolescents: what turns them off physical activity? *Int J Behav Nutr Phys Act.* 2012;**9**:53. doi: 10.1186/1479-5868-9-53. [PubMed: 22554016].
34. Freitas Junior IF, Rosa CS, Codogno JS, Bueno DR, Buonani C, Conterato I, et al. [Cardiorespiratory fitness and body fat distribution in women with 50 years or more]. *Rev Esc Enferm USP.* 2010;**44**(2):395–400. [PubMed: 20642052].
35. Silva DA, Petroski EL, Peres MA. Accuracy and measures of association of anthropometric indexes of obesity to identify the presence of hypertension in adults: a population-based study in Southern Brazil. *Eur J Nutr.* 2013;**52**(1):237–46. doi: 10.1007/s00394-012-0314-8. [PubMed: 22302615].
36. Silva DA. Relationship between Brazilian adolescents' physical activity and social and economic indicators of the cities where they live. *Percept Mot Skills.* 2015;**120**(2):355–66. doi: 10.2466/06.PMS.120v11x5. [PubMed: 25799032].
37. Silva DA, Tremblay M, Pelegrini A, Dos Santos Silva RJ, Cabral de Oliveira AC, Petroski EL. Association Between Aerobic Fitness And High Blood Pressure in Adolescents in Brazil: Evidence for Criterion-Referenced Cut-Points. *Pediatr Exerc Sci.* 2016;**28**(2):312–20. doi: 10.1123/pes.2015-0172. [PubMed: 26731016].
38. American College of Sports Medicine . ACSM's Guidelines for Exercise Testing and Prescription. Philadelphia: Lippincott Williams & Wilkins; 2014.

**Table 4.** Simple and Multiple Linear Regression for the Association Between $VO_2$max and Anthropometric Indicators for Boys

| Variables | | Males | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Simple | | | | | | Multiple[a] | | | | | |
| | | B | SE | $\beta$ | t | P Value | Cohen's f2 | B | SE | $\beta$ | t | P Value | Cohen's f2 |
| **BMI** | | -0.50 | 0.07 | -0.32 | -6.99 | < 0.01 | 0.11 | -0.51 | 0.08 | -0.32 | -6.12 | < 0.01 | 0.15 |
| | $R^2$ | 0.10 | | | | | | 0.15 | | | | | |
| | Adj $R^2$ | 0.10 | | | | | | 0.13 | | | | | |
| | SE | 5.06 | | | | | | 4.90 | | | | | |
| | F (dfn, dfd) | 48.98 (1.413) | | | | 7.41 (8.315) | | | | | | | |
| **WC** | | -0.22 | 0.03 | -0.32 | -7.01 | < 0.01 | 0.11 | -0.23 | 0.03 | -0.33 | -6.37 | < 0.01 | 0.16 |
| | $R^2$ | 0.10 | | | | | | 0.16 | | | | | |
| | Adj $R^2$ | 0.10 | | | | | | 0.14 | | | | | |
| | SE | 5.06 | | | | | | 4.88 | | | | | |
| | F (dfn, dfd) | 49.24 (1.413) | | | | 7.83 (8.315) | | | | | | | |
| **WHtR** | | -36.58 | 5.88 | -0.29 | -6.21 | < 0.01 | 0.08 | -5.29 | 1.11 | -0.25 | -4.75 | < 0.01 | 0.09 |
| | $R^2$ | 0.08 | | | | | | 0.12 | | | | | |
| | Adj $R^2$ | 0.08 | | | | | | 0.09 | | | | | |
| | SE | 5.11 | | | | | | 5.00 | | | | | |
| | F (dfn, dfd) | 38.65 (1.413) | | | | 5.44 (8.315) | | | | | | | |
| **TR SF** | | -0.43 | 0.04 | -0.42 | -9.41 | < 0.01 | 0.20 | -0.42 | 0.05 | -0.39 | -7.78 | < 0.01 | 0.23 |
| | $R^2$ | 0.17 | | | | | | 0.21 | | | | | |
| | Adj $R^2$ | 0.17 | | | | | | 0.19 | | | | | |
| | SE | 4.85 | | | | | | 4.75 | | | | | |
| | F (dfn, dfd) | 88.60 (1.413) | | | | 10.47 (8.315) | | | | | | | |
| **SE SF** | | -0.46 | 0.04 | -0.42 | -9.49 | < 0.01 | 0.20 | -0.46 | 0.05 | -0.41 | -8.08 | < 0.01 | 0.25 |
| | $R^2$ | 0.17 | | | | | | 0.22 | | | | | |
| | Adj $R^2$ | 0.17 | | | | | | 0.20 | | | | | |
| | SE | 4.85 | | | | | | 4.71 | | | | | |
| | F (dfn, dfd) | 90.13 (1.413) | | | | 11.12 (8.315) | | | | | | | |
| **SI SF** | | -0.30 | 0.49 | -0.44 | 94.87 | < 0.01 | 0.23 | -0.28 | 0.03 | -0.40 | -8.01 | < 0.01 | 0.23 |
| | $R^2$ | 0.19 | | | | | | 0.21 | | | | | |
| | Adj $R^2$ | 0.19 | | | | | | 0.19 | | | | | |
| | SE | 4.80 | | | | | | 4.72 | | | | | |
| | F (dfn, dfd) | 99.13 (1.412) | | | | 10.98 (8.314) | | | | | | | |
| **$\Sigma$TR + SE** | | -0.24 | 0.02 | -0.44 | -10.01 | < 0.01 | 0.23 | -0.24 | 0.02 | -0.42 | -8.40 | < 0.01 | 0.27 |
| | $R^2$ | 0.19 | | | | | | 0.23 | | | | | |
| | Adj $R^2$ | 0.19 | | | | | | 0.21 | | | | | |
| | SE | 4.80 | | | | | | 4.68 | | | | | |
| | F (dfn, dfd) | 100.38 (1.413) | | | | 11.82 (8.315) | | | | | | | |
| **$\Sigma$TR + SE + SI** | | -0.14 | 0.01 | -0.45 | -10.38 | < 0.01 | 0.25 | -0.13 | 0.01 | -0.42 | -8,48 | < 0,01 | 0.27 |
| | $R^2$ | 0.20 | | | | | | 0.23 | | | | | |
| | Adj $R^2$ | 0.20 | | | | | | 0.21 | | | | | |
| | SE | 4.76 | | | | | | 4.67 | | | | | |
| | F (dfn, dfd) | 107.84 (1.413) | | | | 11.99 (8.315) | | | | | | | |
| **CI** | | -17.40 | 5.75 | -0.14 | -3.02 | < 0.01 | 0.01 | -16.67 | 6.66 | -0.14 | -2,50 | < 0,01 | 0.05 |
| | $R^2$ | 0.02 | | | | | | 0.07 | | | | | |
| | Adj $R^2$ | 0.01 | | | | | | 0.05 | | | | | |
| | SE | 5.29 | | | | | | 5.13 | | | | | |
| | F (dfn, dfd) | 9.15 (1.413) | | | | | 3.27 (8.315) | | | | | | |

Abbreviations: Adj $R^2$, adjusted determination coefficient; $\beta$, slope coefficient; B, correlation coefficient; BMI, body mass index; CI, Conicity; F (dfn, dfd), analysis of variance test (degree of freedom); P, P value; $R^2$, determination coefficient; SE, standard error of the estimate; SE SF, subscapularis skinfold; t: t-test of parameters; TR SF, triceps skinfold; WC, Waist circumference; WHtR, Waist to height ratio; $\Sigma$TR + SE: sum of triceps and subscapularis skinfolds; $\Sigma$TR + SE + SI, sum of triceps, subscapular and suprailiac skinfolds; index.

[a] Analysis adjusted for sociodemographic factors (skin color, age, school shift, maternals education, socioeconomic status and sexual maturation).

**Table 5.** Simple and Multiple Linear Regression for the Association Between $VO_2$max and Anthropometric Indicators for Females

| Variables | Females | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Simple | | | | | | Multiple[a] | | | | | |
| | B | SE | $\beta$ | t | P Value | Cohen's f2 | B | SE | $\beta$ | t | P Value | Cohen's f2 |
| **BMI** | -0.36 | 0.04 | -0.39 | -9.21 | < 0.01 | 0.17 | -0.34 | 0.04 | -0.37 | -7,35 | < 0,01 | 0.16 |
| $R^2$ | 0.15 | | | | | | 0.16 | | | | | |
| Adj $R^2$ | 0.15 | | | | | | 0.14 | | | | | |
| SE | 3.37 | | | | | | 3.40 | | | | | |
| F (dfn, dfd) | 84.98 (1.462) | | | | | 9.18 (8.376) | | | | | | |
| **WC** | -0.18 | 0.02 | -0.39 | -9.21 | < 0.01 | 0.17 | -0.18 | 0.02 | -0.38 | -7,60 | < 0,01 | 0.17 |
| $R^2$ | 0.15 | | | | | | 0.17 | | | | | |
| Adj $R^2$ | 0.15 | | | | | | 0.15 | | | | | |
| SE | 3.37 | | | | | | 3.39 | | | | | |
| F (dfn, dfd) | 84.88 (1.462) | | | | | 9.66 (8.376) | | | | | | |
| **WHtR** | -26.21 | 3.37 | -0.34 | -7.77 | < 0.01 | 0.12 | -3.21 | 0.58 | -0.27 | -5,50 | < 0,01 | 0.10 |
| $R^2$ | 0.11 | | | | | | 0.11 | | | | | |
| Adj $R^2$ | 0.11 | | | | | | 0.09 | | | | | |
| SE | 3.45 | | | | | | 3.50 | | | | | |
| F(dfn, dfd) | 60.48 (1.462) | | | | | 6.07 (8.376) | | | | | | |
| **TR SF** | -0.22 | 0.02 | -0.42 | -10.19 | < 0.01 | 0.22 | -0.20 | 0.02 | -0.39 | -8,27 | < 0,01 | 0.20 |
| R2 | 0.18 | | | | | | 0.19 | | | | | |
| Adj $R^2$ | 0.18 | | | | | | 0.17 | | | | | |
| SE | 3.31 | | | | | | 3.35 | | | | | |
| F (dfn, dfd) | 103.84 (1.462) | | | | 11.06 (8.376) | | | | | | | |
| **SE SF** | -0.21 | 0.02 | -0.42 | -10.17 | < 0.01 | 0.22 | -0.20 | 0.02 | -0.41 | -8,52 | < 0,01 | 0.22 |
| $R^2$ | 0.18 | | | | | | 0.19 | | | | | |
| Adj $R^2$ | 0.18 | | | | | | 0.18 | | | | | |
| SE | 3.32 | | | | | | 3.33 | | | | | |
| F (dfn, dfd) | 103.57 (1.462) | | | | 11.61 (8.376) | | | | | | | |
| **SI SF** | -0.17 | 0.01 | -0.41 | -9.88 | < 0.01 | 0.20 | -0.16 | 0.02 | -0.40 | -8,40 | < 0,01 | 0.20 |
| $R^2$ | 0.17 | | | | | | 0.19 | | | | | |
| Adj $R^2$ | 0.17 | | | | | | 0.17 | | | | | |
| SE | 3.33 | | | | | | 3.34 | | | | | |
| F (dfn, dfd) | 97.78 (1.462) | | | | | 11.35 (8.376) | | | | | | |
| **ΣTR+SE** | -0.12 | 0.01 | -0.45 | -10.38 | < 0.01 | 0.25 | -0.11 | 0.01 | -0.43 | -8,93 | < 0,01 | 0.23 |
| $R^2$ | 0.20 | | | | | | 0.21 | | | | | |
| Adj $R^2$ | 0.20 | | | | | | 0.19 | | | | | |
| SE | 4.76 | | | | | | 3.30 | | | | | |
| F (dfn, dfd) | 107.84 (1.413) | | | | 12.54 (8.376) | | | | | | | |
| **ΣTR + SE + SI** | -0.07 | 0.00 | -0.45 | -10.92 | < 0.01 | 0.25 | -0.07 | 0.00 | -0.44 | -9,16 | < 0,01 | 0.25 |
| $R^2$ | 0.20 | | | | | | 0.21 | | | | | |
| Adj $R^2$ | 0.20 | | | | | | 0.20 | | | | | |
| SE | 3.27 | | | | | | 3.29 | | | | | |
| F (dfn, dfd) | 119.24 (1.462) | | | | 13.10 (8.376) | | | | | | | |
| **CI** | -3.46 | 2.50 | -0.06 | -1.38 | 0.16 | < 0.01 | -2.72 | 2.61 | -0.05 | -1,04 | 0,29 | 0.02 |
| $R^2$ | 0.00 | | | | | | 0.04 | | | | | |
| Adj $R^2$ | 0.00 | | | | | | 0.02 | | | | | |
| SE | 3.66 | | | | | | 3.63 | | | | | |
| F (dfn, dfd) | 1.92 (1.462) | | | | | 2.26 (8.376) | | | | | | |

Abbreviations: Adj $R^2$, adjusted determination coefficient; $\beta$, slope coefficient; B, correlation coefficient; BMI, body mass index; CI, Conicity; F (dfn, dfd), analysis of variance test (degree of freedom); P, P value; $R^2$, determination coefficient; SE, standard error of the estimate; SE SF, subscapularis skinfold; t, t-test of parameters; TR SF, triceps skinfold; WC, Waist circumference; WHtR, Waist to height ratio; ΣTR + SE, sum of triceps and subscapularis skinfolds; ΣTR + SE + SI, sum of triceps, subscapular and suprailiac skinfolds; index.

[a] Analysis adjusted for sociodemographic factors (skin color, age, school shift, maternals education, socioeconomic status and sexual maturation).