CARDIORESPIRATORY FITNESS, PHYSICAL ACTIVITY, AND INDICATORS OF ADIPOSITY IN BRAZILIAN ADOLESCENTS

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ABSTRACT

Purpose. In view of the increasing prevalence of overweight at early ages and its possible association with physical inactivity, investigations into the best method to assess physical inactivity and its association with excess weight in epidemiological studies are required. This study aimed to examine the associations between cardiorespiratory fitness and physical activity with indicators of adiposity in an adolescent population. **Methods.** This cross-sectional study involved a random sample of 697 students aged 12–19 years from public schools in the metropolitan area of Rio de Janeiro, Brazil. Overweight was classified according to body mass index. Body fat was measured by bioelectrical impedance, cardiorespiratory fitness by a 9 min run/walk test (T9), and physical activity by the International Physical Activity Questionnaire (IPAQ). Odds ratios and 95% confidence intervals (CI) were used to verify the magnitude of the associations. **Results.** Adolescents with poor T9 performance were more likely to be overweight (OR = 2.9, 95% CI 1.2–7.0) and have excess body fat (OR = 2.2, 95% CI 1.1–4.3) than those with better performance. Those classified as moderately active by the IPAQ were more likely to have excess body fat than those classified as active (OR = 1.8, 95% CI 1.2–2.8). **Conclusions.** Because of the greater magnitude of the association between cardiorespiratory fitness, as assessed by using the T9, with being overweight and having excess body fat, the T9 may serve as a valuable instrument in the school environment to identify inactive adolescents who are at risk of developing obesity.

Key words: physical fitness, motor activity, adiposity, adolescents

Introduction

Presently, obesity is a major public health problem due to the fast increase in its prevalence and its association with adverse effects on cardiovascular health, even in young people [1]. There is evidence that physical activity helps in controlling body weight gain and, consequently, in preventing obesity in adults [2]. However, the findings of studies regarding the association between physical inactivity and obesity in adolescents are contradictory. Some report a direct association [3–5] while others report no association [6–8]. It is likely that variations in study design and in the types of instruments and criteria used to classify physical inactivity could explain such discrepancies, at least in part. Most studies use questionnaires to assess physical activity [9–11] due to their low cost and their applicability in epidemiological studies. However, adolescents often have difficulty remembering, interpreting, and quantifying their physical activity, which is a limitation in the effectiveness of such questionnaires. Thus, other methods are needed that are more objective and can be easily applied for screening adolescents displaying inactivity.

Cardiorespiratory fitness is defined as an individual's ability to perform physical activity involving a large muscle mass component at moderate to vigorous intensity for long periods of time [12]. It can be used as a proxy for physical activity [11], and performance on cardiorespiratory fitness tests has been inversely associated with overweight in adolescents based on a meta-analysis of 20 studies [13]. In European adolescents, moderate and high levels of cardiorespiratory fitness have also been inversely related to body mass index (BMI) and abdominal obesity independent of physical activity or sedentary behavior [4].

An investigation using a sample of Brazilian adolescents showed poor agreement between the level of physical activity assessed by the International Physical Activity Questionnaire (IPAQ) and performance in a 9-min run/walk test (T9) to assess cardiorespiratory fitness [14]. In that study, there was a high prevalence of adolescents with poor T9 performance and individuals classified as active by the IPAQ. Because of this, we questioned which method would better associate with measures of adiposity in the same sample of adolescents. To answer this question, the aim of the present study was to examine the association between cardiorespiratory fitness and physical activity levels and measures of adiposity in adolescents.

Material and methods

This was a cross-sectional study based on probability sampling of students aged 12 to 19 years from 13 of the 34 public schools in the city of Niterói located in southeastern Brazil. Niterói is a city about 15 km east of Rio

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de Janeiro. It has an area of approximately 130000 km^2 and is the sixth most populous municipality in the state of Rio de Janeiro with approximately 480000 inhabitants. These adolescents had previously participated in a larger study whose main objective was to evaluate the development of overweight and obesity in adolescents by comparing two cross-sectional studies from 2003 and 2008–2009.

The data analyzed in this study were obtained from the latter study and were collected between May 2008 and April 2009. The design of the study sample from the original study is described in detail in Barros et al. [15]. Among the 928 eligible students who attended the 34 randomly selected schools during the data collection period (exclusion criteria: physical disability, contraindication to anthropometry, and pregnancy), 697 were evaluated for anthropometric measures, 639 for cardiorespiratory fitness test (T9), and 682 for physical activity level via the IPAQ. Only students willing to participate in the study and who had provided signed informed consent by their parent or guardian participated in the study.

Weight, height, and waist circumference were assessed. Weight was measured using portable electronic scales, model PPS (Kratos-Cas Electronic Scales, Brazil), with 150-kg capacity and 50-g resolution. Height was measured using a portable stadiometer (Alturexata, Brazil) at 0.1 cm graduations. Height was measured in duplicate, allowing a maximum variation of 0.5 cm between the two measurements from which the mean value was calculated. The protocol proposed by Gordon et al. [16] was followed for weight and height measurements. Sex- and age-specific BMI (weight/height^2) cut-off points were used to evaluate the appropriateness of the adolescents' weight. They were classified as overweight (BMI > 1 z-score) and not overweight (BMI ≤ 1 z-score) according to World Health Organization criteria [17]. Waist circumference (WC) was measured around the smallest girth of the trunk using an inelastic tape measure with 0.1 cm graduations. Two measurements were taken, allowing a maximum variation of 1.0 cm between both measurements, and the mean value was calculated as based on Callaway et al. [18]. Adolescents above the 90th percentile of the WC sample distribution were considered to have a high WC value indicating abdominal obesity.

Body composition was estimated using bioelectrical impedance with a 101Q analyzer (RJL System, United States). To estimate lean body mass (kg), an equation specific to adolescents was used [19]. Body fat percentages (BF%) were also obtained by using the equation: ([body weight – lean body mass × 100] / body weight). Boys and girls with BF% values greater than 25% and 30%, respectively, were considered to have high BF% [20].

Sexual maturation was assessed according to the criteria proposed by Tanner [21], focusing on the development of breasts, genitalia, and pubic hair using the self-evaluation validated by Saito [22]. The pre-pubertal period was classified as stage 1 for both sexes, the beginning of the growth spurt as stages 2 and 3 for boys and stage 2 for girls, the peak of growth spurt as stage 4 for boys and stage 3 for girls, and growth deceleration as stage 5 for boys and stages 4 and 5 for girls.

Cardiorespiratory fitness was assessed by using the T9 according to the protocol proposed by Gaya and Silva [23]. More details about the T9 procedure can be found in Straatmann et al. [14]. The adolescents were classified into six categories based on their distance running in m, according to sex and age, as follows: very poor, poor, fair, good, very good, and excellent [23]. In later analysis, they were grouped into three categories: poor (very poor and poor), fair (fair and good), and good (very good and excellent). The distance covered in this test was also analyzed as a continuous variable (m).

The adolescents' physical activity level was assessed by using the short version of the IPAQ in an interview format, which has been validated for Brazilian adolescents aged 14 years or older [24]. In this study, we chose to administer the IPAQ to the total sample, regardless of age, as done in other studies [25–26] as we were interested in also investigating the applicability of this questionnaire in a context different from that of the validation study (performed in another region of Brazil).

Based on the frequency and time spent on the activities reported, the students were classified initially into five categories (very active, active, moderately active A, moderately active B, sedentary) [27] and grouped into three categories for the later analysis purposes: active (very active and active), moderately active (A and B), and sedentary.

The information obtained from the IPAQ was also used to estimate a score expressed in metabolic equivalent units (METs) [28–30]. A variable was created for this study titled "total physical activity score", which was calculated by multiplying the METs for each type of activity informed by min per week [28]. The volume of each type of activity was calculated by weighting its energy requirements (walking: 3.3 METs, moderate activity: 4.0 METs, vigorous activity: 8.0 METs). The sum of the scores obtained for each type of physical activity gave the total score of physical activity (walking + moderate physical activity + vigorous physical activity = total physical activity score) [28]. Less than 10 min of physical activity per day was not included in the calculation as scientific evidence indicates that sessions of up to 10 minutes of physical activity do not yield any health benefits. Adolescents with total physical activity scores above 960 minutes (16 hours per day) were excluded from the data analysis [28].

Statistical analyses were performed considering the effect of the cluster sampling design (classes) and the expansion of the sample corrected by relative weight by using the Statistical Package for Social Sciences (SPSS) version 19.0 (IBM, USA).

Initially, we evaluated the distribution of the continuous variables by using the Kolmogorov–Smirnov

test for BMI, BMI z-scores, BF%, waist circumference, lean body mass, distance covered in the T9, and total physical activity score. As none of the variables (except the BMI z-score) presented a normal distribution, we turned these variables into logarithms to obtain a normal distribution of variables.

The frequencies and 95% confidence intervals (CI) were calculated for the categorical variables, and the means and 95% CI were calculated for the continuous variables stratified according to sex. The magnitude of the associations between the binary dependent variables (overweight or not overweight, high or not high BF%, > or ≤ 90th percentile of WC) and the independent variables (obtained from the T9 and IPAQ) was investigated by logistic regression to estimate the odds ratio (OR) and 95% CI. For the continuous variables, General Linear Model procedures were employed to determine the coefficient (β) of linear regression and r^2 value. All associations were adjusted for sex and age (in years), considering the possible confounding effects of these variables on the associations investigated. A p value < 0.05 was considered as statistically significant.

Results

Among 697 adolescents evaluated, 59.6% were girls and approximately 77% were aged 14 or over. Most of the boys were experiencing a growth spurt and most of the girls were experiencing growth deceleration; 19.6% of the girls and 23% of the boys were found to be overweight and three times more girls than boys had excess body fat. The value of waist circumference at the 90th percentile of the sample waist circumference distribution was 79.7 cm for boys and 77 cm for girls. Most of the adolescents (up to 70% of both sexes) were classified as having poor cardiorespiratory fitness and most were classified as active based on IPAQ assessment of physical activity level (Table 1).

The adolescents classified as having poor T9 performance were three times more likely to be overweight (OR = 2.9, 95% CI 1.2–7.0) and two times more likely to have excess body fat (OR = 2.2, 95% CI 1.1–4.3) than those classified as having good performance. As for the association with IPAQ-assessed physical activity level, those classified as moderately active were almost twice as likely to have excess body fat than those classified as active (OR = 1.8, 95% CI 1.2–2.8). After adjusting for sex and age, the associations observed in the crude analysis remained significant and the likelihood of an adolescent classified as having poor T9 performance being overweight (OR = 4.2, 95% CI 1.5–11.7) or excess body fat (OR = 2.96, 95% CI 1.2–7.4) increased compared with that of an adolescent classified as having good performance (Table 2).

In the linear regression analysis adjusted for age and sex (Table 3), there was a significant inverse association between the distance covered in the T9 and BMI (β = –1.88,

$p < 0.001$), BMI z-score (β = –1.45, $p = 0.001$), WC (β = –0.92, $p = 0.002$), and BF% (β = –0.98, $p < 0.001$). No significant association was observed between total physical activity score and the adiposity indicators. When adjusted for sexual maturation, no change in the statistical significance of the investigated associations was observed (data not shown).

Models based on the adiposity indicators adjusted for age and sex explained approximately 30% of the variability in the distance covered in the T9. There was no association between the total physical activity score derived from the IPAQ and the analyzed adiposity indicators, and the models explained 1.5–1.9% of the variability of these variables when adjusted for age and sex.

Discussion

This study found that cardiorespiratory fitness as assessed by the T9 was associated with being overweight and having high BF%. The chance of being classified in these categories, therefore, was higher for those with poor T9 performance. Meanwhile, the level of IPAQ-assessed physical activity was only associated with BF%. After adjusting for sex and age, the magnitude of association between T9 performance and adiposity indicators increased, while the association observed between IPAQ-assessed physical activity and BF% remained significant, albeit with less strength of association. Moreover, the inverse significant relationship between the distance covered in the T9 and the adiposity indicators reinforced the premise that poor cardiorespiratory fitness may be an indicator of risk of obesity among adolescents [13].

Corroborating the findings of this study, Aires et al. [7] observed in a study with Portuguese adolescents that cardiorespiratory fitness was a better predictor of overweight than assessments of physical activity by using a questionnaire. The authors also found that cardiorespiratory fitness remained associated with overweight even after controlling for potential confounders, as in the present study.

In a Food and Assessment of the Nutritional Status of Adolescents study involving 2859 Spanish adolescents, moderate and high levels of cardiorespiratory fitness (rather than physical activity level measured by using a questionnaire) were found to be associated with lower adiposity as measured by BMI and waist circumference [4].

In this same context, a longitudinal survey following Portuguese elementary school children for 2 years found that those with poorer performance on tests assessing cardiorespiratory fitness at baseline presented four times greater risk of weight gain after 2 years of follow-up than those with better performance [31].

In Brazil, these findings have been confirmed by Andreasi et al. [32], who investigated female adolescents, and Rodrigues et al. [33], who studied adolescents of both sexes. In these studies, worse performance on a cardiores-

Table 1. Demographic variables, indicators of adiposity, cardiorespiratory fitness, and physical activity level according to sex

Variables	Male	Female
	% (95% CI)	% (95% CI)
Sex ($n = 697$)	40.4 (34.5–46.7)	59.6 (53.3–65.5)
Age ($n = 697$)		
< 14 years	20.6 (10.3–36.8)	24.5 (13.4–40.7)
≥ 14 years	79.4 (63.2–89.7)	75.5 (59.3–86.6)
Sexual maturation: breasts /genitalia ($n = 697$)		
Beginning of growth spurt	40.5 (33.3–48.3)	4.0 (1.3–11.8)
Peak of growth spurt	51.8 (44.0–59.5)	45.1 (39.2–51.1)
Growth deceleration	7.7 (4.9–11.8)	50.9 (44.0–57.8)
Sexual maturation: pubic hair ($n = 695$)		
Beginning of growth spurt	13.3 (9.2–18.9)	5.5 (3.5–8.7)
Peak of growth spurt	56.0 (48.2–63.4)	27.5 (23.3–32.2)
Growth deceleration	30.7 (24.3–37.9)	66.9 (61.9–71.6)
Classification by BMI ($n = 697$)		
Overweight	80.4 (74.2–85.4)	77.0 (71.7–81.6)
Not overweight	19.6 (14.6–25.8)	23.0 (18.4–28.3)
Body fat percentage ($n = 686$)		
High	90.0 (82.8–94.4)	70.7 (64.0–76.6)
Not high	10.0 (5.6–17.2)	29.3 (23.4–36.0)
Cardiorespiratory fitness test – T9 ($n = 639$)		
Good	8.0 (1.7–30.0)	12.2 (7.7–18.7)
Fair	15.4 (8.8–25.6)	17.0 (12.1–23.5)
Poor	76.6 (63.2–86.1)	70.8 (60.0–79.6)
Physical activity level – IPAQ ($n = 682$)		
Active	69.1 (60.0–76.9)	54.7 (46.1–63.0)
Moderately active	30.3 (22.6–39.3)	43.8 (35.4–52.6)
Sedentary	0.6 (0.1–2.5)	1.5 (0.7–3.4)
	Mean (95%CI)	Mean (95%CI)
Distance run (m)	1452.8 (1259.3–1646.3)	1100.6 (1059.4–1141.8)
Body mass index (kg/m^2)	20.5 (19.8–21.2)	21.3 (20.8–21.9)
BMI z-score	−0.8 (−0.3–0.1)	0.1 (0–0.3)
Lean body mass (kg)	50.3 (47.4–53.3)	40 (39–41)
Fat mass (kg)	8.5 (7.4–9.6)	14.5 (13.6–15.5)
Body fat percentage (%)	13.8 (12.0–15.7)	25.8 (24.6–27.0)
Total PA score (MET min/week)	6574.1 (4892.3–8256)	6471 (5296.1–7647.5)
Waist circumference (cm)	69.1 (67.5–70.8)	66.7 (65.6–67.8)

piratory fitness test was associated with obesity and high abdominal obesity. In our study, the negative association observed between waist circumference with distance covered in the T9 also indicates that better cardiorespiratory fitness could prevent abdominal obesity in adolescents.

Regarding the relationship between IPAQ-assessed physical activity level and adiposity, a recent study with Indian adolescents found that physical inactivity was associated positively and significantly with BMI, BF%, skinfolds, waist circumference, and prevalence of overweight [34]. In Brazil, Farias et al. [35] have also found that physically active adolescents tend to be less likely to carry excess body weight. This differs from the results of the present study, in which we found a significant and increased prevalence of excess body fat only among individuals classified as moderately active compared with those classified as active, similar to that observed by Matos et al. [36] in their study with Cuban adolescents. However, more associations between IPAQ-assessed physical activity level and adiposity indicators were not observed. These findings are similar to those described in other studies conducted in Brazil, in which no differences was found in the level of IPAQ-assessed physical activity between obese and normal weight adolescents [37, 38].

Table 2. Prevalence of overweight, high body fat percentage, high waist circumference, and gross and adjusted odds ratio (OR) according to categories of cardiorespiratory fitness and physical activity level

	Classification by BMI (n = 638[1], 681[2])		Body fat percentage (n = 628[1], 670[2])		Waist circumference (n = 637[1], 679[2])	
	Overweight %	OR (95% CI)	High BF %	OR (95% CI)	≥ p 90 %	OR (95% CI)
Cardiorespiratory fitness – T9						
Good	10.6	1.0	13.2	1.0	8.6	1.0
Fair	10.9	1.0 (0.4–2.7)	8.9	0.7 (0.3–1.8)	0.5	0.0 (0.0–0.5)
Poor	25.9	2.9 (1.2–7.0)	24.1	2.2 (1.1–4.3)	11.5	1.4 (0.5–3.9)
Physical activity level – IPAQ						
Active	20.5	1.0	17.5	1.00	9.5	1.0
Moderately Active	23.8	1.2 (0.8–1.9)	28.5	1.8 (1.2–2.8)	8.9	0.9 (0.6–1.4)
Sedentary	8.5	0.4 (0.5–2.7)	8.5	0.4 (0.1–3.1)	15.4	1.7 (0.4–8.0)
	Classification by BMI adjusted OR[3] (95% CI)		Body fat percentage adjusted OR[3] (95% CI)		Waist Circumference adjusted OR[3] (95% CI)	
Cardiorespiratory fitness – T9						
Good	1.0		1.0		1.0	
Fair	1.1 (0.4–3.6)		0.49 (0.2–1.5)		0.0 (0.0–0.6)	
Poor	4.2 (1.5–11.7)		2.96 (1.2–7.4)		1.3 (0.5–3.5)	
Physical activity level – IPAQ						
Active	1.0		1.0		1.0	
Moderately Active	1.0 (0.6–1.5)		1.7 (1.0–2.8)		1.3 (0.7–2.4)	
Sedentary	0.4 (0.0–4.6)		0.1 (0.0–16.5)		5.3 (0.6–51.0)	

[1] T9, [2] IPAQ, [3] adjusted by sex and age (years), BF – body fat, ≥ P 90 – above 90th percentile of waist circumference

Table 3. Coefficient (β) of linear regression, r^2, and p value for the association between total physical activity (TPS) score and distance run in the T9, and BMI, BMI z-score, body fat percentage, waist circumference, and lean mass; adjusted for sex and age (years)

Variables	TPS score			T9		
	β	r^2	p	β	r^2	p
Body mass index	2.09	0.016	0.669	–1.88	0.344	< 0.001
Age (years)	1.10		0.126	1.63		0.033
Sex (male)	1.48		0.766	0.59		< 0.001
BMI z-score	1.50	0.019	0.632	–1.45	0.338	0.001
Age (years)	1.03		0.101	1.69		0.071
Sex (male)	1.52		0.783	0.60		< 0.001
Body fat percentage	–1.50	0.015	0.812	–0.98	0.339	< 0.001
Age (years)	1.09		0.139	1.72		0.080
Sex (male)	1.40		0.714	0.61		< 0.001
Waist circumference	–1.17	0.016	0.711	–0.92	0.330	0.002
Age (years)	1.07		0.121	1.69		0.056
Sex (male)	1.49		0.762	0.57		< 0.001
Lean body mass	1.12	0.015	0.636	1.48	0.313	0.561
Age (years)	1.10		0.144	1.79		0.099
Sex (male)	1.67		0.849	0.59		< 0.001

This study has some limitations. The lack of IPAQ validation for Brazilian adolescents younger than 14 years old is one limitation and may have hindered understanding of the questions in the questionnaire by younger teens. Moreover, genetic factors as well as motivation could have directly influenced performance in the T9, although for the latter care was taken in the application of the test in order to avoid bias.

Conclusions

Performance in the cardiorespiratory fitness test (T9) was found to be better associated with overweight and body fat percentage in adolescents than the level of physical activity as assessed by the IPAQ. This result suggests that this test can be a more objective alternative in the school environment for screening adolescents with poor activity behaviors and, consequently, identifying young people at risk for obesity. Based on these findings, we would recommend actions to improve school conditions related to physical activity, such as by improving the quality of sports facilities and also teacher training so that cardiorespiratory fitness tests can be administered with improved validity and reliability.

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