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Changes in Cardiorespiratory Fitness Predict Changes in Body Composition From Childhood to Adolescence: Findings From the European Youth Heart Study

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Abstract

Background: Several variables, such as waist circumference (WC) and trunk skinfolds (TS), are indicators of body fat. There is interest in evaluating the effect of cardiorespiratory fitness (CRF) measures on changes in these markers from childhood to adolescence. **Purpose:** To examine CRF as a potential predictor of changes in body fat over an 8-year follow-up period in a pediatric population. **Methods:** A cohort study of 86 children (44 girls, 42 boys) with a mean age of 9.8 ± 0.3 years who participated in the Portuguese arm of the European Youth Heart Study in 2000 completed a follow-up evaluation in 2008 at a mean age of 17.0 ± 0.4 years. Cardiorespiratory fitness, expressed as maximal oxygen consumption (VO_2 max) ($mL \cdot kg^{-1} \cdot min^{-1}$), was assessed during an incremental multistage bicycle test to exhaustion. Physical activity (PA) was objectively measured by accelerometry at both periods of evaluation. Fat mass (FM) was assessed using anthropometric models, sum of TS, and WC. Changes were expressed as a percentage of the baseline value. Comparison of means and linear regression analysis were used for data analysis. **Results:** While CRF significantly increased among boys ($P < 0.05$) and decreased in girls ($P < 0.01$), the percentage of body fat decreased over time in boys ($P < 0.01$) and increased among girls. Alone, CRF explained 39%, 26%, and 25% of the total variance in WC, FM, and TS, respectively ($P < 0.01$). Adjusting for PA, sex, and maturation changes, CRF remained a significant predictor of WC ($\beta = -0.335$; $P < 0.01$), FM ($\beta = -2.084$; $P < 0.01$), and TS ($\beta = -1.500$; $P < 0.01$). **Conclusion:** Changes in CRF are a significant predictor of changes in body fat percentage from childhood to adolescence. School-based PA interventions are encouraged to maintain or improve CRF from childhood and throughout adolescence to prevent increased percentages of body fat, particularly in the abdominal region.

Keywords: cardiorespiratory fitness; body fat; childhood; adolescence

Introduction

During childhood and adolescence, low cardiorespiratory fitness (CRF) is associated with health problems such as obesity, type 2 diabetes, hypertension, and several obesity-related biologic factors.[1–3] In addition, CRF is an important predictor of all-cause mortality and coronary heart disease in the adult population.[4] Among pediatric age groups, however, CRF has a negative association with waist circumference (WC) and sum of trunk skinfolds (TS).[5] Low CRF is also a strong predictor for clustering of cardiovascular disease (CVD) risk,[1] and is linked to CVD risk regardless of objectively measured physical activity (PA) and percentage of body fat.[6] Low CRF seems to be more strongly related to CVD risk than objectively measured PA in children

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and adolescents of both sexes.[7] Short-term longitudinal studies[8–10] have concluded that CRF at baseline is related to total body fat.

Following trends in other European countries, Portugal has a high prevalence of overweight/obesity (31.5%) in children aged 7 to 9 years.[11] Furthermore, a recent report[12] concluded that in Portuguese youths aged 10 to 18 years, 21.6% of girls and 23.5% of boys are overweight and obese. Fat distribution is also an important issue where risk is considered. Abdominal fatness, which is commonly measured by WC, is one of the central risk factors that compose metabolic syndrome in youth.[13] In this context, CRF is associated with lower visceral and abdominal subcutaneous adipose tissue measures among children and adolescents aged 8 to 17 years.[14] Along these same lines, a significant proportion of insulin resistance is explained by low CRF in children with large WCs and high percentages of body fat,[15] which supports its role as a mediator between CRF and fatness in youth.

To date, no longitudinal study has addressed the relative role of changes in CRF, regardless of PA, on changes in total body and abdominal fatness markers from childhood to adolescence. Therefore, the aim of this study was to examine changes in CRF as a potential predictor of changes in total and abdominal fatness, regardless of objectively measured PA, over an 8-year follow-up period in boys and girls aged 9 to 17 years.

Methods

Participants

A cohort study of 145 Caucasian children (80 girls, 65 boys) aged 9 years (9.8 ± 0.3 years) who participated in the Portuguese arm of the European Youth Heart Study (EYHS) in 2000[16] completed a follow-up evaluation in 2008 at age 17 years (17.0 ± 0.3 years). In 2000, these children were randomly selected from 29 primary schools on the Island of Madeira, Portugal. Schools were also randomly selected from a large section of the 152 primary schools in Madeira, based on distribution by municipality and socioeconomic status. Complete anthropometric, body composition, CRF, and PA measurements were available for the 86 (44 girls and 42 boys) children who constitute our sample study. All procedures were conducted in accordance with the International Ethical Guidelines for Biomedical Research Involving Human Subjects, and written informed consent was previously obtained from each child's primary guardian at both points of evaluation. More details on the cohort are available elsewhere.[16]

Measurements

Weight and height were measured while the participants were wearing light clothing, without shoes, using standard techniques. Height was measured to the nearest 0.5 cm using a Seca stadiometer, and weight was measured to the nearest 0.1 kg with a calibrated beam balance scale. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters ($kg \cdot m^{-2}$). Skinfold thickness measurements (triceps, biceps, calf, thigh, subscapular, suprailiac, chest, and abdominal; mm) were taken from the left side of the body in duplicate or triplicate, according to the criteria described by Lohman et al,[17] and the 2 closest measurements at each site were averaged. Waist circumference was measured twice with a metal anthropometric tape immediately above the iliac crest according to National Institutes of Health recommendations,[18] and the average of the 2 measures was used for analysis.

Different equations were used to calculate body fat percentage according to sex, maturity, and weight.[19] If the sum of triceps and subscapular skinfolds was ≤ 35 mm, the following equations were used:

- Prepubescent boys: percent fat = 1.21 × (triceps skinfold + subscapular skinfold) – 0.008 × (triceps skinfold + subscapular skinfold)^2 – 1.7.
- Pubescent boys: percent fat = 1.21 × (triceps skinfold + subscapular skinfold) – 0.008 × (triceps skinfold + subscapular skinfold)^2 – 3.4.
- Girls: percent fat = 1.33 × (triceps skinfold + subscapular skinfold) – 0.013 × (triceps skinfold + subscapular skinfold)^2 – 2.5.

If the sum of triceps and subscapular skinfolds was > 35 mm, the following equations were applied:

- All boys: percent fat = 0.783 × (triceps skinfold + subscapular skinfold) + 1.6.
- All girls: percent fat = 0.546 × (triceps skinfold + subscapular skinfold) + 9.7.

Pubertal status was assessed by trained data collectors using the 5-stage scale for breast development in girls and pubic hair in boys, according to the score by Tanner.[20]

Cardiorespiratory Fitness

Cardiorespiratory fitness was assessed during an incremental multistage bicycle test to exhaustion on an electronically braked cycle ergometer (Monark Ergomedic 839; Healthcare International, Goldberg, Sweden). Cardiorespiratory fitness was estimated as maximum power output relative to body weight (watts [W]/kg). Initial and incremental workloads were 20 W for children < 30 kg and 25 W for heavier children (1º cohort) and 40 and 50 W for adolescent girls and boys, respectively (2º cohort). Workloads were increased every third minute until exhaustion. Criteria defined for a maximal effort were a heart rate of ≥ 185 beats per minute and subjective judgement by the observer that the child or adolescent could no longer continue, even after verbal encouragement. Maximal power output (W_{max}) was calculated in accordance with the following formula:

- $W_{max} = W_1 + (W_i \times t_{ls}/180s)$

where W_1 represents the W during the last completed workload, W_i represents the increment in W for the final stage, and t_{ls} represents the number of seconds completed in the final stage.

Additionally, CRF (ml·kg^{-1}·min^{-1}) was estimated using equations validated for youth in the Denmark-EYHS by Kolle et al[21]:

- Children: maximal oxygen consumption (VO_2 max) (L·min^{-1}) = 0.452 + (0.0108 × W_{max}) + (0.033 × sex)
- Adolescents: VO_2 max (L·min^{-1}) = 0.465 + (0.0112 × W_{max}) + (0.172 × sex)

  Sex = 0 for girls, 1 for boys

The equation for children was developed for those aged ~9 years, and the equation for adolescents was developed for those aged ~15 years. According to Andersen et al[22] and Fredriksen et al,[23] the peak VO_2 values among adolescents aged 14 to 19 years are 40.0 to 48.9 and 51.7 to 60.8 mL·kg^{-1}·min^{-1} for girls and boys, respectively. According to Kolle et al,[21] these numbers do not differ from most of the adolescents aged 15 years who were examined by their team. The value obtained was then converted into relative units (mL·kg^{-1}·min^{-1}), dividing by individual body weight. The Polar Vantage NV (Polar Electro Oy, Kempele, Finland) was used as the method for heart rate monitoring during the bicycle test, and the beat-by-beat option was selected for a beats per minute measurement.

Physical Activity Assessment

For the baseline 2000 assessment,[16] PA was objectively measured using a uniaxial accelerometer (WAM 7164, Computer Science and Applications, Shalimar, FL). For the 2008 assessment, the Actigraph GT1M (Manufacturing Technology Inc, Fort Walton Beach, FL) was used. In a recent study,[24] no significant differences were observed in PA assessment using these 2 accelerometers. These devices were used over a period of ≥ 2 weekdays and 1 weekend day. Subjects wore the accelerometer attached to an elastic waistband on the right hip and were instructed to wear the monitors during the daytime except while sleeping, bathing, and during aquatic activities. Activity data were stored on a minute-by-minute basis and were downloaded to a computer before analysis. The criterion used to define PA levels was ≥ 2000 counts·min^{-1}, which corresponds with moderate and vigorous intensity levels and has been widely used in other recent studies.[25–27]

Statistical Analysis

After initial descriptive procedures, a paired sample t-test was used to compare variables between cohorts in 2000 and 2008, either including the entire sample or divided by sex

Table 1. Descriptive Variables by Age and Sex and Correspondent Significant Differences

	9 Years			17 Years		
	Boys (n = 42)	**Girls (n = 44)**	**Total (n = 86)**	**Boys (n = 42)**	**Girls (n = 44)**	**Total (n = 86)**
Age, y	9.8 (0.3)	9.7 (0.3)	9.8 (0.3)	17.0 (0.3)	17.0 (0.4)	17.0 (0.3)
Weight, kg	35.7 (7.3)	34.6 (8.3)	35.1 (7.8)	67.6 (9.5)	59.3 (10.7)[a]	63.4 (10.9)
Height, cm	139.0 (5.3)	137.8 (6.7)	138.4 (6.0)	174.6 (4.9)	162.8 (5.9)[a]	168.6 (8.0)
BMI, kg/m^2	18.4 (3.0)	18.0 (3.2)	18.2 (3.1)	22.2 (3.2)	22.3 (3.4)	22.3 (3.2)
Waist circumference, cm	67.3 (8.7)	64.7 (8.6)	66.0 (8.7)	78.5 (7.7)	81.9 (8.6)	80.2 (8.3)
Σ Trunk skinfolds	41.8 (27.6)	42.9 (23.7)	42.4 (25.5)	47.8 (27.0)	57.7 (18.9)	52.9 (23.6)
Σ Appendicular skinfolds	50.1 (24.1)	61.5 (22.5)[b]	55.9 (23.9)	35.7 (15.3)	71.4 (17.6)[a]	54.0 (24.4)
Fat mass, kg	7.1 (4.7)	8.0 (4.5)	7.5 (4.6)	11.2 (6.8)	16.5 (5.9)[a]	13.9 (6.8)
Fat mass, %	18.4 (8.0)	21.8 (6.9)[b]	20.2 (7.6)	15.9 (7.2)	27.1 (5.1)[a]	21.6 (8.3)
FFM, kg	28.6 (3.4)	26.5 (4.4)[b]	27.6 (4.0)	56.4 (5.5)	42.9 (5.6)[a]	49.5 (8.8)
FFM, %	81.6 (8.0)	78.2 (6.9)[b]	79.8 (7.6)	84.1 (7.2)	72.9 (5.1)[a]	78.4 (8.3)
Cardiorespiratory fitness, W_{max}/kg	2.5 (0.7)	1.9 (0.4)[a]	2.2 (0.6)	3.0 (0.5)	2.0 (0.3)[a]	2.5 (0.6)
VO_2 max, L·min^{-1}	1.40 (0.25)	1.15 (0.16)[a]	1.28 (0.25)	2.86 (0.37)	1.77 (0.22)[a]	2.30 (0.63)
VO_2 max, mL·kg^{-1}·min^{-1}	40.7 (8.4)	34.5 (6.7)[a]	37.5 (8.1)	42.8 (6.0)	30.3 (4.2)[a]	36.4 (8.1)
PA, > 2000 counts·min^{-1}	193.1 (73.2)	154.9 (47.2)[a]	173.6 (63.9)	189.1 (109.7)	110.1 (67.9)[a]	148.7 (98.6)

Values are mean (SD).
[a]$P < 0.01$.
[b]Significantly different between sexes ($P < 0.05$).
Abbreviations: BMI, body mass index; FFM, fat-free mass; PA, physical activity; SD, standard deviation; VO_2 max, maximal oxygen consumption; W, watt; Σ, sum.

Table 2. Differences and Variations Between First and Second Point of Evaluation ± 8 Years

	Difference	Variation	Difference	Variation	Difference	Variation
	Boys (n = 42)		**Girls (n = 44)**		**Total (n = 86)**	
Weight, kg	32.0 (6.6)[a]	92.9 (23.5)	24.8 (7.3)[a]	75.7 (27.4)	28.3 (7.8)[a]	84.1 (26.9)
Height, cm	35.5 (3.6)[a]	25.7 (3.2)	25.1 (4.9)[a]	18.3 (4.1)	30.2 (6.8)[a]	21.9 (5.2)
BMI, kg/m^2	3.8 (2.1)[a]	21.9 (11.6)	4.3 (2.3)[a]	25.0 (15.1)	4.1 (2.2)[a]	23.5 (13.5)
Waist circumference, cm	11.2 (6.4)[a]	17.5 (9.9)	17.2 (6.2)[a]	27.4 (11.1)	14.2 (7.0)[a]	22.5 (11.6)
∑ Trunk skinfolds	5.9 (20.2)	32.6 (48.3)	14.8 (20.0)[a]	55.2 (57.3)	10.5 (20.5)[a]	44.2 (54.0)
∑ Apendicular skinfolds	–14.4 (17.3)[a]	–23.1 (23.5)	10.0 (18.6)[a]	24.8 (39.4)	–1.9 (21.7)	1.4 (40.4)
Fat mass, kg	4.2 (5.0)[a]	78.5 (71.7)	8.5 (4.3)[a]	135.6 (89.0)	6.4 (5.1)[a]	107.7 (85.5)
Fat mass, %	–2.5 (6.0)[a]	–9.6 (27.2)	5.2 (5.2)[a]	30.5 (29.6)	1.5 (6.8)[b]	10.9 (34.7)
FFM, kg	27.8 (4.0)[a]	98.2 (16.3)	16.3 (3.8)[a]	63.2 (17.8)	21.9 (6.9)[a]	80.3 (24.4)
FFM, %	2.5 (6.0)[a]	3.5 (8.8)	–5.2 (5.2)[a]	–6.3 (6.7)	–1.5 (6.8)[a]	–1.5 (9.2)
Cardiorespiratory fitness, W_{max}/kg	0.5 (0.5)[a]	26.0 (27.6)	0.1 (0.4)	7.5 (25.1)	0.3 (0.5)[a]	16.6 (27.8)
VO_2 max, L·min^{-1}	1.4 (0.3)[a]	105.4 (28.7)	0.6 (0.2)[a]	56.0 (25.2)	1.0 (0.5)[a]	80.1 (36.6)
VO_2 max, mL·kg^{-1}·min^{-1}	2.1 (6.2)[b]	7.5 (16.4)	–4.2 (5.1)[a]	–10.2 (14.3)	–1.1 (6.5)	–1.6 (17.7)
PA, > 2000 counts·min^{-1}	–4.0 (115.3)	19.5 (123.9)	–44.8 (89.3)[a]	–15.8 (74.9)	–24.9 (104.3)[b]	1.5 (102.8)

Values are mean differences (SD) and mean variation (SD); variation = (difference/baseline) × 100.
[a]($P < 0.01$).
[b]Significantly different between sexes ($P < 0.05$).
Abbreviations: BMI, body mass index; FFM, fat-free mass; PA, physical activity; SD, standard deviation; VO_2 max, maximal oxygen consumption; W, watt; ∑, sum.

(Table 1). An independent t-test was also used to compare variables between sexes of the same age group (Table 2). Linear regression analysis was then performed to create several models with the variables under study (Tables 3, 4). Pearson's coefficient of correlation was used to test the association between variables, while Spearman's rank correlation coefficient was used if the distribution of variables was not normal. Analysis of covariance was used to test interactions between CRF and sex. The sample was not analyzed separately by sex, as no significant interactions were found.

All analyses were performed using SPSS software version 17.0 (SPSS Inc., Chicago, IL). The level of significance was defined as $P < 0.05$.

Results

Significant differences between sexes were observed in the older group for body composition variables, such as percentage of fat mass (27.1% for girls vs 15.9% for boys; $P < 0.01$), with the girls being heavier than the boys (Table 1). In a less evident way, we also found significant sex differences in body composition, when sample had

Table 3. Multiple Linear Regression Models Predicting Waist Circumference and Fat Mass

	Variation in Waist Circumference			**Variation in Fat Mass**		
	β	***P* Value**	**R^2 adj**	**β**	***P* Value**	**R^2 adj**
Model 1						
Var CRF	–0.414	0.000	0.390	–2.507	0.000	0.260
Model 2						
Var CRF	–0.419	0.000	0.383	–2.596	0.000	0.256
Var PA	0.003	0.730		0.056	0.487	
Model 3						
Var CRF	–0.371	0.000	0.393	–2.349	0.000	0.255
Var PA	0.004	0.679		0.060	0.462	
Gender	–3.464	0.130		–17.612	0.342	
Model 4						
Var CRF	–0.335	0.000	0.428	–2.084	0.000	0.290
Var PA	0.001	0.930		0.035	0.658	
Gender	–1.712	0.460		–4.550	0.811	
Var maturity	0.042	0.016		0.313	0.028	

P values for independent variables. Variation (%) = (difference/baseline) × 100
Abbreviations: CRF, cardiorespiratory fitness; PA, physical activity; Var, variation; β, standardized regression coefficients.

9 years old. Thus, the percentage of fat mass was significantly greater in girls than in boys (21.8% vs 18.4%, respectively; $P < 0.05$; Table 1). Girls, whether children or adolescents, had significantly lower levels of CRF (34.5 vs 40.7 mL·kg^{-1}·min^{-1} in those aged 9 years; 30.3 vs 42.8 mL·kg^{-1}.min^{-1} in those aged 17 years; $P < 0.01$) and were less physically active than boys (154.9 vs 193.1 min in those aged 9 years; 110.1 vs 189.1 min, respectively, in those aged 17 years engaged in moderate-to-vigorous PA; $P < 0.01$; Table 1).

As shown in Table 2, differences between age groups of the same sex were significant for most of the variables studied. As expected, due to maturation and growing processes, WC was significantly greater among older subjects, regardless of patient sex (girls, +27%; boys, +18%; $P < 0.01$). Similarly, the sum of TS was significantly higher for both sexes when children became older (girls, +33%; boys, +55%; $P < 0.01$), but not for appendicular skinfolds, which were significantly larger for girls but not for boys (+24.8%, $P < 0.01$; –23.1%, $P < 0.05$, respectively). This same trend was observed for percentage of fat mass (+30.5%, −9.6%, respectively; $P < 0.01$). Otherwise, there was significantly greater fat mass in older children regardless of patient sex (+135.6%, +78.5%, respectively; $P < 0.01$), although girls showed a much greater increase.

Cardiorespiratory fitness differences, when expressed in relative units (VO_2 max, mL·kg^{-1}·min^{-1}), showed contradictory results between sexes. While boys increased their CRF, girls demonstrated a decline in this fitness attribute (boys, +7.5%, $P < 0.05$; girls, −10.2%, $P < 0.01$, respectively; Table 2). Table 3 shows that for both sexes, changes in CRF explain 39.0% and 26.0% of the total variance in WC and fat mass. In Table 4, 24.6% of changes in TS are also explained by changes in CRF ($P < 0.01$).

After adjusting for PA, sex, and maturation changes, CRF remained a significant predictor of WC (β = –0.335; $P < 0.01$), fat mass (β = −2.084; $P < 0.01$), and TS (β = −1.500; $P < 0.01$). However, in our study, variance of fat-free mass was not explained by CRF (β = 0.231; $P = 0.12$; Table 4).

The figure clearly demonstrates how variation of CRF over time can explain a concomitant variation in WC (model A), fat mass (model B), and sum of TS (model C), while model D shows the lowest predictive capacity of CRF in relation to fat-free mass.

Discussion

The main findings of this study show that changes in CRF are a significant predictor of changes in body fat from childhood to adolescence, even after controlling for confounding factors such as PA, sex, and maturity (Tables 3, 4; model 4).

A number of studies and reviews[6,28–31] have shown unhealthy associations either in adults or in youth between excessive body fat and risk factors for metabolic disorders and CVD, including dyslipidemia, insulin resistance, and hypertension. In a large sample of youth pertaining to EYHS,[32] values of CRF were dichotomized above cut-offs of 37.4 and 33.0 mL·kg^{-1}·min^{-1} (girls aged 9 and 15 years, respectively), and 43.6 and 46.0 mL·kg^{-1}·min^{-1} (boys aged

Table 4. Multiple Linear Regression Models Predicting Fat-free Mass and ∑ Trunk Skinfolds

	Variation in Fat-free Mass			Variation in ∑ Trunk Skinfolds		
	β	*P* Value	R^2 adj	β	*P* Value	R^2 adj
Model 1						
Var CRF	0.231	0.124	0.016	−1.543	0.000	0.246
Model 2						
Var CRF	0.242	0.124	0.005	−1.548	0.000	0.237
Var PA	–0.007	0.797		0.003	0.950	
Model 3						
Var CRF	–0.339	0.005	0.554	−1.638	0.000	0.231
Var PA	–0.015	0.409		0.002	0.969	
Gender	41.433	0.000		6.406	0.590	
Model 4						
Var CRF	–0.291	0.018	0.567	−1.500	0.000	0.251
Var PA	–0.019	0.283		–0.011	0.838	
Gender	43.799	0.000		13.184	0.286	
Var maturity	0.057	0.073		0.163	0.077	

P values for independent variables.
Abbreviations: CRF, cardiorespiratory fitness; PA, physical activity; Var, variation; β, standardized regression coefficients.

9 and 15 years, respectively) as being in the healthy zone; children under these values were exposed to a higher risk of metabolic disease. These unhealthy links are of great concern, as the problem of overweight and obesity in youth has attained high prevalence levels in North America and several European countries.[33] These harmful associations are even more pronounced when body fat is centrally located. Studies[34,35] have shown that increased WC is associated with risk factors for metabolic disorders and CVD, including lipid profile, high blood pressure, and insulin resistance.

As children grow, their body fat also increases, though in different magnitudes between sexes. Boys and girls have significantly greater amounts of body fat when they reach adolescence. However, girls demonstrate higher values than boys in both absolute and relative terms. In our study, the male sample had a significantly lower percentage of body fat as they grew, unlike the female sample; these results are in agreement with the reviewed literature.[36] Despite significantly larger WCs due to the growing process, both the variation and absolute values were greater among the older girls. This apparent increased unhealthier state in girls is contradicted in a study of visceral fat mass conducted by Shen et al,[37] who reported that although subcutaneous adipose tissue is greater in females when they enter puberty, the contrary is true for visceral adipose tissue, which increases in adolescent boys. Accordingly, boys should be at a higher risk level than girls, despite their smaller WC.

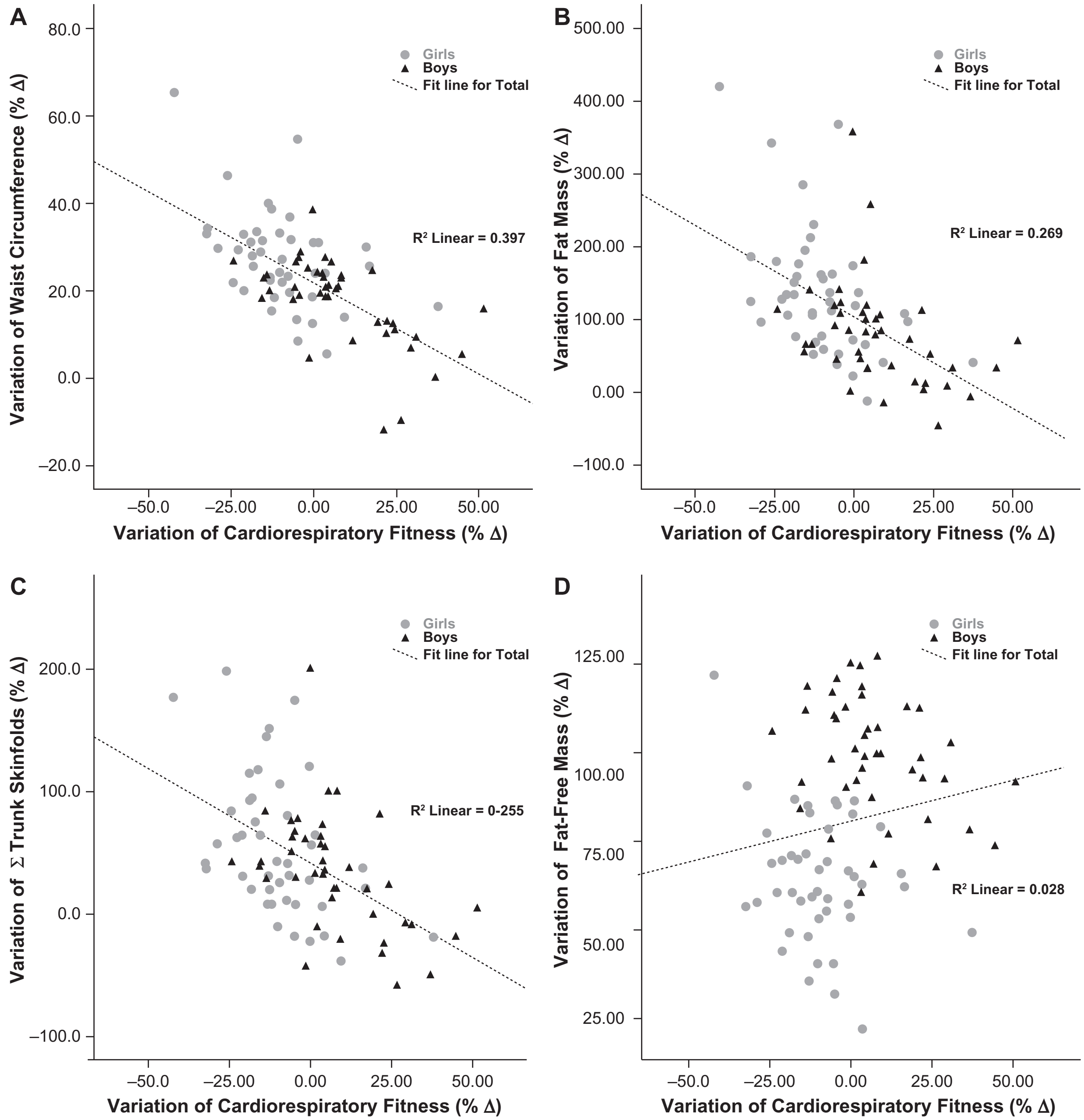
Cardiorespiratory fitness also increases significantly with age in absolute values for both sexes, but not when expressed in relative units ($mL \cdot kg^{-1} \cdot min^{-1}$) for girls. In our study, boys significantly increased their VO_2 max ($mL \cdot kg^{-1} \cdot min^{-1}$), whereas in girls we found the contrary. These results are, in general, similar to those found by Kemper and Verschuur,[38] despite that no significant differences were reported for boys.

Several cross-sectional studies[39–42] have shown significant associations between CRF and body fat in youth. Children and adolescents with low levels of CRF are at a significantly increased risk of being overweight or obese.[39–42] Even more importantly, several studies and reviews[43–45] reported that abdominal fat could be positively affected by CRF levels in youth. Although there is some controversy concerning the precise influence of CRF or abdominal fat on CVD and metabolic risk, at least 1 study[46] has shown the important role of CRF in this relationship. However, these results have the limitations that are characteristic of cross-sectional studies.

A few longitudinal studies[8–10,47–49] have shown relationships between CRF and body fat in youth. For instance, a follow-up study[9] of youth aged 6 to 15 years showed that children with low CRF had larger WCs and a disproportionate weight gain over the 12-month follow-up period. However, PA was not controlled as a possible confounder, and the ages of the sample at baseline ranged from 6 to 15 years. Moreover, maturity was not directly assessed, and instead was calculated from chronological age. A 2-year follow-up study[10] suggested that children who had lower CRF at baseline were likely to have increased BMI gain over time when compared with their more fit counterparts. Interestingly, in this short-term follow-up of children aged 6 to 10 years, changes in CRF did not predict changes in BMI. Two other recent reports[8,47] have shown that BMI changes are associated with changes in fitness over 3 years, and lower levels of CRF are related to the risk of being overweight/obese, respectively. However, unlike the present study, the heterogeneity of the sample at baseline was high (subjects aged 11–19 years), PA was assessed by questionnaire, and sexual maturity was not controlled in a period of rapid growth and changes. Other similar studies[48,49] between childhood and adolescence (follow-up of 5–6 years) showed that lower levels of CRF at baseline are associated with later levels of BMI. However, these studies did not evaluate changes in CRF and outcome variables, BMI was used as a marker of total body fat (the limitations of which are recognized[50]), abdominal fat was not assessed, and PA was not used as a confounding variable.

Over the course of our 8-year longitudinal research, from childhood to later adolescence, it was shown that changes in CRF are a significant predictor of changes in abdominal fatn (model 4). Children who increased their CRF significantly reduced their total fat mass as well as their abdominal fat measured by WC or TS (model 4). As WC is a good marker of visceral fat mass even in youth,[51] youth with higher fitness levels were at lower CVD and metabolic risk compared with their less-fit counterparts. Even if cut-off values for WC are not available for children aged 9 years, we are assuming that a higher WC is a crude marker of visceral fat and, therefore, higher WC values may indicate higher abdominal adiposity, which in turn may contribute to an increased metabolic risk. To our knowledge, this is a unique study that globally has the strength of measuring changes occurring between childhood (aged 9 years) and late adolescence (aged 17 years), using objective measures of fatn, CRF, and PA, and adjusting for possible confounders, namely sex, PA, and maturity, which were limitations reported and assumed by other authors.

Figure1. Linear regression between the variation of cardiorespiratory fitness and the variation of **A)** waist circumference, **B)** fat mass, **C)** sum (∑) of trunk skinfolds, and **D)** fat-free mass.



Conclusion

We do not conclude that there is a significant influence of objectively measured PA on the relationship between CRF and body fat variables. This result is according to the nonsignificant correlation between changes in CRF and changes in PA ($r = 0.196$; $P = 0.071$) found in our study. A very recent systematic review[52] concluded that PA does not appear to be a key factor of excessive body fat gains in children, adolescents, and even adults, which generally is in accordance with our findings.

On the other hand, it seems that only programs with continuous activity (3 sessions/week, 25- to 35-minute sessions at an intensity > 80% of maximal heart rate) improves VO_2 max in children.[53] Together, these findings constitute useful information to develop exercise programs that will improve CRF and reduce body fat in youth.

It is important to highlight that only 2 measurements were assessed during a period of nearly 8 years, which means that changes in CRF and body composition may have occurred in opposite directions during the follow-up period. Additionally, it should be mentioned that WC was used as an alternative approach for assessing changes in visceral adipose tissue, and VO_2 max was estimated rather than directly measured by a gas analyzer. Finally, it is important to address that these results may not be extrapolated for other ethnic groups, as only white subjects were included in this sample.

In summary, changes in CRF from childhood to adolescence, regardless of PA, are a significant predictor of changes in body fat, particularly in the abdominal area. These findings highlight the importance of school-based interventions and exercise programs to maintain or improve CRF from childhood and throughout adolescence in or above the already defined healthy zones that can prevent increases in body fat, particularly in the abdominal region.

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Conflict of Interest Statement

Rui T. Ornelas, MS, Analiza M. Silva, PhD, Cláudia S. Minderico, PhD, and Luís B. Sardinha, PhD disclose no conflicts of interest.

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