

The association between cardiorespiratory fitness and cardiovascular risk in adolescents

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Abstract

Objective: Maximum oxygen uptake is emerging as the measure of preference for expressing cardiorespiratory fitness for the purposes of surveys of physical activity, due to its greater objectivity and lower propensity to errors. Studies indicate that this measure is better correlated with cardiovascular diseases. This paper proposes to relate cardiovascular risk factors in adolescents with their level of cardiorespiratory fitness.

Methods: The study enrolled 380 schoolchildren, 177 boys and 203 girls (10 to 14 years old), who were divided into two groups according to their cardiorespiratory fitness. Anthropometric assessment was carried out, hemodynamic measurements (arterial pressure and heart rate) were taken, cardiopulmonary exercise testing was performed and biochemical tests were run (triglycerides, total and partial cholesterol).

Results: Among the boys, significant differences were observed between boys defined as "weak" and those classed as "not weak" in terms of baseline heart rate, maximum oxygen uptake, body mass index and triglycerides. Among the girls, significant differences were detected between baseline heart rates, maximum oxygen uptake and body mass indices. In both sexes, the group classified as "weak" exhibited a significantly greater number of overweight individuals than the "not weak" group ($\chi^2 = 25.242$; $p = 0.000$; $\chi^2 = 12.683$; $p = 0.000$, for boys and girls, respectively). A significant association between cardiorespiratory fitness and triglycerides ($\chi^2 = 3.944$; $p = 0.047$) was observed among the boys only.

Conclusions: A low level of cardiorespiratory fitness appears to have a negative influence on cardiovascular risk factors among adolescents, especially with relation to overweight in both sexes and to biochemical profile in the male sex, providing evidence of the need for early preventative interventions.

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Introduction

Historically, cardiovascular diseases have been considered an important public health problem for several decades, although their role is not as prominent as that of infectious and contagious diseases.¹ Currently, the mortality profile of the Brazilian population is in transformation, with the most striking changes being the fall in infant deaths, the relative reduction in deaths due to infectious diseases and the increase in deaths from chronic and degenerative diseases, especially those affecting the circulation.²

In the past, it was believed that cardiovascular diseases were specific to older populations, however a significant prevalence is now being observed among young adults.³ Furthermore, clinical trials indicate that the process of atherosclerosis, which is one of the principal manifestations of cardiovascular disease, begins very early and that this is related to risk factors similar to those observed in the adult population, such as hypertension, dyslipidemia, obesity, smoking, inactivity and low physical fitness.^{4,5}

The relationship between physical fitness and a profile of lower cardiovascular risk has been demonstrated in children

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and adolescents of both sexes.⁶⁻¹⁰ Even among very young children, this association has been confirmed, when it was observed that the increase in arterial blood pressure that is expected as age advances was attenuated among those who exhibited the best physical fitness.¹⁰ Nevertheless, contradictory results also exist which could be attributable to differences in the methodology used to identify physical fitness, to the body fat composition of the samples being studied,^{8,11} or even to genetic differences and differences in rates of maturation and growth.¹²

Defined as a behaviour, physical activity includes all types of muscular activity during which energy expenditure is significantly increased. Physical fitness is defined as an attribute, and is generally understood to mean the ability to perform physical work, and is considered to be an adaptive state which is, in part, genetically determined.¹² Therefore, it has been suggested that measurements of physical fitness are preferable in relation to those of physical activity, due to their greater objectivity and lower propensity to errors. Furthermore, it is aerobic fitness and not physical activity that is best correlated with cardiovascular diseases in adults.¹²

This being so, our proposal was to seek an association between cardiorespiratory fitness and the presence of cardiovascular risk factors in adolescents, employing for the task a classification of physical fitness proposed for Brazilian samples.¹³

Methods

Sample

This study was carried out with schoolchildren aged from 10 to 14 years, of both sexes, from the public education system of the city of Vitória (ES). Vitória is the state capital of Espírito Santo, Brazil, and has an entirely urban population of **292,304 inhabitants**. According to United Nations statistics, the rate of school attendance in the city of Vitória is 93%, life expectancy has reached 70.7 years of age and the city has the highest per capita income in the state. In 2001, the mortality rate for the state, in the age group of 10 to 14 years, accounted for 0.71% of the total number of deaths and, of all the different causes of death in the overall population, diseases of the cardiocirculatory system caused 26.58% of deaths.¹⁴

The minimum sample size calculation was determined by means of the general equation for sample sizes in all populations,¹⁵ with a confidence level of 95% and a confidence interval of 5%. The sample was obtained by means of a random sample selection process, taking into account the proportion within the population of this age group (a total of 27,491 adolescents). Schools from all seven administrative regions of the city were chosen by lots and invited to participate by means of a request to the school principal, who then provided a list of students. Working from these lists, 380 schoolchildren were chosen by lots, 177 of whom were male and 203 of whom were

female. Just two of the children who had been chosen quit the study and were substituted, also by lots.

The chosen adolescents were invited, through their parents or guardians, to participate in the study. All of them signed a free and informed consent form detailing the study benefits, risks and procedures. The study protocol was approved by the Research Ethics Committee at the Faculdade Salesiana de Vitória. None of the adolescents stated that they smoked, had a previously detected metabolic disease or were using oral contraceptives, all of which were exclusion criteria. The adolescents' chronological age was determined based on their date of birth and the date of data collection and expressed in years and fractions.

The sample was divided into two groups based on a maximum oxygen uptake (VO_{2max}) classification proposed for Brazilian samples:¹³ "weak" VO_{2max} ($\leq 36.4 \text{ mL.kg}^{-1}.\text{min}^{-1}$ for girls, and $\leq 43.3 \text{ mL.kg}^{-1}.\text{min}^{-1}$ for boys) and "not weak" VO_{2max} ($\geq 36.5 \text{ mL.kg}^{-1}.\text{min}^{-1}$ for girls, and $\geq 43.4 \text{ mL.kg}^{-1}.\text{min}^{-1}$ for boys).

Identification of cardiovascular risk factors

Overweight

Body mass was determined using an anthropometric balance accurate to 100 g and with a maximum capacity of 150 kg, while height was measured using a stadiometer with a 0.1 cm scale, in accordance with recognized standards. These two variables were then used to calculate body mass index (BMI, kg.m^{-2}). Adolescents were defined as overweight if they met the conditions for overweight or obesity, defined as BMI values for their age and sex equating to ≥ 85 th and < 95 th percentile for overweight and ≥ 95 th percentile for obesity, with adolescents whose BMI was below the 85th percentile classified as having normal body weight.¹⁶

Cardiorespiratory fitness

Cardiopulmonary exercise testing was used to identify and classify cardiorespiratory fitness. Before starting subjects were instructed on the precautions necessary for taking the test. Cardiopulmonary variables were monitored using a MedGraphics Corporation (MGC) spirometer which provided information on oxygen consumption (VO_2), carbon dioxide production (VCO_2), pulmonary ventilation (VE), ventilatory equivalent of oxygen (VE/VO_2), ventilatory equivalent of carbon dioxide (VE/VCO_2) and respiratory exchange ratio ($RER = VCO_2/VO_2$). In this study we used a progressive ramping protocol that has been described in a previous publication,¹³ increasing inclination in accordance with predicted VO_2 compared with the observed VO_2 . Testing was stopped if the subject indicated (by means of predefined gestures) fatigue or any type of discomfort that impeded continuation of the test. In order to define the VO_2 attained as maximum, at least three

of the following criteria had to be met: a) exhaustion or inability to maintain the required velocity; b) RER ≥ 1.0 ; c) maximum HR attained $\geq 90\%$ of estimated HR; d) peak VO_2 describes a plateau or attains values $\geq 85\%$ of predicted.¹⁷

Gas analysis

Gas analysis during exercise was performed with the aid of an MGC Cardio2 spirometer, which consists of an open-circuit calorimetry system, i.e. the calibration gas was adjusted using a mixture of gasses with constant concentrations of carbon-dioxide (CO_2) and oxygen (O_2). Breeze Suite software was used to determine the concentrations of VO_2 and VCO_2 by measuring, in VE (minute volume or expired volume per minute), the difference between gas pressures in inspired air and expired air, measured breath by breath. The spirometry equipment was duly calibrated before performing the test. The laboratory was equipped with equipment and drugs to deal with emergencies.

Blood pressure and heart rate

Blood pressure was measured according to methodology laid out by the IV Brazilian Directives on Arterial Hypertension (IV Diretrizes Brasileiras de Hipertensão Arterial),¹⁸ and was taken three times with a rest period of around 2 minutes between measurements. A standard Wan Med[®] mercury column sphygmomanometer was used, duly calibrated and with cuffs chosen to match the size of each child's arm, which had been measured in advance. Measurements of systolic (SBP) and diastolic (DBP) blood pressure were taken in a calm and silent atmosphere with the child seated, relaxed and with their right arm supported on a table and at the height of the precordium. Children were allowed to rest for a period of 5 to 10 minutes. The DBP measurement was taken at Korotkoff phase V. The mean of three measurements was taken to determine individuals' SBP and DBP. The classification criteria chosen were the blood pressure levels equating to the 90th and 95th blood pressure percentiles for children and adolescents, according to height percentiles for both sexes. Adolescents with blood pressure values < 90 th percentile were defined as normotense, those with levels within the 90th to the 95th percentiles as borderline hypertense and adolescents with blood pressure ≥ 95 th percentile were defined as having arterial hypertension.^{5,18}

Heart rate (HR) at rest was obtained using a twelve-lead electrocardiograph, with individuals in decubitus dorsal, after stabilization had been confirmed with the monitor.

Biochemical profiling

In order to determine biochemical profiles, blood was taken after a minimum of 12 hours' fasting. Cholesterol, HDL-cholesterol (HDL-c) and triglycerides were determined by the colorimetric-enzymatic method.¹⁹ Triglycerides were measured photometrically, while LDL-cholesterol and VLDL-cholesterol respectively were calculated using the following

formulae [(cholesterol - HDL-c) - (triglycerides/5)] and [triglycerides/5].²⁰ Glycemia was determined with the BioSystems[®] enzymatic spectrophotometric oxidase/peroxidase assay. Lipid prevalence rates were calculated based on the references values proposed by the I Directive on the Prevention of Atherosclerosis in Childhood and Adolescence (I Diretriz de Prevenção da Aterosclerose na Infância e na Adolescência).²¹

Statistics

Statistical analysis of data was carried out employing descriptive statistical methods (mean, standard deviation and frequency percentage), by age and sex. Comparisons between means were carried out using Student's *t* test for independent samples. Means were calculated for cholesterol levels and fractions and triglycerides by sex and physical fitness category. Spearman's coefficient of non-parametric correlation (ρ_s) and analysis of covariance (ANCOVA) were applied when necessary. Differences between prevalence rates were compared with the chi-square test and odds ratios, with a 95% confidence interval (95%CI). When needed, the relative risk (RR) and the number needed to harm (NNH) were calculated to a 95%CI. The definition "overweight" included both overweight and obese adolescents, i.e., anyone whose BMI was above the 85th percentile. Therefore, overweight was included, being a risk factor for cardiovascular diseases²² and, in our sample, affecting a much greater proportion of the adolescents than obesity. Arterial blood pressure was defined as "abnormal" when either SBP or DBP was above the 90th percentile for the reference population. For lipid profile variables, adolescents were defined as in the "abnormal" group if they exhibited values above those considered desirable by the references adopted for this study, or below them in the case of HDL-c.

The level of statistical significance for rejection of the null hypothesis was set at $p \leq 0.05$ or 5% for all tests.

Results

Tables 1 and 2 list anthropometric, hemodynamic and biochemical characteristics of the two groups, according to the classification adopted here, defined as "weak" (very "weak" and "weak" fitness) or "not weak" (normal, good and excellent fitness), for males and females.

Among the males, significant differences between the "weak" and "not weak" groups were observed in age (12.14 ± 1.30 vs. 12.99 ± 1.49 years; $p = 0.000$), baseline HR (77.13 ± 8.96 vs. 74.28 ± 9.73 beat/min; $p = 0.050$), $\text{VO}_{2\text{max}}$ (37.47 ± 4.98 vs. 50.79 ± 5.51 mL.kg⁻¹.min⁻¹; $p = 0.000$), BMI (19.54 ± 4.14 vs. 17.35 ± 2.41 ; $p = 0.000$) and triglycerides (78.00 ± 39.38 vs. 65.37 ± 24.19 mg/dL; $p = 0.008$). Among the females, significant differences were observed in baseline HR (83.94 ± 9.55 vs. 79.95 ± 9.01 beat/min; $p = 0.002$), $\text{VO}_{2\text{max}}$ (32.49 ± 3.06 vs. 41.48 ± 4.50 mL.kg⁻¹.min⁻¹; $p = 0.000$) and BMI (19.92 ± 4.24 vs. 17.99 ± 2.39 ; $p = 0.000$).

Table 1 - Anthropometric, hemodynamic and biochemical characteristics by aerobic fitness for males

	Cardiorespiratory fitness		
	Weak	"not weak"	p
Age (years)	12.1±1.3	13.0±1.5	0.000*
Height (m)	1.50±0.12	1.53±0.12	0.115
Baseline HR (beats/min)	77±9	74±10	0.050*
SBP (mmHg)	106±12	108±109	0.248
DBP (mmHg)	62±7	63±7	0.395
VO _{2max} (mL.kg ⁻¹ .min ⁻¹)	37.47±4.98	50.79±5.51	0.000*
BMI (weight/height ²)	19.54±4.14	17.35±2.41	0.000*
Total cholesterol (mg/dL)	155.23±25.69	148.03±26.88	0.077
HDL-cholesterol (mg/dL)	44.83±9.99	45.78±9.41	0.519
LDL-cholesterol (mg/dL)	94.8±22.49	89.24±22.79	0.112
Triglycerides (mg/dL)	78.00±39.38	65.37±24.19	0.008*

Values expressed as mean ± standard deviation.

HR = heart rate; BMI = body mass index; DBP = diastolic blood pressure; SBP = systolic blood pressure; VO_{2max} = maximum oxygen uptake.

* p ≤ 0.05 = comparison between "weak" and "not weak" by Student's *t* test.

It is known that age can act as an important confounding variable and, among the males, it differed significantly between the two groups. This being so, by applying Spearman's non-parametric correlation coefficient (p_s), significant, "weak" to moderate, influences were detected of age on one or on both groups (weak and/or not weak), on DBP ($p_s = -0.25$; $p = 0.01$, not weak), VO_{2max} ($p_s = 0.27$; $p = 0.006$, not weak), BMI ($p_s = 0.40$; $p = 0.000$, for both groups), cholesterol total CT ($p_s = -0.20$; $p = 0.040$, not weak), and on HDL ($p_s = -0.29$; $p = 0.021$ and $p_s = -0.25$; $p = 0.012$; "weak" and not weak, respectively). At this point ANCOVA was applied to

adjust the means of these variables for age. After adjustment, the differences previously observed between means for the "weak" and "not weak" group remained unchanged.

Among the females, there were no significant differences in age between the two groups and, therefore, there was no need to consider adjusting other variables for age.

Tables 3 and 4 demonstrate the association between cardiorespiratory fitness (VO_{2max}) and obesity for both sexes. Among both males and females, the groups classified as

Table 2 - Anthropometric, hemodynamic and biochemical characteristics by aerobic fitness for females

	Cardiorespiratory fitness		
	Weak	"not weak"	p
Age (years)	12.5±1.4	12.4±1.4	0.934
Height (m)	1.52±0.09	1.50±0.10	0.115
Baseline HR (beats/min)	84±10	80±9	0.002*
SBP (mmHg)	109±11	107±9	0.293
DBP (mmHg)	64±8	64±7	0.796
VO _{2max} (mL.kg ⁻¹ .min ⁻¹)	32.49±3.06	41.48±4.50	0.000*
BMI (weight/height ²)	19.92±4.24	17.99±2.39	0.000*
Total cholesterol (mg/dL)	150.41±24.60	151.85±31.93	0.732
HDL-cholesterol (mg/dL)	44.30±8.59	44.8±7.82	0.670
LDL-cholesterol (mg/dL)	91.18±21.65	91.19±29.69	0.997
Triglycerides (mg/dL)	74.68±28.00	79.34±30.03	0.268

Values expressed as mean ± standard deviation.

HR = heart rate; BMI = body mass index; DBP = diastolic blood pressure; SBP = systolic blood pressure; VO_{2max} = maximum oxygen uptake.

* p ≤ 0.05 = comparison between "weak" and "not weak" by Student's *t* test.

Table 3 - Association between “weak” and “not weak” cardiorespiratory fitness and body mass index, arterial pressure and biochemical profile, for males

Variables	Chi-square	p	Odds ratio	RR	NNH
VO _{2max} × BMI	25.242	0.000*	9.983*	7.00*	4
VO _{2max} × Pressure	0.001	0.970	1.021	1.01	-
VO _{2max} × Total cholesterol	2.545	0.111	1.639	1.31	-
VO _{2max} × HDL-c	0.029	0.865	0.949	0.98	-
VO _{2max} × LDL-c	3.793	0.051	1.994	1.68	-
VO _{2max} × Triglycerides	3.944	0.047	2.960	2.63	9

Chi-square coefficients and p values, odds ratio, relative risk (RR) and number needed to harm (NNH); BMI = body mass index; VO_{2max} = maximum oxygen uptake; * significant at p ≤ 0.05 and 95%CI.

“weak” included a significantly higher number of cases of overweight than the “not weak” groups, which can be observed in the form of significant odds ratio values (9.98 and 4.81 for boys and girls, respectively). The same groups exhibited 7 and 3.95 times greater RR of having abnormal BMI, in relation to the “not weak” groups. Furthermore, one in every four male adolescents and one in every six female adolescents classed as having a “weak” VO_{2max} was overweight (NNH). A significant association ($\chi^2 = 3.944$; p = 0.047) can also be observed between cardiorespiratory fitness and triglycerides among the males, with the “weak” group exhibiting a significantly greater number of adolescents with abnormal triglyceride levels (odds ratio = 2.960) at a RR of 2.63. One in every nine adolescents classified as “weak” exhibited abnormal triglyceride levels.

Discussion

The purpose of this study was to seek for associations between cardiorespiratory fitness, measured directly, and the presence of cardiovascular risk factors in adolescents, employing physical fitness categories proposed for Brazilian samples.

The results indicate that BMI is greater in the group with a lower cardiorespiratory fitness, with no significant blood pressure abnormalities, for both females and males. Nevertheless, the mean BMI value in the “weak” VO_{2max} group was not

high enough to be classified as overweight or obesity. This appears to us to be one possible reason why a significantly higher BMI in the “weak” group did not influence blood pressure levels, as has been described in the literature.²³

Epidemiological studies report that physical activity and/or fitness are effective at reducing arterial blood pressure among hypertensive adults; however, it is not clear if these benefits can also be observed in children.¹² In this study, the association between physical fitness and arterial blood pressure was not confirmed, which is supported by data presented in the literature.^{24,25} Nevertheless, other studies have reported contrasting results.⁸⁻¹⁰ It is believed that the contradictory data are the result of methodological differences and the great diversity of factors that affect blood pressure. Furthermore, there is great variety in the methods employed in clinical investigations to identify physical fitness, such as direct and indirect measurements of VO_{2max}^{11,26,27} and recovery HR,⁷ which can cause results to diverge between studies.

A faster HR was observed in the group with lower physical fitness (males and females). This could have occurred equally as a result of physical training, which improves cardiovascular function,²⁸ as due to the cardiac overload in post by the greater body mass of this group.²³ Additionally, it is known that overweight and obese individuals exhibit lower levels of

Table 4 - Association between “weak” and “not weak” cardiorespiratory fitness and body mass index, arterial pressure and biochemical profile, for females

Variables	Chi-square	p	Odds ratio	RR	NNH
VO _{2max} × BMI	12.683	0.000*	4.811*	3.95*	6
VO _{2max} × Pressure	1.279	0.258	1.632	1.53	-
VO _{2max} × Total cholesterol	0.253	0.615	1.156	1.09	-
VO _{2max} × HDL-c	0.260	0.610	1.158	1.08	-
VO _{2max} × LDL-c	0.022	0.882	0.954	0.97	-
VO _{2max} × Triglycerides	0.465	0.495	0.767	0.80	-

Chi-square coefficients and p values, odds ratio, relative risk (RR) and number needed to harm (NNH); BMI = body mass index; VO_{2max} = maximum oxygen uptake; * significant at p ≤ 0.05 and 95%CI.

physical fitness.²⁹⁻³¹ It is therefore difficult to identify where cause and effect lie in this relationship.

Higher triglyceride levels were observed in the group with lower physical fitness, among males only. Data published previously provide evidence of a negative correlation between VO_{2max} and triglycerides, but only among post pubescent boys.³² It is known that, because they are deposited on the vessel walls and begin the process of low-density lipoprotein accumulation, triglycerides are strongly associated with the risk of atherosclerotic disease.^{33,34} It is appropriate to point out that dyslipidemia that starts in childhood tends to be maintained throughout growth and exhibits a direct relationship with cardiovascular diseases in adulthood.³⁵

While this investigation determined VO_{2max} directly, this has not been the habitual method employed, with cardiorespiratory fitness being determined by a variety of indirect methods. In our sample, this important variable of physical fitness, when determined directly, was unable to significantly influence levels of total cholesterol or fractions. Only triglyceride levels, among males, were sensitive to cardiorespiratory fitness. It is worth pointing out that Wilmore & McNamara³⁶ were also unable to demonstrate a significant association between VO_{2max} and blood lipid levels in adolescents. Further studies, with well-designed and standardised methodology are necessary in order to identify the true predictive power of cardiorespiratory fitness on blood lipid levels of adolescents. It is possible, therefore, that the lack of criteria may be the origin of the divergences between those who identify or fail to identify this variable as an independent predictor of lipid profiles in adolescents.³⁷

It has been suggested that measures of physical fitness are preferable to those of physical activity, due to their greater objectivity and lower propensity to errors. Furthermore, studies indicate that aerobic fitness, and not physical activity, is better correlated with cardiovascular diseases in adults.^{12,38,39} Therefore, efforts should be redoubled to identify the initial point of daily physical activity to increase the physical fitness of young people.

Although the present study is based on data from a specific location, the group investigated represents 59.71% of the entire population of this age group, in a city where school attendance is high (93%). This is, therefore, a representative sample of the universe of adolescents within this age group. It should, however, be pointed out that the results should not be extrapolated to the entire population, since only public school students were assessed.

This investigation has suggested that cardiorespiratory fitness is associated with an increased frequency of risk factors (BMI, arterial pressure and total cholesterol for both sexes; LDL-c and triglycerides for males, and HDL-c for females). However, in our dataset, the difference was significant only in terms of overweight in both sexes and triglyceride levels among males.

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