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Determinant factors of cardiorespiratory fitness in Portuguese adolescents of different ethnicities

Fatores Determinantes na aptidão cardiorrespiratória em Portugueses de diferentes etnias

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Abstract – Cardiorespiratory fitness is an important health indicator in young people. The aim of this study was to investigate the effects of age, gender, body adiposity, and ethnicity on cardiorespiratory fitness in a sample of Portuguese adolescents. The sample consisted of 266 adolescents aged 12-18 years [112 boys (80 Caucasians and 32 African-Portuguese, AP) and 154 girls (109 Caucasians and 45 AP)]. Percent body fat was estimated with a hand-to-hand bioelectrical impedance device (BF300, OMROM). Cardiorespiratory fitness was assessed by a shuttle run test (Fitnessgram battery). Multiple regression models were used for statistical analysis. The results showed that girls presented lower maximal oxygen consumption and higher percent body fat than boys. Cardiorespiratory fitness was lower in Caucasian than in AP girls. Multiple regression analysis showed that percent body fat, age and the interaction of age with being Caucasian and age with female gender were significant determinants that were negatively associated with cardiorespiratory fitness. The results suggest that maximal oxygen consumption is lower in adolescents with higher adiposity and in older adolescents. The findings highlight the importance of promoting physical fitness in schools across ages, especially in older adolescents, adjusting for determinant factors such as gender and ethnicity.

Key words: Adiposity; Adolescent; Ethnicity; Physical fitness.

Resumo – *A aptidão cardiorrespiratória é um importante indicador de saúde em jovens. O objetivo do presente estudo foi analisar a influência da idade, sexo, adiposidade corporal e etnia na aptidão cardiorrespiratória em uma amostra de adolescentes portugueses. A amostra foi composta por 266 adolescentes, 112 rapazes (80 caucasianos e 32 Afro-Portugueses) e 154 moças (109 caucasianas e 45 Afro-Portuguesas) com idades entre os 12 e 18 anos. Para avaliação da aptidão cardiorrespiratória, foi utilizado o Teste de vai e vem de 20 metros, para a determinação do consumo máximo de oxigénio (VO2max). A impedância bioelétrica (BF300, OMROM) foi utilizada para a estimativa do percentual da massa gorda (%MG). Na análise estatística, foram utilizados modelos de regressão linear múltipla. As adolescentes do sexo feminino apresentaram valores inferiores de VO2max e superiores de %MG em comparação aos do sexo masculino. Em relação a etnia, as moças caucasianas apresentaram valores inferiores de VO2max quando comparadas com as afro-portuguesas. O modelo de regressão múltipla demonstrou que o %MG, a idade e a interação da idade com ser caucasiano e da idade com ser do sexo feminino foram determinantes significativos, apresentando uma associação negativa com a aptidão cardiorrespiratória. Os resultados sugerem que os adolescentes com maior adiposidade e os mais velhos apresentam um menor consumo máximo de oxigênio. Os dados parecem salientar a importância da promoção da aptidão física nas escolas ao longo da idade, especialmente, os adolescentes mais velhos e adequando a fatores determinantes, como o sexo e a etnia.*

Palavras-chave: *Adiposidade; Adolescente; Etnia; Aptidão física.*

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INTRODUCTION

Obesity is a strong risk factor for cardiovascular disease in the adult population[1]. According to previous investigations from developed countries[2,3], epidemiologic studies in Portugal suggests an increase in overweight/obesity prevalence in the last 10 years[4]. Data in Portugal shows a prevalence of overweight/obesity in children close to 32%[5].

Cardiorespiratory fitness is an important predictor for the clustering of cardiovascular diseases (CVD)[6]. Studies in paediatric populations show a relationship between body composition and cardiorespiratory fitness[7,8]. In the European youth heart study[7] there was a strong relation between body composition and cardiorespiratory fitness in children and adolescents. Mota et al.[8], with a sample of Portuguese children and adolescents concluded that the most important factor accounting for variation in maximal oxygen consumption (VO_{2max}) was percent body fat (%BF), explaining 10% of cardiorespiratory fitness differences in girls and 22% in boys. It is known that after sexual maturation girls increase body fat (BF) more pronounced when compared with boys[9]. Relative VO_{2max} tends to decrease with maturation in girls. This decline is usually attributed to the effect of BF associated with sexual maturity[8], in contrast, in boys cardiorespiratory fitness increases slightly with maturation[8].

Previous investigations have noted differences in maximal oxygen uptake, body composition and physical inactivity between Caucasians and African American (AA) subjects in all ages[10-13]. The main conclusions point to lower VO_{2max}, higher %BF and higher levels of physical inactivity in AA[10-13]. All of these previous ethnical related studies were performed in United States while in Europe investigation reporting and explaining differences in cardiorespiratory fitness between Caucasian and African European adolescents is absent. At this regard, it is important to highlight that since the 70's, the number of immigrants from the African Continent has been increasing in Portugal[14].

Therefore, we aimed to understand the effects of variables, such as body composition, age, ethnicity and gender in VO_{2max} in an ethnically diverse sample of Portuguese adolescents [Caucasians and African Portuguese (AP)].

METHODS

Subjects

Subjects were a convenient sample recruited in a school from Lisbon, Portugal consisting in 266 adolescents, 12-18 years of age [112 boys (80 Caucasians and 32 AP) and 154 girls (109 Caucasians and 45 AP)]. Classification into ethnical groups was self-reported and required similar parent ethnicity. As we aimed to assess all school population the proportion of Caucasians and AP is in accordance to the reality of the school and the region of Lisbon. All the procedures were conducted after informed consent was obtained. The study was conducted according to the ethical principles for clinical research involving human subjects in accordance to the Declaration of Helsinki.

Anthropometry

To assess body mass index (BMI) subjects were weighed to the nearest 0.1kg using a scale (*Seca, Hamburg, Germany*). Height was measured to the nearest 0.1cm with a stadiometer (*Seca, Hamburg, Germany*). Anthropometric measures were collected according to the standard procedures[15].

To estimate the prevalence of overweight and obesity age and gender specific cut off values proposed by Cole et al[16] were used.

Body composition measures

Body fat measurement was carried out after a 4-hour fast and 12-hours without exercise. %BF was estimated by a hand-to-hand bioelectrical impedance device (BF300, *OMRON Healthcare Europe, Hoofddorp*) which provides absolute and %BF. The removal of absolute BF in body mass allowed us to calculate FFM.

Cardiorespiratory fitness

Cardiorespiratory fitness was assessed by the *shuttle test* from the *Fitnessgram* battery[15]. The *shuttle test* is progressive in intensity, it is easy at the beginning (8.0km/h) and speed increases 0.5km/h every stage after the first minute. The progressive nature of the test provides a built-in single beep at the end of the time for each lap and a triple beep at the end of each minute. When runners could no longer keep up the pace by reaching the line at the time of the tone, participation was terminated and the number of laps completed was recorded. Scores of the last stage number were converted to VO_{2max}, using the *Fitnessgram* software.

Statistical Methods

All group results are expressed as the mean and standard deviation. Analyses were carried out using SPSS v15.0 (SPSS, 2007). Significance was set at $p<0.05$ for all tests. Two-way ANOVA was used to

compare ethnicity and gender groups for all variables. Scheffé's adjustment for multiple comparisons was made if variances were equal, Dunnett's T3 adjustment was used if variances were not equal.

Multiple regression analysis was applied to investigate the association of VO_{2max} with other variables. The tested variables were gender, ethnicity, weight, height, BMI, %BF, FFM and two- and three-way interactions. Variables or interactions making no significant contribution were eliminated from the final model. If a non-significant ethnicity by gender interaction was found the analysis would be conducted in the whole sample. During model development, homogeneity of variance and normality of residuals were tested. Because residuals were not normal, the dependent variable was transformed using a logarithmic function (log_{10}). This brought the model into compliance with the assumptions of multiple linear regression models.

To better illustrate the relation of relative VO_{2max} with the contributing independent variables, adjusted VO_{2max} values were plotted separately against age for each ethnical group and against %BF. Adjusted values were calculated by adding the relative VO_{2max} mean value to the residuals after completing the regression analysis for each model created.

RESULTS

The characteristics of the sample are summarized in Table 1.

Significant gender differences were found for %BF and relative VO_{2max} ($p<0.001$), with girls presenting higher values in %BF and lower in VO_{2max}. AP girls presented higher values in VO_{2max} compared to Caucasian girls.

The relative VO_{2max} model on the entire sample is presented in Table 2.

Table 2. $Log_{10}VO_{2max}$ regression model for the whole group.

Variables	β	SE	p
Intercept	1.891	0.040	<0.001
%BF	-0.003	0.000	<0.001
Age	-0.011	0.002	<0.001
Ethnicity x Age			
Caucasian x Age	-0.001	0.000	<0.01
AP x Age	0	-	-
Gender x Age			
Girl x Age	-0.004	0.000	<0.001
Boy x Age	0	-	-

R^2=0.505, adjusted R^2=0.498; Standard error of estimate=0.05; Abbreviations: β, regression coefficient; SE, standard error; %BF, percent body fat; AP, African Portuguese.

The final model included %BF, age, and an age by gender and an age by ethnicity interaction. The contribution of the age by ethnicity interaction and the age by gender interaction indicated that ethnicity and gender, as main effects, were associated with relative VO_{2max} but the relation was dependent on age, as observed by the negative coefficients of the age by Caucasian interaction (ß=-0.001) and the age by girls interaction (ß=-0.001). Older Caucasians and older girls presented lower VO_{2max} values than younger ones. These associations are

Table 1. Subject characteristics for the whole group (mean ± SD).

	Boys (n=112)		Girls (n=154)	
	Caucasians (n=80)	AP (n=32)	Caucasians (n=109)	AP (n=45)
Age (years)	15.80±1.42	16.09±1.28	15.94±1.53	15.67±1.52
Weight (kg)	63.0±12.2[a]	63.6±11.0	58.0±11.1[a]	56.5±10.8[a]
Height (m)	1.71±0.08[b]	1.74±0.11[b]	1.61±0.06[b]	1.61±0.06[b]
BMI* (kg/m^2)	21.6±3.6	21.0±2.7	22.5±4.3	21.8±3.9
%BF	16.0±7.4[c]	15.8±7.2[c]	23.5±7.0[c]	23.1±5.8[c]
BF (kg)	10.4±6.3[d]	10.3±5.4[d]	14.0±6.8[d]	13.5±5.8
FFM (kg)	52.6±8.9[b]	53.4±9.3[b]	43.9±6.5[b]	43.1±6.3[b]
VO_{2max} (ml/kg/min)	45.0±6.2[b]	45.6±6.3[b]	36.2±4.9[b.e]	38.8±4.9[b.e]

Abbreviations: AP, African Portuguese; BMI, body mass index; BF, body fat; FFM, fat free mass; VO_{2max}, maximal oxygen consumption.
*Prevalence of overweight/obesity in all sample 19.2% (Caucasians: 19% boys, 25 % girls; AP: 3.2% boys; 17.1% girls).
[a)] Two-way Anova with Shefé's adjustment ($p<0.05$) showed differences between Caucasian boys and Caucasians and AP girls; [b)] Two-way Anova with Dunett T3 adjustment ($p<0.001$) showed differences between boys and girls; [c)] Two-way Anova with Shefé's adjustmentment ($p<0.001$) showed differences between boys and girls; [d)] Two-way Anova with Sheffé's adjustment ($p<0.05$) showed differences between Caucasian girls and Caucasian and AP boys; [e)] Two-way Anova with Dunett T3 adjustment ($p<0.05$) showed differences between Caucasian girls and AP girls;

illustrated in Figure 1 that shows the relation between adjusted VO_{2max} with age according to ethnicity and gender.

Figure 1a demonstrates that older girls had lower relative VO_{2max} values than the younger ones. The reduction of 0.004 units on $Log_{10}VO_{2max}$ indicates a negative association in cardiorespiratory fitness, with older girls showing lower values than the younger ones. Gender differences in older ages are clearly observed in Figure 1a.

An age by ethnicity interaction also contributed to explain the variability in $Log_{10}VO_{2max}$. Figure 1b shows adjusted relative VO_{2max} , among ages both for Caucasians and AP. Older Caucasians presented lower VO_{2max} than younger ones (β=-0.001). In Figure 1b, a non-significant association with age was found in AP, presenting lower values for adjusted relative VO_{2max} in younger ages and higher values in older ages, demonstrating an opposite trend compared to Caucasians. Thus, below and above 14 years, further disparities between ethnical groups were observed in adjusted relative VO_{2max} (Figure 1b). In Table 1 ethnical differences were observed only in girls with Caucasian girls presenting lower levels of VO_{2max} than AP girls.

In the model a negative association between %BF and $Log_{10}VO_{2max}$ (β=-0.003) was also found. For a better illustration, we controlled for the effect of variables that influenced the relative VO_{2max}: age, age by gender interaction, and age by ethnicity (Figure 2).

Figure 2 illustrates the inverse relationship found between adjusted relative VO_{2max} and %BF, meaning that a lower cardiorespiratory fitness was observed in adolescents with higher adiposity.

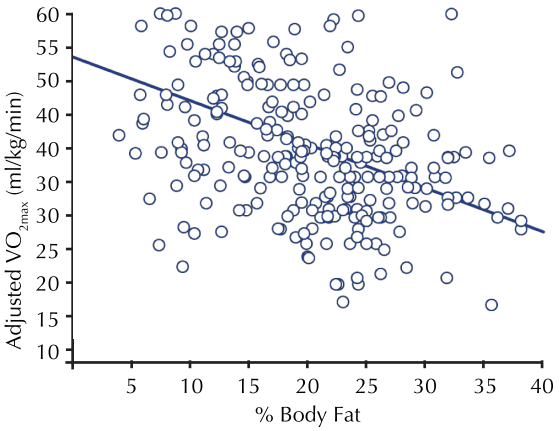

Figure 2. Relation between adjusted VO_{2max} and %BF, controlling for the effect of an age by gender and an age by ethnicity interactions.

DISCUSSION

To our knowledge no study has addressed the differences in cardiorespiratory fitness between Caucasians and AP adolescents in Portugal. One of the objectives of this investigation was to identify, in a sample of Portuguese adolescents, the effect of ethnicity in cardiorespiratory fitness, in addition to age, body composition, and gender and the variability of cardiorespiratory fitness in our sample.

Body Composition and Cardiorespiratory Fitness

Higher %BF was observed in girls compared to boys. This result is in accordance to other studies that found lower adiposity in boys[8,17]. Also, gender differences in cardiorespiratory fitness, have been demonstrated,

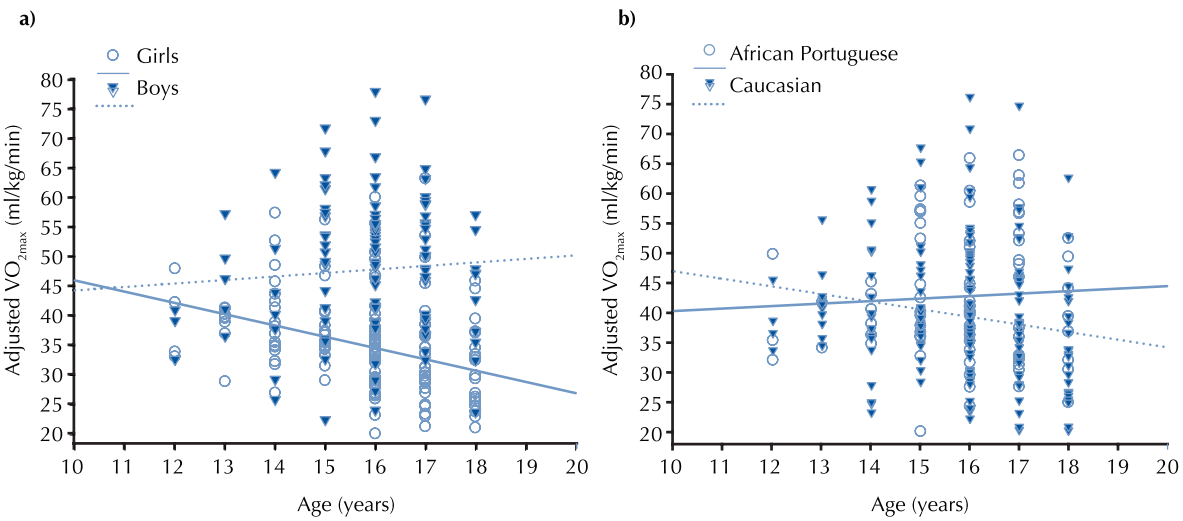

Figure 1. Relation between adjusted VO_{2max} and age by gender, controlling for the effect of %BF and an age by ethnicity interaction (a),and between adjusted relative VO_{2max} and age by ethnicity, controlling for the effect of %BF and an age by gender interaction (b).

with boys showing higher values of VO_{2max} [8,17,18].

As presented by several studies[8,19-22], there was a negative relationship between cardiorespiratory fitness and levels of adiposity in our adolescents. Ortega et al.[23] indicated that moderate and high values of VO_{2max} are associated with lower values of adiposity. Other parameters of body composition, such as FFM, have been used to explain cardiorespiratory fitness and a positive association between these variables was found in adolescents[24]. However, in our sample, this variable did not make any contribution to the model in explaining relative VO_{2max}. The different body composition methods might explain the differences between studies.

A negative association between BMI and VO_{2max} in pediatric population has also been shown[18]. In our model the BMI was not a predictor variable of cardiorespiratory fitness. Thus, it seems that, whenever possible, the body composition in schools should be evaluated in order to estimate BF. Mota et al.[8] observed a negative relation between adiposity and cardiorespiratory fitness in both genders and our results extend these findings. The level of obesity in population is associated with a decrease in cardiorespiratory fitness[21]. Our study showed that girls tend to present higher values of %BF and lower levels of VO_{2max}. Sopher et al.[25] refer the importance of understanding changes in body composition at lower ages, because several and significant differences occur over the years from childhood to adulthood.

Although our study did not assess the impact of cardiorespiratory fitness in health indicators for CVD, we observed a close relationship between adiposity and VO_{2max} in a sample of Portuguese adolescents. This result seems, however, promising for future action with regard to the promotion of physical activity and consequently its impact on increasing the cardiorespiratory condition[26].

Age, Gender and Cardiorespiratory Fitness

Several studies, using children and adolescents samples, have demonstrated differences between boys and girls in cardiorespiratory fitness[9,21,23,27], our results, by showing that girls had lower of VO_{2max} than boys, seem to reinforce the mentioned studies. There was a negative effect of age in VO_{2max}, indicating that older adolescents seem to present lower values in cardiorespiratory fitness. The explanation for this trend may be that younger individuals tend to be more active and less inactive[28]. However, to draw this conclusion it would be necessary to evaluate physical activity or inactivity and see if these levels might explain these findings.

There was an age by gender interaction, where a negative coefficient was observed in girls, indicating that older girls had lower values of VO_{2max}. This conclusion is in line with studies in this area[8,21,26]. In boys we observed that removing the effect of %BF and the age by ethnicity interaction, a non-significant slope in the relationship of VO_{2max} with age was positive, indicating that older boys presented higher values in VO_{2max}, which again reinforces the results of other studies[8,26]. The differences in VO_{2max} with age may be due to the rapid decline in physical activity in girls during adolescence[26]. Regarding body composition, the author indicates that the age is a factor that affects gender differences because, although differences in childhood exist they are stable, increasing in adolescence with boys presenting a gain of muscle and bone mass[9].

Age, Ethnicity and Cardiorespiratory Fitness

In the last 30 years the number of immigrants in Portugal increased significantly and there are about 9 times more immigrants than in the early 80s. Immigrants from African countries represent about 37% of all immigrants living in Portugal. These numbers refer only to foreign subjects, the number of African-descendents naturalized Portuguese is not known[14]. Literature is absent regarding the related issues of cardiorespiratory fitness in African European and Caucasian subjects in Europe, though, many studies in United States have addressed this issue[10-13]. Most of these investigations point to a lower VO_{2max} in AA when compared with Caucasians[10-13]. In our sample, only girls presented ethnical differences, with AP girls showing higher VO_{2max} comparing to Caucasian. Contrary to our findings, Pivarnik et al.[13], comparing a sample of Caucasian and AA with similar adiposity levels, concluded that AA had lower values of VO_{2max}. Pate et al.[26] also performed comparisons of AA and Caucasian adolescents using a large database with participants from 12 to 19 years, whose mean age was similar to that of our sample. In this longitudinal study the authors found no differences in cardiovascular fitness of AA and Caucasian subjects.

Andreaci et al.[10] performed multiple regression analysis to understand the variables that explained differences in cardiorespiratory fitness, concluding that both ethnicity and gender were significant predictors of VO_{2max}, however, in their sample AA presented higher values in VO_{2max}. The authors also found that the differences observed between

ethnicities could not be explained by body composition differences, even adjusting for FFM. To our knowledge none of these investigations wanted to understand the explanatory factors for cardiorespiratory fitness in an ethnically diverse sample, testing age as a possible variable that could modulate the association of ethnicity with VO_{2max}. In fact in our study, ethnicity alone was not related to VO_{2max}, its association existed but was dependent on age, meaning that in Caucasian age was a determinant factor in the decline of VO_{2max}.

All studies including different ethnicities were conducted mainly in the US, and it is known that cultural variations determine habits, attitudes and behaviours related to diet and physical activity, among other factors [9]. Malina et al.[9] states that, although individuals are labelled as belonging to an ethnic group, there are possible variations within each category. Freedman et al.[29] hunted to describe secular changes in BMI of AA and Caucasian North Americans in the past 30 years, noting that the prevalence of overweight increased by 14% in AA children and adolescents while in Caucasians only increased by 7%. It would be able to speculate that the current ethnicity differences reported in US studies may be due to behavioural changes in the context of physical activity, in the past 30 years.

There are several methodological limitations of the current study. First, the method to estimate BF was not highly sophisticated relative to more established laboratory methods. Therefore, it may have impacted the results of the relation between body composition and cardiorespiratory fitness, including the effect of FFM, identified as a predictor of cardiorespiratory fitness[24]. Maturation was not accessed, our results considered only chronological age. Mota and colleagues[8] found differences in cardiorespiratory fitness between chronological and maturational age in Portuguese girls. Habitual physical activity was not assessed in our adolescents, so it was not clear if the gender and race differences in cardiorespiratory fitness with age were related to different levels of physical activity or inactivity. However cardiorespiratory fitness relates more strongly to cardiovascular risk factors than components of objectively measured physical activity in children and adolescents[30].

CONCLUSIONS

Our data suggests that cardiorespiratory fitness is lower in older ages, and this relation is also mediated by gender and ethnicity. Older girls and older Caucasians seem to present lower values of relative VO_{2max} when compared to their counterparts. Our findings also reinforce the negative role of adiposity on cardiorespiratory fitness. These results highlight the role of interventions in health education for physical fitness in schools across ages, especially in older adolescents, adjusting for determinant factors, such as gender and ethnicity.

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