Associations of Cardiorespiratory Fitness in Children and Adolescents With Physical Activity, Active Commuting to School, and Screen Time

Luisa Aires, Michael Pratt, Felipe Lobelo, Rute Marina Santos, Maria Paula Santos, and Jorge Mota

Background: The objective of this study was to analyze associations of cardiorespiratory fitness (CRF) with physical activity, time spent watching television and using computer, mode of commuting to school (CS), and adiposity, by gender. Methods: Participants were 1708 students (53.8% girls), aged 11 to 19 years. CRF was evaluated with a 20-meter shuttle-run test using VO2max by previously published equation. Maturation stages determined by Tanner’s criteria, body mass index, and skinfolds were measured, and a questionnaire used to assess socioeconomic status, PA, television and computer time, and mode of CS. We conducted a regression analysis using CRF as the dependent variable. Results: CRF was independent and positively associated with physical activity \( \beta = 0.338 \) (95% CI = 0.119; 0.188); \( P < .001 \) and with maturation \( \beta = -0.876 \) (95% CI = 0.666; 1.087); \( P < .001 \); independent and negatively associated with television time \( \beta = -0.003 \) (95% CI = -0.005; -0.002); \( P < .001 \) and adiposity \( \beta = -0.068 \) (95% CI = -0.076; -0.060); \( P < .001 \). CRF was positively associated with CS \( \beta = 0.337 \) (95% CI = 0.014; 0.741); \( P = .014 \). No associations were found for computer time. Conclusions: These findings suggest that increasing overall physical activity levels through interventions in different domains such as active CS, reducing sedentary activities, such as television time, might be effective strategies for improving CRF in youth.

Keywords: adolescent, health, physical fitness

Recent studies have shown that poor cardiorespiratory fitness (CRF) is independently associated with cardiovascular disease risk factors and adiposity.\(^1,2\) Higher levels of physical fitness (PF) and physical activity are considered the main components required to protect youth from excessive weight gain as well as other metabolic diseases.\(^3,4\) Given that development of cardiovascular disease begins in childhood and tracks into adulthood,\(^5\) these modifiable risk factors should be addressed early.\(^6\)

Several studies have assessed the association between active commuting to school (eg, walking or bicycling), habitual physical activity, and CRF in children and adolescents. Active commuting to school can be related to higher amounts of habitual physical activity especially for moderate to vigorous intensities in children and adolescents.\(^7-9\) Recently, bicycling to school was associated with higher levels of cardiovascular fitness in children and adolescents;\(^10\) however, it remains to be determined whether walking to school alone is sufficient to improve CRF.\(^11\)

Other behavioral changes, such as reducing sedentary time, may also have beneficial health effects in children and adolescents. Electronic media use is a common pastime for children today, becoming more prominent as they get older. The household media environment has been associated with many negative outcomes, including poor scholastic performance,\(^12\) sleep deprivation,\(^13\) poor diet,\(^14\) and higher BMI.\(^15\) The current guideline from American Academy of Pediatrics recommends limiting children’s total media time to no more than 2 hours of quality programming per day.\(^16\) Evidence indicates that physical activity and sedentary time are independent constructs. Sedentary behaviors and physical activity are only modestly correlated; they have different type of sociodemographic determinants and are differently associated with health-related risk factors,\(^17\) but there is limited evidence showing inverse associations between amount of sedentary time, compliance with current physical activity standards, and CRF.\(^18,19\) Activity intensities should be treated as potentially independent influences on health outcomes, and conclusions should be stated
in terms that are limited to those behaviors actually measured.

Although associations of adiposity with physical activity, sedentary time, and mode of commuting to school have been commonly reported, the relationship of all these variables with CRF is less well established. Therefore, the purpose of this study was to investigate whether physical activity levels, time spent watching television or using computer, mode of commuting to school and adiposity were independently associated with levels of CRF in girls and boys aged 11 to 19 years.

Methods

Subjects and Data Collection

This is a cross-sectional study comprising 1708 students (53.8% of girls and 46.3% of boys) from 2 middle/high schools set in Valongo. Situated in the Porto District, (Portugal) Valongo is a largely urban area (total area, 78 km²; 100,000 inhabitants) that also includes some rural and forested areas. The majority of the population comes from lower socioeconomic backgrounds; the average educational level is 4th grade. All students were invited to perform a 20-meter shuttle run test (20mSRT) and to answer a questionnaire. Written consent from the family was required of all participants. A consent letter was sent home 2 weeks before the measurements. Participation was voluntary for all evaluations. The Fitnessgram battery is an integrated fitness and activity assessment program that can greatly enhance the effectiveness of school-based physical education programs and is included in the Portuguese national curriculum; 6 tests are recommended in the Physical Education program (curl-up; push-up; trunk-lift; the modified back saver sit and reach, 20mSRT, and body composition). However, for this study only 20mSRT was used. Students, who did not perform the 20mSRT, did not meet exhaustion criteria or did not perform anthropometric measures (30.2%), were excluded from the analysis. The experimental protocol was approved by the Review Committee of the Scientific Board of the Faculty of Sport of the University of Porto as well as by the Foundation of Science and Technology and performed in accordance with the ethical standards required elsewhere.

Anthropometry

Height was measured using a Holtain stadiometer. Values of height were recorded in meters to the nearest millimeter. Body mass was measured to the nearest 0.1 kg with an electronic weight scale (Tanita Inner Scan BC 532) with subjects in t-shirts and shorts. Body mass index (BMI) was calculated from the ratio weight/height² (Kg·m⁻²). Triceps, subscapular, and midcalf skinfold thickness were measured according to established protocol. Each skinfold was measured twice consecutively, on the right side of the body. If measurements differed by more than 5%, a third measure was taken. A Harpenden Skinfold Caliper with a constant pressure of 10 g/mm² was used and the same observer completed all measurements. The sum of the 3 skinfold thickness measurements was calculated as a final value.

Socioeconomic Status

Socioeconomic status (SES) was established from Parents’ educational level. Categories were based on the Portuguese Educational system: (1) 9 years education or less—subsecondary level; (2) 10 to 12 years education—secondary level; and (3) college/master’s/doctoral degree—higher education level). These 3 levels were named as Low, Middle, and High level of education. Similar procedures have previously been applied in the Portuguese context.

Maturational Stage

Children and youth were grouped by maturation stages determined by Tanner’s criteria. To determine maturational stage (ranging from Stage 1 to 5), each subject was asked to self-assess his/her stage of secondary sex characteristics. Stage of breast development in females and pubic hair in males was evaluated which were previously validated in a similar sample.

Cardiorespiratory Fitness

FITNESSGRAM reference standards for VO₂max and the number of laps were applied to classify subjects. Subjects performed the 20mSRT according to the protocol previously defined. All participants were familiar with the test since it is widely used in Portuguese schools. Participants were required to run back and forth between 2 lines 20 meters apart starting at 8.5 km·h⁻¹ with speed increasing by 0.5 km·h⁻¹ each minute. Subjects were instructed to run in a straight line, pivot, and turn on completing a shuttle, and to pace themselves in accordance with audio signals. The test was finished when participants stopped due to fatigue or when they failed to reach the lines concurrent with the audio signals on 2 consecutive occasions. Exhaustion was confirmed when (1) subjects desired to stop or demonstrated an inability to maintain the required running pace despite strong verbal encouragement; (2) subjects showed symptoms of discomfort and/or signs of high sweating, facial flushing, and grimacing; or (3) subjects had reached a value near or above 200 b·min⁻¹. Heart rate was recorded every 5 seconds during the 20mSRT using a Polar telemetry system (Polar Team System, Vantage NV). The total number of completed laps was recorded and then transformed into a VO₂max by previously determined equation.

Physical Activity Index

Physical activity was assessed by a questionnaire that was previously determined to have good reliability with
intercorrelation coefficients (ICC: 0.92 to 0.96). The questionnaire has 5 questions:

1. Do you take part in organized sport outside school?
2. Do you take part in nonorganized sport outside school?
3. How many times per week do you take part in sport or physical activity for at least 20 minutes outside school?
4. How many hours per week do you usually take part in physical activity outside school, which causes you to get out of breath or sweat?
5. Do you take part in a competitive sport?

Each question could have 4 or 5 choices (4/5-point scale): For the first and second questions: 1) Never, 2) Less than 1 week, 3) at least 1 week, 4) almost every day. For the third question: 1) Never, 2) less then once a month, 3) between once a week and once a month, 4) 2 or 3 times a week, 5) 4 times a week or more. For the forth question: 1) Never, 2) 30 minutes to 1 hour, 3) 2 to 3 hours, 4) 4 to 6 hours, 5) 7 hours or more. For the fifth question: 1) Never, 2) No, but I already had, 3) Yes, at school, 4) Yes, in a club. The overall maximum possible number of points possible was 22; we used each student’s total score as a physical activity index (PAI).

**Mode of Commuting to School**

Participants were asked how they do commute home/school (by car, bus, train, bicycle, or walking), and how much time it took. Based on their answers, the respondents were categorized as using active (walking, bicycling) or passive (bus, train, car) commuting. For the purpose of this study, we considered participants to be active commuters if they reported at least 1 trip to school by walking or bicycling. We classified time spent commuting to and from school into 5 categories: 1) 5 minutes or less, (2) between 5 and 15 minutes, (3) between 15 and 30 minutes, (4) between 30 and 60 minutes, and (5) more then 60 minutes.

**Screen Time**

We measured time watching television (TV time) and using computer (PC time) with a questionnaire. Participants were asked how many hours and minutes they usually watched television or used a computer for work or leisure during the day preceding the examination (to measure weekday usage) as well as during the weekend, using the following questions:

- How much time per day do you spend watching television?
- How much time per day do you use your computer to work or study?
- How much time per day do you use your computer for leisure?

Students were asked how many hours they spent in each activity; we converted this figure to minutes for the purpose of our analysis.

**Statistical Analysis**

All variables and anthropometric characteristics were compared between gender using Independent sample t test for continuous variables and Mann-Whitney U Test for nominal variables. We used a chi-square test to find associations between amount of time spent in active commuting and gender. Linear regression was used to estimate CRF based on PAI, TV Time, PC Time, skinfold measurements and maturational stage (as continuous variables), commuting to school, and gender (as nominal variables). After analyzing each variable separately in linear regression, we then used models that treated all variables as covariates. We performed statistical analysis using SPSS v.15 software and Microsoft Excel 2000; the level of significance was set at P ≤ .05.

**Results**

Participants’ characteristics as mean and standard deviation, or frequency and valid percentage, are shown in Table 1. Overall, boys were heavier and taller (P < .001; P < .001) and more active (P < .001), and spent less time watching television (P = .026) and more time using computer (P < .001). In terms of mode of commuting, the percentage of boys versus girls who were active commuters did not differ significantly. Buses were the most common mode of transport to school in all participants (45.5% in girls and 41.2% in boys), followed by cars (27.8% in girls and 30.4% in boys). A smaller percentage of students used active modes of transportation (19.9% in girls and 22.7% in boys). Time spent traveling to school is summarized by gender in Table 2. No significant differences in time of transport were found between boys and girls. Active commuters generally spent between 5 and 15 minutes in transit. A higher percentage of boys spent 5 to 15 minutes walking or biking to school, compared with girls, who tended to spend less time (5 minutes or less) doing so.

From regression analysis (Table 3), our results showed that CRF was independent and positively associated with physical activity [β = 0.338 (95% CI = 0.119; 0.188); P < .001] and with maturation [β = –0.876 (95% CI = 0.666; 1.087); P < .001]; independent and negatively associated with television time [β = –0.003 (95% CI = –0.005; –0.002); P < .001] and adiposity [β = –0.068 (95% CI = –0.076; –0.060); P < .001]. CRF was positively but not independently associated with active commuting to school [β = 0.337; (95% CI = 0.014; 0.741); P = .014]. No associations were found for computer time.

Figure 1 shows the association between time spent actively commuting and CRF, by gender. Among boys
Table 2  Association Between Time Spent in Active Commuting and Gender

<table>
<thead>
<tr>
<th></th>
<th>Girls (%)</th>
<th>AR</th>
<th>Boys (%)</th>
<th>AR</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 min or less</td>
<td>25.0</td>
<td>1.6</td>
<td>17.9</td>
<td>-1.6</td>
<td>21.4</td>
</tr>
<tr>
<td>5–15 min</td>
<td>45.9</td>
<td>-1.3</td>
<td>53.1</td>
<td>1.3</td>
<td>49.6</td>
</tr>
<tr>
<td>15–30 min</td>
<td>22.7</td>
<td>-0.5</td>
<td>25.1</td>
<td>0.5</td>
<td>23.9</td>
</tr>
<tr>
<td>30–60 min</td>
<td>6.4</td>
<td>1.1</td>
<td>3.9</td>
<td>-1.1</td>
<td>5.1</td>
</tr>
</tbody>
</table>

Abbreviations: AR, Adjusted Residuals.

Note. Associations estimated by Pearson chi-square ($\chi^2 = 4.264; P = .234$).
Table 3  Linear Regression Predicting CRF

<table>
<thead>
<tr>
<th>Model</th>
<th>CRF</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β</td>
<td>(95% CI)</td>
<td>P</td>
</tr>
<tr>
<td>Model 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender a</td>
<td>5.087</td>
<td>(4.775; 5.399)</td>
<td>0.000</td>
</tr>
<tr>
<td>Sum of skinfolds</td>
<td>–0.072</td>
<td>(–0.080; –0.064)</td>
<td>0.000</td>
</tr>
<tr>
<td>Maturation</td>
<td>0.876</td>
<td>(0.635; 1.061)</td>
<td>0.000</td>
</tr>
<tr>
<td>SES</td>
<td>0.097</td>
<td>(–0.017; 0.210)</td>
<td>0.096</td>
</tr>
<tr>
<td>Commuting to school b</td>
<td>0.337</td>
<td>(0.014; 0.741)</td>
<td>0.014</td>
</tr>
<tr>
<td>Model 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender a</td>
<td>4.617</td>
<td>(4.296; 4.939)</td>
<td>0.000</td>
</tr>
<tr>
<td>Sum of skinfolds</td>
<td>–0.068</td>
<td>(–0.076; –0.060)</td>
<td>0.000</td>
</tr>
<tr>
<td>Maturation</td>
<td>0.876</td>
<td>(0.666; 1.087)</td>
<td>0.000</td>
</tr>
<tr>
<td>SES</td>
<td>–0.012</td>
<td>(0.124; 0.099)</td>
<td>0.827</td>
</tr>
<tr>
<td>Physical activity index</td>
<td>0.338</td>
<td>(0.119; 0.188)</td>
<td>0.000</td>
</tr>
<tr>
<td>TV time</td>
<td>–0.003</td>
<td>(–0.005; –0.002)</td>
<td>0.000</td>
</tr>
<tr>
<td>PC time</td>
<td>–0.001</td>
<td>(–0.003; 0.001)</td>
<td>0.218</td>
</tr>
<tr>
<td>Commuting to school b</td>
<td>0.313</td>
<td>(–0.044; 0.671)</td>
<td>0.086</td>
</tr>
</tbody>
</table>

Abbreviations: β, nonstandardized coefficients; CI, confidence interval; CRF, estimated VO2 max equation by Ruiz et al (2008)
Reference categories: a boys; b active.

Note. Model 1: R Square = 0.608; Model 2: R Square = 0.638.

Figure 1 — Associations between active commuters to school and VO2 max, by gender.
CRF levels tend to increase as the time spent actively commuting to/from school increases, although no significant differences were found ($P = .455$).

**Discussion**

It is widely accepted that youth spend too much time watching TV and using computers and do not engage in sufficient amounts of physical activity. These behaviors can contribute to lower CRF, overweight and obesity, and other unhealthy outcomes. The main results of our study demonstrate CRF was independent and positively associated with physical activity and maturation, independent and negatively associated with television and adiposity. CRF was positively but not independently associated with CS. Mean time spent watching TV exceeded the current guidelines of 2 hours or less per day. Compared with girls, boys were consistently more active and spent more time using the computer.

The positive associations that we found between physical activity and CRF are consistent with previous research, as are the associations of sedentary activities and lower total adiposity (assessed by skinfold thickness) with higher CRF levels.

Physical activity levels may be decreased by time spent watching TV or using computers or videogames. However, studies examining these relationships have reported contradictory results; with no association between physical activity and TV time or positive associations between physical activity and computer time. In addition, negative association have been found between sedentary behavior and CRF. Since fit children are typically more active, this inverse association might be related to the amount of time absorbed by sedentary activities. In both cross-sectional and longitudinal analyses, Lobelo et al found an inverse relationship in girls between exposure to electronic media and current physical activity guidelines. These researchers noted a possible threshold effect for compliance with standards at an exposure level of 4 or more 30-minute blocks per day, highlighting the potential importance of public health recommendations that address physical activity and CRF, in addition to body composition standards.

Regarding transportation to school, higher fitness levels in the active commuters may be due in part to walking, especially for those with longer commuting distances. Most of the active commuters in our study chose walking as their primary form of transportation, citing social, environmental, and personal factors as reasons for doing so. Lack of secure pathways and bicycle lanes were commonly identified as barriers to walking and bicycling to and from school. In a previous study, children who were active commuters spent 19% more time in moderate intensity physical activity compared with peers who were driven to school. However, to the best of our knowledge, only 1 study with cross-sectional and longitudinal components has analyzed the association between mode of commuting and fitness in youth. In that study, bicycling to school was associated with higher fitness levels, but walking to school was not. Trends among American school children document a sharp decrease in active commuting from 1969 to 2001, and a similar trend has occurred in Europe. This declining rate represents a worrisome loss of physical activity that may negatively influence fitness levels in children and adolescents. We do not know if the differences in fitness between active and passive commuters observed in our study are due exclusively to walking or biking behaviors. As it pertains to the associations between active commuters and CRF by gender, results are somewhat difficult to explain. However, some considerations can be given. First, our data might be related with the reduced number of active commuters in our study. Second, Figure 1 represents only a direct relationship between CRF and active commuters, without further adjustments for SES, maturation or adiposity. Finally, girls are usually more engaged in supervised activities, while boys prefer spontaneous recreational activities. Depending on SES and safety concerning, girls can be more supportive relating to parents transportation to school and to extracurricular activities. Nevertheless, these data suggest that walking to school may improve youth fitness.

Our findings in children and adolescents aged 11 to 19 years showing associations of CRF with adiposity, as well as with several domains of physical activity, (eg, commuting mode, household, recreation in organized or nonorganized activities, competitive sports) suggests that all of these factors may make important contributions to health-related fitness. Different mechanisms may account for each of these relationships. Physical activity and sedentary behaviors have diverse sociodemographic determinants and are associated differentially with risk factors for health. Despite differences in assessing CRF our results are consistent with other studies showing an inverse relationship with adiposity. In this case, obese children are in disadvantage in tests where they need to apply a greater energy to move or lift their larger mass against gravity, which may be an explanation for the inverse relationship between CRF and body fatness. Obese children may reduce their fitness by abstaining from exercise, conversely, higher fitness is associated with lower fat mass but it is more likely that both factors are interrelated and interdependent. Some limitations of this study should be noted. The study was limited in sample size and provides only cross-sectional data from 2 schools, which makes it difficult to generalize these findings. The self-reported nature of the data for physical activity, or sedentary behavior is also a limitation and may bias results. There are, as well, more accurate maturation measures such as hand–wrist radiographs or even cervical vertebra maturation. However it is expensive and not easy to apply for a large number of subjects. To overcome this limitation, linear regressions were adjusted to maturational stage and adiposity. In addition, we were not able to use more sophisticated and objective approaches to geographic information.
A strength of this study was the application of the 20mSRT to estimate CRF and the use of a recent equation \textsuperscript{27} to established VO\textsubscript{max}. 20mSRT is easy to administer in a typical school setting and it has been previously shown to be a valid, reliable research tool. \textsuperscript{52}

Based on our findings, we encourage the inclusion of CRF testing in health monitoring systems. Schools that commonly administer physical fitness tests are prime places for identifying high-risk children. Work has already begun in Portugal to implement the Fitnessgram battery in elementary and secondary schools, during physical education classes, although it will take some time to widely institutionalize these procedures. Schools offer guaranteed access to a large majority of children, and the potential is great for health surveillance and control systems for all children, including adolescents at high risk. It is equally important to provide opportunities for being active at school, through recess and physical education classes. Bicycle lanes and pedestrian pathways also can provide a good environment for encouraging active commuting, provided they are well designed and safe. Another effective strategy might be to build schools within neighborhoods so that a majority of students live within reasonable walking distance. However, distance from school may still preclude active commuting for some students, suggesting that physical education and after-school programs will remain important components of youth physical activity promotion programs.

In conclusion, although more research is needed to further elucidate the complex interrelationships between CRF, obesity, and physical activity in youth, our results suggest that adiposity and physical activity-related domains in this analysis independently contribute to CRF. Thus, interventions should target all of these factors through a variety of strategies including environment and policy change.

Acknowledgments

This work was supported by grants: SFRH/BD/23128/2005 and SFRH/BSAB/1025/2010 from the Foundation for Science and Technology. The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention.

References


32. Schneider M, Dunton GF, Cooper DM. Media use and obesity in adolescent females. *Obesity (Silver Spring).* 2007;15(9):2328–2335.


