Intensity of Physical Activity, Cardiorespiratory Fitness, and Body Mass Index in Youth

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Background: The purpose of this study was to analyze the relation between body mass index (BMI), Cardiorespiratory Fitness (CRF), and levels of physical activity (PA) from sedentary to very vigorous intensities, measured by accelerometry, in students from a middle and high school.

Methods: This cross-sectional study included 111 children and adolescents, age 11 to 18 years. PA was assessed with an accelerometer for 7 consecutive days (1 minute epoch) using specific cut-points. PA components were derived using special written software (MAHUffe). CRF was assessed by maximal multistage 20m shuttle run. T-test was used to test differences between BMI groups, Pearson’s correlation, to analyze correlations between all variables and multinomial logistic regression, and to predict the value of BMI categories.

Results: This paper provides evidence that BMI was inversely and significantly correlated with CRF. Only CRF was correlated with Vigorous and Very Vigorous PA levels and total amount of PA. Children with Overweight/Obesity were less likely to perform more laps than normal weight counterparts. The total amount or intensity level of PA did not show any influence on BMI level.

Conclusions: Low CRF is strongly associated with obesity, which highlights the importance of increasing CRF for a protective effect even in youth. No associations were found for PA and BMI.

Keywords: accelerometry, cardiovascular health, body composition, adolescent

The increasing prevalence of overweight and obesity has been linked to environments that encourage sedentary behaviors. Portuguese children have one of the highest prevalence of obesity and the lowest rates of physical activity (PA) in European Union.

Current guidelines encourage healthy children and adolescents to engage in moderate to vigorous physical activities (MVPA) at least 60 minutes per day, 5 or more days per week. However, it is unknown what is recommended for overweight and obese children. In fact, 1 hour of MVPA might not be enough for normal weight children to prevent a clustering of cardiovascular risk factors. Nevertheless, studies examining the relationship between intensity of PA and body composition have been equivocal, recently showing that adolescents who engage in larger amounts of vigorous but not moderate PA tended to have better cardiorespiratory fitness (CRF) and lower body fat than those who did not. Thus, it seems that vigorous PA (VPA) may have a greater effect on preventing obesity in children than does PA of lower intensity.

Besides PA level, physical fitness (PF), especially CRF, is also an important factor associated with body mass index (BMI) and adiposity in youngsters. Indeed, moderate to higher levels of CRF have been associated with lower abdominal adiposity, suggesting a mechanism exists by which CRF attenuates the health risk of obesity independent of sedentary activities or PA. Few studies have addressed the relationship between objectively assessed PA intensities, CRF, and obesity level in youngsters. However, it has been difficult to identify in which intensity level PA varies between overweight and obese students and their peers of normal weight. Therefore, the purposes of this study were (1) to compare levels of PA (sedentary, light, moderate, vigorous, and very vigorous) assessed by accelerometers between normal weight and overweight/obesity categories and (2) to analyze how these intensities are associated with CRF and BMI categories.
Methods

Subjects and Settings
This is a cross-sectional study carried out in a suburban middle and suburban high school comprising all the students from 7th to 12th grade registered in the 2007 academic year. A letter informing families that students would be in the study was sent home 2 weeks before measurements were taken. Written consent was obtained from all parents. The Portuguese Ministry for Science and Technology granted permission to conduct this study.

The school population comprised 1226 students of which 1024 resided in a suburban area, 280 were from a periphery area, and 202 students lived out of these areas. For the purpose of this study only students who wore accelerometers (n = 111) correctly during 7 days were included. Thus, the sample of the current study was comprised of 49 boys and 62 girls age 11 to 18 years.

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. The BMI was calculated from the ratio weight/height$^2$ (Kg/m$^2$) and categorized using age- and sex-adjusted cut-off points described by Cole et al.$^{10}$ For the purpose of this study students were assigned into 2 groups: normal weight and overweight/obese.

Maturation Criteria
Regarding the maturational stage, the children and adolescents were inquired separately during physical examination. Each subject self-assessed his/her stages of secondary sex characteristics. Stage of breast development in females and pubic hair in males was evaluated according to Tanner’s criteria and have been previously used and validated in a similar sample.$^{11}$

Physical Activity
PA was assessed during 7 consecutive days using an accelerometer from Manufacturing Technology Inc. (MTI), model 7164, formerly known as the Computer Science Applications activity monitor (Shalimar, FL). This lightweight, electronic motion sensor measures acceleration/decelerations in the vertical plain of body movement. Validation studies examining this accelerometer suggest that it provides a valid and reliable measurement of PA in children being strongly correlated ($r = .86$) with energy expenditure, assessed by indirect calorimetry as well as a high degree of interinstrument reliability.$^{12-14}$

For the current study, the accelerometer was worn on the hip secured by an elastic waist belt. The epoch period (ie, the duration of the sampling period) was set at 1 minute and the output was expressed as counts per minute (counts·min$^{-1}$). Subjects were provided with written instructions regarding care and placement of the accelerometers. A data sheet was given to each participant providing instructions to remove the accelerometers each time they performed any restricted activities like showering and swimming. Before each testing period and for every participant the activity monitors were tested to check abnormal functions or battery capacity. The monitors were initialized as described by the manufacturer.

Data Reduction
Activity counts were summed for each hour that the accelerometer was worn between 7:00 h and 24:00 h to provide a representative picture of daily activity. Criteria for a successful recording were a minimum of 4 days of the week and 1 day of the weekend, and more than 600 minutes per day. Time periods of at least 10 consecutive minutes of zero counts were considered as periods when the monitor was not worn and thus disregarded before analysis. The data were processed with specific software (MAHUFFE, www.mrc.epid.cam.ac.uk). The counts ranges for the various activity intensities were 0 to 499 for sedentary, 500 to 1999 for light (LPA), 2000 to 2999 for moderate (MPA), 3000 to 4499 for vigorous (VPA), and >4500 for very vigorous (VVPA). The threshold of MVPA (>2000 counts/min) corresponds to walking about 3 to 4 Km/h.$^{15}$

Cardiorespiratory Fitness
CRF was assessed by a maximal multistage 20m shuttle-run test according to procedures described from FITNESSGRAM. The FITNESSGRAM was selected because of its ease of administration to large numbers of subjects and its choice of reliable and valid health-related physical fitness measures.$^{16}$ The shuttle-run test predicted maximal aerobic capacity and showed significant correlation with VO$_2$max ($r = .80$), suggesting that it could be used as a measure of aerobic fitness in children.$^{17}$ Students were familiarized with the procedure for each test before recording data. Furthermore, the participants received verbal encouragement from the investigators to achieve maximum performance. The results were recorded as laps taken to complete the 20m shuttle-run test.

Statistics
Mean and Standard Deviation (SD) were used to describe participants’ characteristics according to BMI categories (normal weight and overweight/obesity). The square root of VPA and VVPA was calculated to proceed with parametric analysis. Independent sample $t$-tests were used to test differences between BMI groups for anthropometric measures, age, and PA intensities. Pearson’s correlation was used to analyze the correlations...
between all variables. Multinomial logistic regression was used to obtain adjusted odds ratio (OR) and 95% confidence intervals (CI) to predict the value of BMI categories. Statistical analysis was performed using SPSS 15 software (SPSS Inc., Chicago, IL) and Microsoft Excel 2000. The level of significance was set at $P < .05$.

**Results**

The descriptive data (mean ± SD) of physical characteristics are shown in Table 1. Overweight/obese participants were heavier ($P < .05$) and had higher BMI ($P < .05$) than their lean peers. Further, they had lower CRF levels ($P < .05$) than their normal weight counterparts. 27.4% of the girls and 38.8% of the boys were found to be overweight/obese.

The bivariate association between all variables in analysis are shown in Table 2. The data showed that BMI was inversely correlated with CRF ($r = -0.200, P < .05$). CRF was positively correlated with VPA ($r = .393, P < .001$), VVPA ($r = .278, P < .001$), and with the amount of PA ($r = .282, P < .001$).

Maturation status was not correlated with BMI and CRF; therefore, logistic regression was adjusted only for age and gender.

Logistic regression adjusted to age and gender found significant inverse association between overweight/obesity and CRF. Results showed that children and adolescents with higher levels of CRF presented lower relative risk of being overweight/obesity (OR = 0.968; $P = .037$) than normal weight counterparts (Table 3). Either total amount of PA or PA intensity level did not show any association with BMI level.

### Table 1 Descriptive Characteristics of Subjects by BMI Categories

<table>
<thead>
<tr>
<th></th>
<th>All subjects</th>
<th>Normal weight</th>
<th>Overweight/obesity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean (SD)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td>14.54 (1.58)</td>
<td>14.61 (1.55)</td>
<td>14.42 (1.66)</td>
</tr>
<tr>
<td><strong>Weight (kg)</strong></td>
<td>61.40 (11.86)</td>
<td>56.00 (7.99)c</td>
<td>72.03 (11.02)</td>
</tr>
<tr>
<td><strong>Height (m)</strong></td>
<td>1.66 (0.09)</td>
<td>1.66 (0.09)</td>
<td>1.66 (0.09)</td>
</tr>
<tr>
<td><strong>BMI (kg/m2)</strong></td>
<td>22.24 (3.53)</td>
<td>20.34 (1.82)c</td>
<td>26.09 (2.88)</td>
</tr>
<tr>
<td><strong>CRF</strong></td>
<td>44.10 (22.06)</td>
<td>46.73 (21.35)c</td>
<td>39.10 (22.72)</td>
</tr>
<tr>
<td><strong>PA from Accelerometers</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary (min/day)</td>
<td>626.05 (63.18)</td>
<td>634.39 (62.16)</td>
<td>608.68 (62.59)</td>
</tr>
<tr>
<td>Light (min/day)</td>
<td>84.33 (23.68)</td>
<td>81.61 (23.98)</td>
<td>90.01 (22.29)</td>
</tr>
<tr>
<td>MPA (min/day)</td>
<td>34.02 (16.49)</td>
<td>33.31 (14.02)</td>
<td>35.50 (20.88)</td>
</tr>
<tr>
<td>VPA (min/day)</td>
<td>2.0 (1.95)</td>
<td>2.16 (2.06)</td>
<td>1.67 (1.67)</td>
</tr>
<tr>
<td>VVPA (min/day)</td>
<td>0.23 (0.24)</td>
<td>0.23 (0.23)</td>
<td>0.23 (0.26)</td>
</tr>
<tr>
<td>MVPA (min/day)</td>
<td>36.62 (17.96)</td>
<td>36.02 (15.42)</td>
<td>37.87 (22.54)</td>
</tr>
<tr>
<td>Count/min</td>
<td>528.97 (141.56)</td>
<td>521.36 (131.45)</td>
<td>544.82 (161.45)</td>
</tr>
</tbody>
</table>

- Square-Root-transformed values were used in the analysis but nontransformed values are presented in the table.
- Adjusted for Age and Gender for Independent t-test.
- Significantly different from Overweight/Obesity ($P < .05$).

### Table 2 Bivariate Correlations Between BMI, CRF, Intensities of PA and Total Amount of PA

<table>
<thead>
<tr>
<th></th>
<th>BMI</th>
<th>CRF</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td>0.171</td>
<td>0.288 **</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td>0.038</td>
<td>0.601 **</td>
</tr>
<tr>
<td><strong>Tanner</strong></td>
<td>0.133</td>
<td>0.115</td>
</tr>
<tr>
<td><strong>Sedentary time</strong></td>
<td>-0.095</td>
<td>0.105</td>
</tr>
<tr>
<td><strong>LPA</strong></td>
<td>0.086</td>
<td>0.031</td>
</tr>
<tr>
<td><strong>MPA</strong></td>
<td>0.082</td>
<td>0.020</td>
</tr>
<tr>
<td><strong>VPA</strong></td>
<td>-0.166</td>
<td>0.393 **</td>
</tr>
<tr>
<td><strong>VVPA</strong></td>
<td>-0.087</td>
<td>0.278 **</td>
</tr>
<tr>
<td><strong>MVPA</strong></td>
<td>0.054</td>
<td>0.314**</td>
</tr>
<tr>
<td><strong>Counts·min</strong></td>
<td>0.147</td>
<td>0.282 **</td>
</tr>
<tr>
<td><strong>BMI</strong></td>
<td>1</td>
<td>-0.200 *</td>
</tr>
<tr>
<td><strong>CRF</strong></td>
<td>-0.200 *</td>
<td>1</td>
</tr>
</tbody>
</table>

- Correlation is significant at the 0.05 level (2-tailed); ** Correlation is significant at the 0.01 level (2-tailed); * Square-root-transformed values were used in the analysis.
Discussion

This study reports information about the relationship of BMI, CRF, and PA assessed by accelerometers during 7 consecutive days. There are few studies evaluating accelerometer-derived PA patterns in overweight/obese children. However, such data are valuable for assisting in the design of interventions to increase PA as well as for tailoring an individual exercise prescription.18

The main finding of this study was that after adjustment for age and gender, CRF showed a significant and inverse relationship with BMI. Despite differences in assessing CRF, this result is consistent with a large number of studies.19–21 Although the mechanism by which high CRF reduces the hazard risk of obesity is not clear, the relationship between aerobic fitness and fatness with particular risk factors has been reported in children.22 Indeed, several cross-sectional and longitudinal studies showed an association between CRF and cardiovascular risk factors in youth,23,24 including obesity.22,25,26 One study showed a curvilinear relation between CRF and health parameters, identifying the health impact of small increases in children and adolescents with lower fitness levels.25 Indeed, there is evidence showing that low levels of CRF associated with excess body fat and a sedentary daily lifestyle are significant predictors of heart disease.27

Bivariate correlation showed that CRF was positively associated with VPA, VVPA, and counts·min⁻¹, and negatively correlated with BMI. The lack of a relationship between PA intensity and BMI is somehow unexpected. However, while a few studies showed inverse associations,28,29 others did not find evidence of this relationship,30 especially when energy expenditure is adjusted for fat free mass.31 Nevertheless, the relationship of vigorous intensities to lower levels of body fat as been described in both American7 and European children.32 In adolescents, it has been reported that those engaged in higher intensity exercise improved their body fat percentage as well as their CRF, although for some obese adolescents it is difficult to maintain the high-intensity PA levels.33

In addition, some methodological issues should be considered. In fact, there is a lack of consensus with regard to the cut-off points applied to define intensity levels in youth, which can give different PA levels depending on the criterion selected to distinguish activity from inactivity.34 This problem raised questions about the difference in the prevalence estimates of PA. Another potential consideration is associated with differences in estimating VPA according to the epoch time (sampling interval) procedures. Some studies point out that a shorter epoch (5 seconds) would be more sensitive to assess PA activities for vigorous PA35 than the one used in our study. Nevertheless, when longer epochs are used, as in this study, creating a new variable with the sum of moderate, vigorous, and very vigorous intensities, as MVPA, it can minimize the underestimation of these intensities.36

In the current study, 87.4% didn’t accomplish recommendations, which is lower than what was found in a European Youth Heart Study.37 This might be one reason why no association between PA and BMI was found. As the level of PA is lower, even for normal-weight students, it might be possible that we could not find a relationship between those variables. According to guidelines of PA for health, our data do suggest that children and adolescents accumulate less MVPA than is recommended. However, we have to recognize that these recommendations are based on an arbitrary threshold to classify moderate activity of 3 METs for health, and there remains a lack of empirical evidences for establishing these guidelines.4,38,39

Even if controversy remains about the association of PA and total or central adiposity, PA still is considered the modifiable variable of body weight genesis and the common denominator for CRF. Thus, it might be possible that PA directly influences CRF levels and may favorably impact BMI. Indeed, obese individuals may have lower levels of fitness due to sedentary lifestyles;19 conversely, higher fitness is associated with lower fat mass.40 However, the fundamental concern is to improve CRF levels, in particular for those with overweight/obesity. In adults, Blair et al41 showed that those who improved or maintain

| Table 3  Odds Ratios (OR) and 95% Confidence Intervals (CI) from Logistic Regression Predicting Overweight/Obesity Adjusted for Age and Gender |
|----------------|----------------|---------|
|                | OR             | 95% CI  | p       |
| Sedentary time | 0.993          | (0.984;1.002) | 0.143   |
| LPA            | 1.003          | (0.985;1.021) | 0.779   |
| MPA            | 1.01           | (0.976;1.046) | 0.548   |
| VPA            | 0.634          | (0.332; 1.209) | 0.167   |
| VVPA           | 0.484          | (0.124; 1.889) | 0.296   |
| MVPA           | 1.003          | (0.984;1.023) | 0.727   |
| Counts·min⁻¹   | 1.403          | (0.998; 1.040) | 0.867   |
| CRF            | 0.968          | (0.939; 0.998) | 0.037   |

*a Square-root-transformed values were used in the analysis.
adequate PF were less likely to die of all causes of mortality than persistently unfit men.

The main strength of this study was the use of accelerometers to assess PA, which allowed for the intensities classification. The use of an objective measure with a high compliance rate (at least 10 hours/day) enhances the confidence in our findings because it was suggested that objective measures such as accelerometers provide more valid assessments for youth of all ages. On the other hand, ease of administration of shuttle-run test and its common use in large-scale studies makes it a valuable tool for studying CRF in youngsters. Some limitations of the study should, however, be recognized. First, the study was limited in sample size and provides only cross-sectional data focus on 1 school, which makes it difficult to generalize these findings and thus offers poor external validity. Second, obesity was assessed indirectly. Although BMI has become a very common way of assessing obesity, it does not capture variations in fat and fat-free mass. Nevertheless, recently it was shown that, regardless of the cut-off point, overweight/obesity assessed by BMI during childhood is a strong predictor of that, regardless of the cut-off point, overweight/obesity assessed by BMI during childhood is a strong predictor of obesity, which highlights the importance of our data from a preventive point of view. Nonetheless, our data were adjusted for age, which may overcome those concerns and can lead to the importance of our data from a preventive point of view.

Conclusions

In conclusion, our data showed that low level of CRF is strongly associated with obesity, which highlights the importance of increasing CRF for a protective effect, even in youth. No associations were found for PA, either total amount or intensity level, with BMI level. Further longitudinal studies are needed to analyze these interactions in a long-term period.

Acknowledgments

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References


