Relations of total physical activity and intensity to fitness and fatness in children: the European Youth Heart Study

Jonatan R Ruiz, Nico S Rizzo, Anita Hurtig-Wenläöf, Francisco B Ortega, Julia Wärnberg, and Michael Sjöström

ABSTRACT

Background: It is unclear how the amount and intensity of physical activity (PA) are associated with cardiovascular fitness (CVF) and body fatness in children.

Objective: We aimed to examine the associations of total PA and intensity levels to CVF and fatness in children.

Design: A cross-sectional study of 780 children aged 9–10 y from Sweden and Estonia was conducted. PA was measured by accelerometry and was expressed as min/d of total PA, moderate PA, and vigorous PA. CVF was measured with a maximal ergometer bike test and was expressed as W/kg. Body fat was derived from the sum of 5 skinfold-thickness measurements. Multiple regression analysis was used to determine the degree to which variance in CVF and body fat was explained by PA, after control for age, sex, and study location.

Results: Lower body fat was significantly associated with higher levels of vigorous PA, but not with moderate or total PA. Those children who engaged in >40 min vigorous PA/d had lower body fat than did those who engaged in 10–18 min vigorous PA/d. Total PA, moderate PA, and vigorous PA were positively associated with CVF. Those children who engaged in >40 min vigorous PA/d had higher CVF than did those who accumulated <18 min vigorous PA/d.

Conclusions: The results suggest that PA of vigorous intensity may have a greater effect on preventing obesity in children than does PA of lower intensity, whereas both total and at least moderate to vigorous PA may improve children’s CVF.

KEY WORDS Physical activity, cardiovascular fitness, body fat, children, obesity

INTRODUCTION

Obesity among children and adolescents represents an uncontrolled and increasing worldwide epidemic (1, 2). A sedentary lifestyle and the reduction of physical activity (PA) are suggested to be implicated in this trend (3–5). Negative associations between objectively measured PA and fatness in children and adolescents have been shown (6–9).

Low cardiovascular fitness (CVF) is another important health problem (10–13). High CVF during childhood and adolescence has been associated with a healthier cardiovascular profile not only during these years (14–17) but also later in life (18–20). Comparison of habitually active and less active children and adolescents shows better CVF in the former (9, 17, 21).

For preventive purposes, it is of interest to understand the relative importance of the total amount and intensity of PA. New data have shown positive associations between vigorous PA (>6 metabolic equivalents (METs)) and CVF and negative associations between vigorous PA and fatness in adolescents aged 16 y (6). Similar results were found in a small sample of children aged 8–10 y (9). The present study examined the relations of objectively measured total PA and intensity levels to CVF and fatness in a population sample of children aged 9–10 y.

SUBJECTS AND METHODS

Subjects

The present cross-sectional study involved Swedish (n = 413) and Estonian (n = 367) children aged 9–10 y. The subjects were part of the European Youth Heart Study (EYHS) (22). The pooling of data was considered possible because of the use of common protocols (22). Study design, selection criteria, and sample

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2 The Swedish part of the study was supported by grants from the Stockholm County Council (to MS) and the Estonian part was supported by a grant from the Estonian Science Foundation (no. 3277 and 5209) and by the Estonian Centre of Behavioural and Health Sciences. JRR and FBO were supported by a grant from Ministerio de Educación y Ciencia de España (AP2003-2128, AP2004-2745).

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Received December 8, 2005.
Accepted for publication March 10, 2006.
calculations are reported elsewhere (22, 23). In Estonia, the city of Tartu and its surrounding rural area was the geographical sampling area. In Sweden, 8 municipalities (Botkyrka, Haninge, Huddinge, Nynäshamn, Salem, Södertälje, Tyresö, and Örebro) were chosen for data collection. The local ethical committees approved the study (Örebro City Council no. 690/98, Huddinge University Hospital no. 474/98). One parent or legal guardian provided written informed consent, and all children gave verbal assent. The study procedures were explained verbally to all children.

**Physical examination**

Height and weight were measured by the use of standardized procedures. Body mass index (BMI) was calculated as weight/height squared (kg/m²). Skinfold thicknesses were measured with a Harpenden caliper at the biceps, triceps, subscapular, suprailiac and triceps surae areas on the left side of the body according to the criteria described by Lohman et al (24). These measures have been shown to correlate highly with dual-energy X-ray absorptiometry-measured body fat percentages in children of similar ages (25). All measurements were taken twice and in rotation, and the mean calculated. If the difference between the 2 measurements differed by >2 mm, a third measurement was taken and the 2 closest measurements were averaged. The sum of 5 skinfold thicknesses was used as an indicator of body fat rather than BMI, because BMI has been suggested to not be a good measurement of body fatness in children (7, 8), and because fatness rather than weight has been shown to be associated with poor health (26). Pubertal development was assessed according to Tanner (27). Pubertal stage was assessed by a researcher of the same sex as the child through brief observation. Breast development in girls and genital development in boys was used for pubertal classification.

**Cardiovascular fitness**

CVF was determined by a maximum cycle-ergometer test as described elsewhere (28). Briefly, the workload was programmed on a computerized cycle ergometer (Monark 829E Ergomedic, Vansbro, Sweden) to increase every 3rd minute until the subject reached exhaustion. Heart rate was registered continuously by telemetry (Polar Sport Tester, Kempele, Finland). The criteria for exhaustion were a heart rate ≥185 beats/min, failure to maintain a pedalling frequency of ≥30 revolutions/min, and a subjective judgment by the observer that the child could no longer keep up, even after vocal encouragement. The power output was calculated as \( W_1 + (W_2 \times t/180) \), where \( W_1 \) is the work rate at the last fully completed stage, \( W_2 \) is the work rate increment at the final incomplete stage, and \( t \) is the time in seconds at the final incomplete stage. CVF was expressed as the maximal power output per kilogram body mass (W/kg). The test used to measure CVF was previously validated in children of the same age (29).

**Assessment of physical activity**

PA was measured over 4 consecutive days (2 weekdays and at least 1 weekend day) with an activity monitor (MTI model WAM 7164; Manufacturing Technology Inc, Shalimar, FL, formerly known as Computer Science and Applications Inc) attached on the right hip. At least 3 days of recording, with a minimum of 10 h registration per day, was set as an inclusion criterion. Total PA (also called amount of PA) was expressed as total counts recorded divided by total daily registered time (counts/min). The time engaged in moderate and vigorous PA was calculated and presented as the average time per day during the complete registration. Moderate PA (3–6 METs) and vigorous PA (>6 METs) intensities were based on cutoffs published elsewhere (30). Also, the time spent in at least moderate-intensity PA (>3 METs) was calculated as the sum of time spent in moderate and that spent in vigorous PA (MVPA, min/d). Each minute over the specific cutoff was summarized in the corresponding intensity level group. Validation studies examining the accelerometer used in this study and the construction of summary variables for intensity of movement suggest that this is a valid and reliable measure of children’s PA (31, 32).

Controversy exists, however, about the best way to express PA. When expressed as energy expended in movement, heavier adolescents seem to be engaging in relatively large amounts of PA because they use more energy than lighter adolescents do to move their bodies a given amount. However, when PA is expressed as movement (6), heavier adolescents will appear to engage in less PA than their lighter peers. The time spent in activities of various intensities seems more pertinent for the purpose of making exercise recommendations (33).

**Statistical analyses**

The data are presented as means ± SDs. All variables were checked for normality of distribution before the analysis. The sum of 5 skinfold thicknesses was normalized by transformation to the inverted natural logarithm and by multiplying by minus one. The square root of total PA and of vigorous PA was calculated. Country differences were analyzed by analysis of variance (ANOVA) for boys and girls separately. Sex differences were assessed by ANOVA after adjustments for age and study location. Standard multiple regression was used to determine the degree to which variance in CVF and body fat was explained by PA after control for sex, chronologic age, and study location. The variance explained by the demographic variables was similar when pubertal development rather than age was used in the analyses; thus, age was used in all statistical analyses. The analyses were conducted by using total PA and PA intensities (moderate, vigorous, and MVPA) with either CVF or body fat as the outcome variable. For both outcome variables, a series of models was tested. Model 1 examined the influence of total PA (amount of PA) and its interaction with the covariates. Model 2 examined the influence of moderate PA and its interaction with the covariates. Model 3 examined the influence of MVPA and its interaction with the covariates, and model 4 examined the influence of vigorous PA and its interaction with the covariates. All analyses were adjusted for sex, age, and study location. Statistical significance was set at \( P < 0.05 \) in all analyses. The analyses were performed with SPSS (version 13.0 for WINDOWS; SPSS Inc, Chicago).

**RESULTS**

The ANOVA showed that the Estonian boys had a lower sum of 5 skinfold thicknesses and lower total and vigorous PA than did the Swedish boys. The Estonian girls had a lower sum of 5 skinfold thicknesses and lower BMI and vigorous PA than did the Swedish girls. The physical characteristics, CVF, and PA patterns of the 780 children are shown in Table 1. The results of the
TABLE 1
Descriptive characteristics of the subjects

<table>
<thead>
<tr>
<th></th>
<th>All subjects (n = 780)</th>
<th>Boys (n = 379)</th>
<th>Girls (n = 401)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>9.5 ± 0.4</td>
<td>9.6 ± 0.4</td>
<td>9.5 ± 0.4</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>32.6 ± 6.4</td>
<td>32.7 ± 6.0</td>
<td>32.4 ± 6.8</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>138.3 ± 6.6</td>
<td>138.6 ± 6.2</td>
<td>138.0 ± 6.9</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>16.9 ± 2.3</td>
<td>16.9 ± 2.2</td>
<td>16.9 ± 2.4</td>
</tr>
<tr>
<td>Body fat (mm)</td>
<td>42.0 ± 19.1</td>
<td>37.3 ± 17.1</td>
<td>46.5 ± 19.8</td>
</tr>
<tr>
<td>CVF (W/kg)</td>
<td>3.0 ± 1.4</td>
<td>3.6 ± 1.4</td>
<td>2.4 ± 1.2</td>
</tr>
<tr>
<td>Total PA (counts/min)</td>
<td>714.0 ± 274.4</td>
<td>769.9 ± 278.1</td>
<td>661.2 ± 200.9</td>
</tr>
<tr>
<td>Moderate PA (min/d)</td>
<td>170.9 ± 56.0</td>
<td>181.5 ± 61.6</td>
<td>161.0 ± 48.0</td>
</tr>
<tr>
<td>Vigorous PA (min/d)</td>
<td>26.3 ± 19.6</td>
<td>30.9 ± 22.5</td>
<td>22.0 ± 15.2</td>
</tr>
<tr>
<td>MVPA (min/d)</td>
<td>197.3 ± 69.3</td>
<td>212.4 ± 76.8</td>
<td>183.0 ± 58.0</td>
</tr>
</tbody>
</table>

All values are ± SD. CVF, cardiovascular fitness; PA, physical activity; MVPA, moderate to vigorous PA; body fat, sum of 5 skinfold thicknesses.

ANOVA showed that girls had significantly lower CVF than did the boys and higher body fat. Moreover, girls spent significantly fewer minutes per day in total PA, moderate PA, vigorous PA, and MVPA than did boys.

The results of the regression models that used body fat (sum of 5 skinfold thicknesses) or CVF as the outcome variable are shown in Table 2. Each model included sex, age, and the study location as covariates. Vigorous PA was the only significant predictor of body fat (model 4); total PA (model 1), moderate PA (model 2), and MVPA (model 3) did not explain significant amounts of variance. The results did not change when BMI was used as an indicator of body fat instead of the sum of 5 skinfold thicknesses. Variation in CVF was significantly explained by total PA (model 1), moderate PA (model 2), MVPA (model 3), and vigorous PA (model 4). Subsequent analyses examining the association between CVF and body fat showed that CVF was also a significant predictor of body fat (expressed as the sum of 5 skinfold thicknesses or BMI).

The children were divided into 5 groups (quintiles) on the basis of their time spent in vigorous PA (ie, >6 METs). General linear models with Bonferroni’s adjustment for sex, age, and study location showed a significant association between activity group and body fatness derived from the sum of 5 skinfold thicknesses and cardiovascular fitness (W/kg) with physical activity (PA) after adjustment for sex, age, and study location.

DISCUSSION

The results of the present study suggest that, after adjustment for demographic factors, the intensity of PA, especially vigorous PA, but not total PA is negatively related to body fatness, whereas both amount and intensity of PA are positively associated with CVF in children. Participation in moderate PA explained a significant proportion of the variance in CVF, whereas moderate PA did not explain a significant proportion of the variance in body fat. Total PA showed a significant positive association with

TABLE 2
Standardized multiple regression coefficients (β), 95% CIs, and standardized coefficient of determination ($R^2$) for the association of body fat (sum of 5 skinfold thicknesses) and cardiovascular fitness (W/kg) with physical activity (PA) after adjustment for sex, age, and study location

<table>
<thead>
<tr>
<th>Model</th>
<th>Predictor variable</th>
<th>β</th>
<th>P</th>
<th>95% CI</th>
<th>$R^2$</th>
<th>β</th>
<th>P</th>
<th>95% CI</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total PA</td>
<td>-0.054</td>
<td>0.115</td>
<td>(-0.00007, 0.00074)</td>
<td>0.13</td>
<td>0.129</td>
<td>&lt;0.001</td>
<td>(0.00737, 0.0219)</td>
<td>0.22</td>
</tr>
<tr>
<td>2</td>
<td>Moderate PA</td>
<td>0.018</td>
<td>0.597</td>
<td>(-0.00004, 0.00002)</td>
<td>0.12</td>
<td>0.087</td>
<td>0.008</td>
<td>(0.00022, 0.00143)</td>
<td>0.21</td>
</tr>
<tr>
<td>3</td>
<td>Moderate to vigorous PA</td>
<td>-0.011</td>
<td>0.751</td>
<td>(-0.00002, 0.00003)</td>
<td>0.12</td>
<td>0.108</td>
<td>0.001</td>
<td>(0.00034, 0.00132)</td>
<td>0.21</td>
</tr>
<tr>
<td>4</td>
<td>Vigorous PA</td>
<td>-0.081</td>
<td>0.02</td>
<td>(0.00019, 0.00222)</td>
<td>0.13</td>
<td>0.124</td>
<td>&lt;0.001</td>
<td>(0.01625, 0.0525)</td>
<td>0.21</td>
</tr>
</tbody>
</table>

1 Inverted natural log-transformed values multiplied by minus one were used.

2 The square root of the measures was calculated.
FIGURE 2. Mean cardiovascular fitness stratified (in quintiles) by time spent at vigorous physical activity. The square root of vigorous physical activity was calculated. Errors bars represent 95% CIs. Data were analyzed by general linear models with Bonferroni’s adjustment for sex, age, and study location. Significantly different from those who accumulated <18 min vigorous physical activity/d at this intensity level, \( P < 0.001 \). Significantly different from those who accumulated 10–18 min vigorous physical activity/d, \( P = 0.018 \).

CVF, whereas total PA did not explain a significant proportion of the variance in body fat. These findings suggest that intensity rather than amount of PA may be more important in relation to the prevention of obesity in children, as has been argued by others (8, 34).

The association between vigorous PA and CVF and fatness is consistent with other findings reported in a recent observational study in North American adolescents (6). Similarly, Rowland et al (9) found significant correlations between vigorous PA and CVF and body fat, as well as between moderate PA and both CVF and body fat, in a small sample of children aged 8–10 y. In both studies, PA was objectively assessed over 5 or 7 days, respectively, whereas 4 days of data were available for most of the participants in the present study. This slightly shorter monitoring period may have masked the true association between moderate PA and body fat, as well as the association between total PA and body fat. Four to 5 days of activity monitoring has been proposed as a suitable duration for accurately and reliably estimating usual PA behavior in children (35).

The relation between vigorous PA, assessed by accelerometry, and body fat has been observed in several studies of normal-weight American and European children and adolescents (6, 7, 9, 18, 34). The association between PA and body fat seems to be intensity- but not age-dependent. Data from 5 days of accelerometry registration showed that normal-weight North American adolescents spend a mean of only 5 min/d in vigorous PA, and despite this modest time, a significantly positive association with body fat was observed (6). We found similar results in the present study. However, the time engaged in vigorous PA observed in our children was 26.3 ± 19.6 min/d, which is slightly higher than that observed in previous studies. Interventional studies have shown that programs of moderately intense exercise of 30–60 min/d in duration did not influence body fatness in normal-weight children and adolescents (36, 37). Taken together, these results may suggest that relatively large amounts of vigorous PA may be needed to affect adiposity in normal-weight children and adolescents. In fact, it has been suggested that, for nonobese adolescents, the interventions should be high in both intensity and volume (>80 min/d) (38).

The findings in obese children and adolescents are slightly different. In overweight children, beneficial effects in body fat control may be attained with 30–60 min of moderate PA, 3-7 d/wk (39–41). However, obese adolescents who spent the most weekly time engaged in vigorous PA tended to be those who increased the most in body fat (40, 41). For several reasons, it is reasonable to recommend moderate PA for obese children and adolescents until higher intensities can be attained. Moderate PA is better tolerated than vigorous PA (41), and tiring PA may lead to less PA on the following day (42), although it likely depends on the type of exercise performed (39). Therefore, for obese children and those who have been physically inactivity, an incremental approach to the 45–60-min/d goal of moderate PA 5 or more days per week is recommended (43). Increasing activity by ≈10% per week appears to be acceptable and achievable (43), because attempting to achieve too much too rapidly is often counterproductive and may lead to injury.

The cross-sectional nature of this study limits our ability to determine any causality in the results. One limitation of the study is that the accelerometer does not compensate for the relative increase in energy expenditure by increase in body size. To further increase our understanding of PA pattern among normal-weight and obese children, the amount of continuous bouts of PA at different intensity levels should be explored. Moreover, to be able to address the relative intensities of PA, another method has to be used, eg, heart rate monitoring, to collect data on the individual heart rate response as a percentage of maximum heart rate.

We also do not know whether an extrapolation of the association may be made for overweight and obese children. Nevertheless, with regular reports of increasing childhood obesity prevalence worldwide, the results of this study are noteworthy. Although we controlled for several potential confounders, such as age, sex, and study location, other variables such as food intake and genetic aspects may also have an influence. Interventional studies are needed to examine the effect of different PA intensities on CVF and fatness and to establish a threshold of amount and intensity of PA that has a better effect on CVF and body fatness in nonobese and obese children and adolescents. In conclusion, our cross-sectional results suggest that vigorous-intensity PA may have a greater impact in preventing obesity in children than lower PA intensity levels, whereas both total and at least moderate to vigorous PA may improve children’s CVF.

We thank Maarike Harro for the opportunity to use the Estonian data and Pekka Oja for highly valuable comments.

JRR and NSR conceived the hypothesis and conducted the statistical analyses for this manuscript. JRR drafted the manuscript. NSR, AH-W, FBO, JW, and MS contributed to the interpretation and discussion of the results. AH-W and MS contributed to the concept and design of the EYHS study. All the authors critically revised the drafted manuscript. None of the authors had any conflict of interest.

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