Associations between objectively assessed physical activity and indicators of body fatness in 9- to 10-y-old European children: a population-based study from 4 distinct regions in Europe (the European Youth Heart Study)1–3

Ulf Ekelund, Luis B Sardinha, Sigmund A Anderssen, Marike Harro, Paul W Franks, Søren Brage, Ashley R Cooper, Lars Bo Andersen, Chris Riddoch, and Karsten Froberg

ABSTRACT
Background: The rising prevalence of obesity in children may be due to a reduction in physical activity (PA).
Objective: Our aim was to study the associations of objectively measured PA volume and its subcomponents with indicators of body fatness.
Design: A cross-sectional study of 1292 children aged 9–10 y from 4 distinct regions in Europe (Odense, Denmark; the island of Madeira, Portugal; Oslo; and Tartu, Estonia) was conducted. PA was measured by accelerometer, and indicators of body fatness were the sum of 5 skinfold thicknesses and body mass index (BMI; in kg/m2). We examined the associations between PA and body fatness by using general linear models adjusted for potential confounding variables.
Results: After adjustment for sex, study location, sexual maturity, birth weight, and parental BMI, time (min/d) spent at moderate and vigorous PA (P = 0.032) and time (min/d) spent at vigorous PA were significantly (P = 0.015) and independently associated with body fatness. Sex, study location, sexual maturity, birth weight, and parental BMI explained 29% (adjusted R2 = 0.29) of the variation in body fatness. Time spent at vigorous PA explained an additional 0.5%. Children who accumulated <1 h of moderate PA/d were significantly fatter than were those who accumulated ≥2 h/d.
Conclusions: The accumulated amount of time spent at moderate and vigorous PA is related to body fatness in children, but this relation is weak; the explained variance was <1%. Am J Clin Nutr 2004;80:584–90.

KEY WORDS Accelerometry, adiposity, children, energy expenditure, physical activity, skinfold thickness, European Youth Heart Study

INTRODUCTION
Recent data from the United States, Australia, and many European countries consistently show that the prevalence of overweight and obesity in young people is increasing exponentially (1–4) and is now of pandemic proportions (5). Childhood obesity is multifactorial, involving genetic (6), social, cultural, and environmental components (5, 7). However, the rise in the prevalence of excess body fat is most likely due to environmental changes, such as easy access to large portion sizes of energy-dense foods and a reduced physical activity (PA) level (5, 7, 8).

Unfortunately, data derived from direct measurements of PA are unavailable to support the notion that sedentary behavior and the prevalence of obesity have increased simultaneously (9).
Identifying the components of PA (ie, sedentary behavior; time spent at light, moderate, and vigorous PA; and the total amount of PA) that are related to overweight and obesity in children may be essential for the primary and secondary prevention of all diseases that result from sedentary behavior, not the least of which is the prevention of obesity and its comorbidities. However, interventions designed to reduce sedentary behavior, to increase PA, or both may not be efficient if they focus on inappropriate subcomponents of PA predicted from observational studies. Unfortunately, measuring the subcomponents of PA in epidemiologic studies is difficult because of the complex and latent nature of the exposure (10).
As is true for other behaviors, the assessment of PA in children is more challenging than is that in adults. Although some previous population-based epidemiologic studies that assessed the

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Subjects and Methods

Subjects

The present cross-sectional study includes 1292 children aged 9–10 y (638 boys and 654 girls) from 4 geographically defined areas in Europe (the city of Odense, Denmark; the city of Oslo; the city and surrounding rural areas of Tartu, Estonia; and the island of Madeira, Portugal). Thus, the children represented diverse cultural, socioeconomic, and geographic environments. Selection criteria and sample size were reported elsewhere (15). Briefly, at each study location, a defined population of children was identified, and from this population a 2-stage cluster sample of children was randomly selected. The primary sampling unit was schools and the secondary unit was school registers. A minimum of 20 schools were randomly selected from local authority lists within appropriate age, sex, and socioeconomic strata by using probability proportional to school size. Thus, all randomly selected children (n = 2164) were invited to attend the study for the collection of data; written informed consent was obtained from a parent or guardian of 1623 (75%) of these children. Valid and complete data were unavailable in 331 (20%) participants; thus, the sample available for analysis consisted of 1292 children. There were no significant differences in height, weight, or skinfold thickness between the participants (n = 1292) and those persons who did not fulfill the inclusion criteria for PA (n = 331).

The study procedures were explained verbally to all children. The local research ethics committee of the 4 study regions approved the study protocol, which was uniform across study locations.

Anthropometric measures

Weight was measured to the nearest 0.1 kg with a calibrated beam balance scale while the children were wearing light clothing. Height was measured to the nearest 0.5 cm with a transportable Harpenden stadiometer while the children were shoeless. The beam balance was calibrated by using a weight of known mass, and the stadiometer was calibrated with a metal measuring tape. Body mass index (BMI) was calculated as weight (kg)/height squared(m). On the basis of BMI, the children were grouped in normal-weight (boys: <19.1–19.8; girls: <19.1–19.9), overweight (boys: ≥19.1–19.8 and <22.8–24.0; girls: ≥19.1–19.9 and <22.8–24.1), and obese (boys: ≥22.8–24.0; girls: ≥22.8–24.0) groups according to the age-adjusted cutoffs described by Cole et al (16). Five skinfold-thickness measurements (triceps, biceps, subscapula, suprailiac, and calf) were taken on the left side of the body according to the criteria described by Lohman et al (17). All measurements were taken twice and in rotation. If the difference between the 2 measurements differed by >2 mm, a third measurement was taken, and the 2 closest measurements were averaged. All data collectors were centrally trained, and inter- and intracollector reliabilities were assessed at each study location on a regular basis. The sum of 5 skinfold thicknesses was used as an indicator of body fat percentage. Sexual maturity was assessed by the data collectors, using Tanner’s (18) 5-stage scale for breast development in girls and pubic hair in boys. Few children (n = 9 girls) were classified as Tanner stage 3; therefore, we combined these children with those in Tanner stage 2. The children’s’ birth weights and their parents’ BMIs were obtained from the parents.

Assessment of physical activity

Free-living PA was assessed with the MTI (formerly known as the CSA activity monitor) model WAM 7164 (Manufacturing Technology Inc, Fort Walton Beach, FL) accelerometer over 2 weekdays and 2 weekend days, as previously described (15). Briefly, the children wore the accelerometer in an elastic waistband on the right hip during the daytime, except while bathing and during other aquatic activities. Children who did not manage to record ≥600 min/d of activity for ≥3 d were excluded from further analyses. Activity data were stored on a minute-by-minute basis and were downloaded to a computer before analysis. A Microsoft Excel-based macro was used for data reduction and further analyses. The outcome variables were daily activity counts (counts·min⁻¹·d⁻¹), which is an indicator of the total volume of PA, and time (min/d) spent at different PA-intensity categories. These were calculated to determine which subcomponents of PA, if any, are associated with overweight and obesity and to establish whether these subcomponents were related in a dose-response manner. Because published cutoffs for different intensity levels in children vary substantially between studies [eg, between 906 (19) and 3200 counts/min for moderate intensity (20)], 10 intensity categories were established in multiples of 500 counts/min from 0 to >4500 counts/min. Sedentary behavior was defined as ≤500 counts/min, light PA as 500–1999 counts/min, moderate and vigorous PA as ≥2000 counts/min, and vigorous PA as ≥3000 counts/min. The lower cutoff for moderate activity (ie, 2000 counts/min) is broadly equivalent to walking at 3 km/h (21).

PA-related energy expenditure (PAEE) was predicted on the basis of activity counts (counts/min) and sex by using an equation derived from the simultaneous measurements of PA by the accelerometer and from free-living total energy expenditure (TEE) measured by the doubly labeled water method (14). Resting energy expenditure (REE) was estimated from prediction equations (22), and TEE was calculated by summing PAEE and REE.

Statistical methods

The data are presented as means ± SDs unless otherwise stated. All variables were normally distributed except for the sum
TABLE 1

Physical characteristics, energy expenditure estimates, and fraction of the daytime spent at different subcomponents of physical activity (PA) for 1292 children from 4 distinct regions in Europe.

<table>
<thead>
<tr>
<th></th>
<th>All</th>
<th>Estonia</th>
<th>Denmark</th>
<th>Norway</th>
<th>Portugal</th>
<th>P (ANOVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boys (n = 638)</td>
<td>Girls (n = 545)</td>
<td>Boys (n = 171)</td>
<td>Girls (n = 165)</td>
<td>Boys (n = 164)</td>
<td>Girls (n = 154)</td>
</tr>
<tr>
<td>Age (y)</td>
<td>9.7 ± 0.4</td>
<td>9.6 ± 0.4</td>
<td>9.6 ± 0.4</td>
<td>9.4 ± 0.4</td>
<td>9.7 ± 0.4</td>
<td>9.6 ± 0.4</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.39 ± 0.07</td>
<td>1.37 ± 0.07</td>
<td>1.37 ± 0.07</td>
<td>1.37 ± 0.07</td>
<td>1.40 ± 0.06</td>
<td>1.38 ± 0.07</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>33.3 ± 6.3</td>
<td>32.6 ± 6.8</td>
<td>31.9 ± 5.5</td>
<td>30.8 ± 6.4</td>
<td>33.2 ± 5.4</td>
<td>32.8 ± 6.1</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>17.2 ± 2.4</td>
<td>17.2 ± 2.7</td>
<td>16.7 ± 1.9</td>
<td>16.4 ± 2.3</td>
<td>17.0 ± 2.0</td>
<td>17.1 ± 2.4</td>
</tr>
<tr>
<td>AEE (kcal/d)</td>
<td>213 ± 82</td>
<td>212 ± 83</td>
<td>189 ± 60</td>
<td>187 ± 62</td>
<td>226 ± 84</td>
<td>227 ± 82</td>
</tr>
<tr>
<td>TEE (kcal)</td>
<td>115 ± 44</td>
<td>114 ± 45</td>
<td>109 ± 43</td>
<td>109 ± 44</td>
<td>121 ± 46</td>
<td>121 ± 45</td>
</tr>
<tr>
<td>AE (kcal/kg/d)</td>
<td>188 ± 74</td>
<td>189 ± 75</td>
<td>176 ± 61</td>
<td>178 ± 63</td>
<td>203 ± 76</td>
<td>203 ± 75</td>
</tr>
<tr>
<td>Sedentary (%)</td>
<td>61.8 ± 7.9</td>
<td>60.7 ± 8.3</td>
<td>62.9 ± 8.8</td>
<td>63.0 ± 8.3</td>
<td>62.9 ± 8.3</td>
<td>63.3 ± 8.6</td>
</tr>
<tr>
<td>Active (%)</td>
<td>26.1 ± 5.3</td>
<td>26.0 ± 5.5</td>
<td>25.8 ± 5.4</td>
<td>26.1 ± 5.5</td>
<td>27.0 ± 5.4</td>
<td>27.5 ± 6.1</td>
</tr>
<tr>
<td>Vigorous (%)</td>
<td>10.2 ± 2.1</td>
<td>10.3 ± 2.2</td>
<td>12.2 ± 2.6</td>
<td>13.6 ± 2.8</td>
<td>12.5 ± 2.2</td>
<td>12.3 ± 2.5</td>
</tr>
<tr>
<td>Pearsons r</td>
<td>0.45 ± 0.03</td>
<td>0.43 ± 0.03</td>
<td>0.43 ± 0.03</td>
<td>0.43 ± 0.03</td>
<td>0.43 ± 0.03</td>
<td>0.43 ± 0.03</td>
</tr>
</tbody>
</table>

1 TEE, total energy expenditure; AEE, activity energy expenditure; sedentary, < 500 counts/min; light, 500–2000 counts/min; moderate and vigorous, > 2000 counts/min; vigorous, > 3000 counts/min.

Results

The physical characteristics, energy expenditure estimates, and PA patterns of the 1292 children are displayed in Table 1. Significant differences were observed between study locations for all of the anthropometric variables (P < 0.001). The distribution of overweight and obese children differed significantly between countries. Twenty-seven percent of Portuguese children, 13.4% of Norwegian children, 12.0% of Danish children, and 9.8% of Estonian children were classified as overweight or obese. In total, 191 (14.8%) children were classified as overweight or obese, of whom 39 (3%) were obese.

As displayed in Table 1, the results of the analysis of variance showed that TEE, PAEE, the total volume of PA, and the fraction of time spent at moderate and vigorous PA were significantly higher in boys than in girls (P < 0.001). Girls spent significantly more time in sedentary activities (P = 0.002). We also observed significant differences between study locations (P < 0.001), although the main impression was consistency across study locations. No significant effect of sexual maturity was observed for any of the PA components.

The normal-weight children, on the basis of BMI, were significantly (P = 0.022) more active (ie, greater fraction of time spent at moderate and vigorous PA) than were the obese children, after adjustment for sex, study location, and sexual maturity (Figure 1).

The total amount of PA (r = −0.12, P < 0.0001), the fraction of time spent at moderate and vigorous intensity PA (r = −0.15,
including birth weight and parental BMI in 1047 children aged 9–10 y.

TABLE 2
β Coefficients from the generalized linear models examining the association between body fatness (log_{10} skinfold thicknesses) and predictor variables in 1292 children aged 9–10 y.

<table>
<thead>
<tr>
<th>Factor</th>
<th>β</th>
<th>P</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>−0.22</td>
<td>&lt;0.0001</td>
<td>(−0.25, −0.18)</td>
</tr>
<tr>
<td>Maturity</td>
<td>0.17</td>
<td>0.0001</td>
<td>(0.14, 0.19)</td>
</tr>
<tr>
<td>Estonia</td>
<td>−0.14</td>
<td>&lt;0.0001</td>
<td>(−0.16, −0.10)</td>
</tr>
<tr>
<td>Denmark</td>
<td>−0.05</td>
<td>0.002</td>
<td>(−0.08, −0.02)</td>
</tr>
<tr>
<td>Norway</td>
<td>−0.02</td>
<td>0.12</td>
<td>(−0.06, 0.006)</td>
</tr>
<tr>
<td>Sex × maturity</td>
<td>−0.19</td>
<td>&lt;0.0001</td>
<td>(−0.23, −0.15)</td>
</tr>
<tr>
<td>Intercept</td>
<td>1.85</td>
<td>&lt;0.0001</td>
<td>(1.82, 1.88)</td>
</tr>
</tbody>
</table>

Model 1: total activity (counts ∙ min^{-1} ∙ d^{-1})

Model 2: sedentary (%)

Model 3: light (%)

Model 4: moderate and vigorous (%)

Model 5: vigorous (%)

<table>
<thead>
<tr>
<th>Factor</th>
<th>β</th>
<th>P</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country: Portugal</td>
<td>0.00032</td>
<td>0.0013</td>
<td>(0.0006, 0.0013)</td>
</tr>
<tr>
<td>Norway</td>
<td>0.00054</td>
<td>0.012</td>
<td>(0.0001, 0.002)</td>
</tr>
</tbody>
</table>
| Maturity: 0 = Tanner stage 1, 1 = Tanner stage 2. 

The results of the general linear models are presented in Table 2. The sum of 5 skinfold thicknesses (log_{10}) was significantly influenced by sex (P < 0.0001), study location (P < 0.0001), and sexual maturity (P < 0.0001). A significant interaction effect (sex × sexual maturity) was also observed. After adjustment for sex, study location, and sexual maturity, time spent at moderate and vigorous PA (P = 0.04) and time spent at vigorous PA (P = 0.02) were independent predictors of body fatness. Sex, study location, and sexual maturity explained 24% (adjusted R^2 = 0.24) of the variation in body fatness. PA (ie, time spent at vigorous PA) explained an additional 0.5% of the variance.

Further adjustment for birth weight, maternal and paternal BMI in a subsample of the children (n = 1047), time spent at moderate and vigorous PA (P = 0.032), and time spent at vigorous PA (P = 0.015) remained as independent predictors of body fatness (Table 3). In these models, sex, study location, sexual maturity, birth weight, and parental BMI explained 29% (adjusted R^2 = 0.29) of the variation in body fatness. As above, vigorous PA explained an additional 0.5% of the variance. Adjustment for age at examination did not affect our results.

The sum of 5 skinfold thicknesses was significantly correlated with BMI (r = 0.80, P < 0.0001). However, when BMI was substituted for the sum of skinfold thicknesses in the general linear models, sex, study location, and sexual maturity contributed significantly to the explained variation in BMI (adjusted R^2 = 0.17), whereas none of the PA components contributed to the explained variation in BMI.

TABLE 3
β Coefficients from the generalized linear models examining the association between body fatness (log_{10} skinfold thicknesses) and predictor variables, including birth weight and parental BMI in 1047 children aged 9–10 y.

<table>
<thead>
<tr>
<th>Factor</th>
<th>β</th>
<th>P</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>−0.17</td>
<td>&lt;0.0001</td>
<td>(−0.22, −0.12)</td>
</tr>
<tr>
<td>Maturity</td>
<td>0.16</td>
<td>&lt;0.0001</td>
<td>(0.13, 0.18)</td>
</tr>
<tr>
<td>Estonia</td>
<td>−0.14</td>
<td>&lt;0.0001</td>
<td>(−0.17, −0.10)</td>
</tr>
<tr>
<td>Denmark</td>
<td>−0.04</td>
<td>0.036</td>
<td>(−0.07, −0.02)</td>
</tr>
<tr>
<td>Norway</td>
<td>−0.01</td>
<td>0.47</td>
<td>(−0.05, 0.02)</td>
</tr>
<tr>
<td>Sex × maturity</td>
<td>−0.17</td>
<td>&lt;0.0001</td>
<td>(−0.22, −0.12)</td>
</tr>
<tr>
<td>Birth weight</td>
<td>0.000021</td>
<td>0.01</td>
<td>(0.0000047, 0.000037)</td>
</tr>
<tr>
<td>BMI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mother</td>
<td>0.0048</td>
<td>&lt;0.0001</td>
<td>(0.0025, 0.0072)</td>
</tr>
<tr>
<td>Father</td>
<td>0.0060</td>
<td>&lt;0.0001</td>
<td>(0.0032, 0.0088)</td>
</tr>
<tr>
<td>Intercept</td>
<td>1.21</td>
<td>&lt;0.0001</td>
<td>(1.10, 1.32)</td>
</tr>
<tr>
<td>Model 1: moderate and vigorous activity (%)</td>
<td>−0.0019</td>
<td>0.032</td>
<td>(−0.0036, −0.0013)</td>
</tr>
<tr>
<td>Model 2: vigorous activity (%)</td>
<td>−0.0034</td>
<td>0.015</td>
<td>(−0.006, −0.0006)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Factor</th>
<th>β</th>
<th>P</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country: Portugal</td>
<td>0.00032</td>
<td>0.0013</td>
<td>(0.0006, 0.0013)</td>
</tr>
<tr>
<td>Norway</td>
<td>0.00054</td>
<td>0.012</td>
<td>(0.0001, 0.002)</td>
</tr>
</tbody>
</table>

Subcomponents of physical activity were entered separately into the models.

Sex: 0 = boys, 1 = girls.

Maturity: 0 = Tanner stage 1, 1 = Tanner stage 2.

Country: Portugal (reference) = 0.
It is generally believed that the current obesity epidemic is mainly due to environmental changes, affecting the energy balance equation (23). However, the relative and absolute contributions of sedentary behavior and excess food intake on obesity are unknown. Results from studies that examined the relation between energy expenditure and body fatness in children, in which energy expenditure was measured by using the doubly labeled water method, are equivocal (24–29). This has led some to suggest that time devoted to PA is a more important factor than is energy expenditure in energy regulation (30). Our data indicated that <1% of the variation in body fatness was explained by time devoted to level of activity.

Prospective studies using the doubly labeled water method have indicated that PAEE does not predict future weight gain in children (26). This finding may suggest that food intake, especially the consumption of energy-dense food, plays a more important role in the development of overweight and obesity in children than does the amount of PA (31). Data suggest that the consumption of sugar-sweetened soft drinks among children has more than doubled during recent decades (32). This is important because excessive sweetened drink consumption is associated with greater weight gain (33), and the odds of becoming obese may increase by as much as 60% with each additional serving of sugar-sweetened drinks that a child consumes (34). One serving (250 mL) of a soft drink is broadly equal to 130 kcal. A child can consume this amount of energy within minutes, whereas >30 min of moderate PA (equal to brisk walking) is required to maintain energy balance. However, aside from the data published by Ludwig et al (34), there is little additional evidence that food intake predicts obesity in childhood (35, 36), although a mechanism for the relation between soft drink consumption and body fat has been suggested (37).

There are several limitations that should be considered when interpreting the findings from the present study. First, it is not possible to infer a causal relation from cross-sectional data such as that in the present study. Although we controlled for several potential confounders such as sex, study location, sexual maturity, birth weight, and parental BMI, we cannot be certain that other unmeasured confounders, such as dietary composition and volume, genetic variation, and sociocultural factors, do not explain our observations.

We reduced the potential for recall bias, which is an unavoidable component of self-report assessment of PA in children and adults, by directly assessing PA with accelerometers. Despite the advantages associated with the use of direct assessment when exploring associations between the components of PA and body fatness in children, these methods also have limitations, which should be considered when interpreting our findings. First, accelerometers do not accurately reflect the energy expenditure associated with bicycling, upper body movement, walking uphill, and stair climbing and cannot be used to any practical extent during aquatic activities. Furthermore, the cutoffs used to define intensity categories are arbitrary because they depend on the type of activities performed when establishing the relation between activity counts and energy expenditure (38). Nonetheless, accelerometry accurately reflects energy expenditure during walking and jogging, within the approximate range of 3 to 9 km/h. We reduced our data into multiples of 500 counts/min and defined moderate PA as >2000 counts/min, because this value is broadly equivalent to walking at 3–4 km/h in 9–10-y-old children (21, 23, 29, 30).
Furthermore, this value approximates the mean for previously published cutoffs for moderate-intensity activity in children (19, 20). Ideally, one should individually calibrate the relation between movement counts and energy expenditure during locomotion in each child (40). However, this is often unfeasible in large epidemiologic studies such as ours. Furthermore, 4–5 d of activity monitoring have been proposed as a suitable duration for accurately and reliably assessing the usual activity behavior in children (41), whereas only 3 d of data were available in some of our participants. It is possible that this slightly shorter monitoring period may be less reflective of the usual PA pattern in children, which may mask the true association between PA and body fatness.

The relations that we observed between PA and body fatness were small. Nonetheless, these findings may have important public health implications because sedentary behavior is common in most industrialized societies. The recent consensus statement put forward by the International Association for the Study of Obesity relating to PA level in adults suggests that ≈45–60 min of moderate PA or more is required to prevent unhealthy weight gain. The prevention of weight regain may require an even greater volume of PA (42). Moreover, according to the same statement, the volume of PA required for successful primary and secondary prevention of obesity in children may well exceed that required in adults, although no specific recommendation was put forward. Given the uncertainty in defining cutoffs for different intensity levels by means of accelerometry, our data suggest that children who are physically active for >2 h/d at an intensity level broadly equivalent to that associated with walking were significantly leaner than those who accumulated <1 h PA/d at the same intensity level. This may imply that ≥60 min of moderate PA each day, similar to the current recommendation for health-related PA in young people (43), is the minimal amount of PA that needs to be undertaken if the aim is to curb the increasing prevalence of obesity in children. However, the data in the present study are sufficient only for the generation of such hypotheses, because to address these questions properly requires data from longitudinal prospective studies.

The environmental factors that promote overweight and obesity are multi-level and multifactorial (44). Thus, effective preventive strategies need to address the underlying social, cultural, physical, and economical determinants of childhood obesity and are likely to include interventions designed to decrease sedentary behavior in children. Nonetheless, it is probably wise to consider strategies that promote integrated approaches to the prevention of obesity, because obesity etiology is evidentially complex and multifactorial. Furthermore, the beneficial effects on obesity of combining preventive strategies may at least be additive and quite possibly synergistic.

We are very grateful to the participants and their families who gave their time to this study and to the members of the European Youth Heart Study Group. UE drafted the manuscript and conducted the data analysis. UE, LBS, SAA, MH, ARC, CR, LBA, and KF contributed to the concept and design of the EYHS study. UE, CR, AC, SB, and LBA are members of the physical activity group within EYHS. LBS, SAA, MH, and KF obtained funding and organized the data collection within each study location. CR and LBA were responsible for cleaning and analyzing the physical activity data. UE, SB, and PWF contributed to the interpretation and discussion of the results. All authors critically revised the drafted manuscript.

None of the authors had any financial interest in this study.

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