Recommended Levels and Intensities of Physical Activity to Avoid Low-Cardiorespiratory Fitness in European Adolescents: The HELENA Study

DAVID MARTINEZ-GOMEZ,1,2 JONATAN R. RUIZ,3 FRANCISCO B. ORTEGA,1,3 JOSE A. CASAIDIUS,4 OSCAR L. VEIGA,3 KURT WIDHAML,4 YANNIS MANIOS,5 LAURENT BEGHN,6 MARCELA GONZALEZ-GROSS,7 ANTHONY KAFATOS,10 VANESA ESPANA ROMERO,10 DENES MOLNAR,11 LUIS A. MORENO,1 ASCENSION MARCOS,2 MANUEL J. CASTILLO,7 and MICHAEL SJOSTROM11 ON BEHALF OF THE HELENA STUDY GROUP

1Unit for Preventive Nutrition, Department of Biosciences and Nutrition at NOVUM, Karolinska Institutet, Huddinge, Sweden
2Inmunonutrition Research Group, Department of Metabolism and Nutrition, Instituto del Frio (IF), Instituto of Food Science, Technology and Nutrition (IFCT), Madrid, Spain
3Department of Medical Physiology, Faculty of Medicine, Granada, Spain
4GENUD “Growth, Exercise, Nutrition and Development” research group, University School of Health Sciences, University of Zaragoza, Zaragoza, Spain
5Department of Physical Education, Sport and Human Movement, Facultad de Formacion del Profesorado y Educacion, Universidad Autonoma de Madrid, Madrid, Spain
6Division of Nutrition and Metabolism, Department of Pediatrics, Medical University of Vienna, Vienna, Austria
7Institut fu¨r Erna¨hrungs- und Lebensmittelwissenschaften—Erna¨hrung und Medizinische Wissenschaften, Department of Nutrition, University of Pecs, Pe´cs-Jo´zsef, Hungary
8Division of Nutrition, Department of Pediatrics, Medical University of Vienna, Vienna, Austria
9Istituto Nazionalen di Ricerca per gli Alimenti e la Nutrizione (Italy)
10Department of Physical Education, Sport and Human Movement, Facultad de Formacion del Profesorado y Educacion, Universidad Autonoma de Madrid, Madrid, Spain
11Department of Medical Physiology, Faculty of Medicine, Granada, Spain
12Medical University of Vienna (Austria)
13Harokopio University (Greece)

14. Institut Pasteur de Lille, Lille, France
15. Karolinska Institutet (Sweden)
16. Asociación de Investigación de la Industria Agroalimentaria (Spain)
17. Campden BRI (United Kingdom)
18. Meurice Recherche and Development asbl (Belgium)
19. Meurice Recherche and Development asbl (Belgium)
20. Campden and Chorleywood Food Development Institute (Hungary)
21. Productos Aditivos SA (Spain)
22. CIC-9301-Inserm-CHRU of Lille, U995 and Faculty of Medicine, IMPRET, University Lille 2, Lille, France
23. Cederroth International AB (Sweden)
24. Lantma¨nnen Food R&D (Sweden)
25. European Food Information Council (Belgium)
26. Universidad Polite´cnica de Madrid (Spain)

© 2010 Wiley-Liss, Inc.

Objectives: The purpose of this study was to determine the sex-specific physical activity (PA) intensity thresholds that best discriminate between unhealthy/healthy cardiorespiratory fitness (CRF).

Methods: Participants included 1,808 adolescents (964 girls), aged 12.5–17.5 years, from the HELENA study. We measured PA by accelerometer and calculated the time spent at light, moderate, vigorous, and moderate-to-vigorous (MVPA) intensities. CRF was assessed by the 20-m shuttle-run test. Adolescents were dichotomized (unhealthy/healthy) based on sex- and age-specific FITNESSGRAM standards. Receiver operating characteristic (ROC) analysis was used to determine thresholds that best discriminate between CRF categories.

Results: ROC analyses revealed that the PA thresholds that best discriminate between unhealthy/healthy CRF were ≥152, ≥33, ≥13, and ≥52 min/day in light, moderate, vigorous, and MVPA, respectively. In boys, the PA thresholds associated with a healthy CRF were ≥37, ≥19, and ≥66 min/day in moderate, vigorous, and MVPA, respectively, whereas in girls were ≥152, ≥34, ≥12, and ≥51 min/day in light, moderate, vigorous, and MVPA, respectively. Spending at least 60 min/day in MVPA was also associated with a healthy CRF (odds ratios: 1.75, 1.94, and 1.57, all P < 0.05, for the whole sample, boys, and girls, respectively).

PA measurements

Patterns of PA were objectively assessed using the Actigraph GT1M (Actigraph Inc., Pensacola, FL). This accelerometer is a compact, small (3.8 × 3.7 × 1.8 cm), lightweight (27 g), and uniaxial monitor designed to detect vertical accelerations ranging in magnitude from 0.05 to 2.00 G’s with a frequency response of 0.25–2.5 Hz. The Actigraph has been previously validated in laboratory and free-living conditions in young people (Freedson et al., 2005).

Adolescents were instructed to wear the accelerometer for 7 consecutive days positioned at the lower back by using an elastic waistband. The accelerometer was worn during all time awake and only removed during water-based activities. In the HELENA-CSS, the interval of time (epoch) was set at 15 s according to consensus recommendations for assessing PA in youth (Ward et al., 2005). The data were downloaded onto a computer using the software provided by the manufacturer and were later analyzed by a software based on Visual Basic.

The choice of the inclusion criteria was based on thorough analyses of accelerometer data performed immediately after data collection. These analyses aimed to identify an optimal balance between the selection of appropriate criteria that lead to reliable PA data and avoid large reductions in the statistical power. Three criteria were examined: (i) number of valid days; (ii) length of a valid day, and (iii) definition of the nonwear time (i.e., 10, 20, 30, and 60 min of 0 values). The results suggested that a fair trade-off between the number of days needed to identify the usual PA level (reliability of at least 0.80), and statistical power can be achieved when using the following inclusion criteria: (i) minimum of 3 days measured, (ii) at least 8 h/day of valid records, and (iii) 20 min of consecutive epochs with 0 counts were deleted (unpublished observations).

The time spent in light PA (1.5–3 metabolic equivalents, METs), moderate PA (3–6 METs), and vigorous PA (>6 METs) were calculated based upon cut-offs of 100, 2,000, and 4,000 counts per minute, respectively (Ekelund et al., 2007; Nilsson et al., 2009). Furthermore, the time spent in MVPA was calculated as the sum of moderate and vigorous periods. These cut-offs points to define the intensity categories are similar to those used in previous studies in youth (Ekelund et al., 2007; Nilsson et al., 2009).

CRF measurements

Levels of CRF were assessed by using the standardized 20-m shuttle-run test (Leger et al., 1988). Procedures, reliability, and normative levels of this test in the adolescents participating in the HELENA-CSS can be found elsewhere (Ortega et al., 2008a, in press). In brief, participants were required to run between two lines 20-m distant while keeping pace with audio signals emitted from a prerecorded CD. The initial speed is 8.5 km/h, which is increased by 0.5 km/h per minute or stage. The test was finished when the participant failed to reach the end lines concurrent with the audio signals on two consecutive occasions or stopped because of fatigue. The maximal oxygen consumption (VO2max, ml/kg/min) was estimated by the Leger et al. (1988) equation. Adolescents were dichotomized based on meeting (healthy) or failing (unhealthy) the sex- and age-specific VO2max FITNESSGRAM standards (The Cooper Institute, 2004).

Mean (SD) differences in descriptive statistics between boys and girls, and CRF status categories (unhealthy/healthy) were examined by two-way analysis of variance (ANOVA) for continuous variables and the χ² test for nominal variables.

Receiver operating characteristic (ROC) curve analysis (Zweig and Campbell, 1993) was used to calculate the optimal PA cut-off points for light PA, moderate PA, vigorous PA, and MVPA that best discriminate between unhealthy and healthy CRF. The area under the ROC curve (AUC) represents the ability of the test to correctly classify adolescents with unhealthy and healthy CRF. Values of AUC range from 0.5 (noninformative test) to 1.0 (ideal test). Sensitivity was considered as the probability to correctly identify an adolescent with healthy CRF (true-positive rate). Specificity was considered as the probability to correctly identify an adolescent with unhealthy CRF. The ROC curve provides the whole spectrum of specificity/sensitivity values for all the possible cut-off points. The optimal combination of true-positive rate and false-positive rate is the point closest to the perfect test.

Differences in stages and VO2max, between adolescents who meet or not the cut-off points obtained in the ROC curves, were analyzed by analysis of covariance (ANCOVA) adjusting for age, center, and BMI. We also performed binary logistic regression analysis to examine the relationship between meeting the PA cut-offs and having a healthy CRF adjusting for age, center, and BMI.

Additionally, ANCOVA was performed to examine whether meeting the current PA guidelines, that is, spending at least 60 min/day at MVPA, are associated with high-CRF. Moreover, we performed logistic regression analysis to study whether meeting the PA guidelines was associated with healthy CRF.

ANOVA, ANCOVA, and logistic regression analyses were conducted using SPSS version 15.0 for Windows (SPSS, Chicago, IL), and ROC analyses were performed with the MedCalc statistical software (version 10.4.5, MedCalc Software, Mariakerke, Belgium). The level of significance was set at P < 0.05 for all the analyses.

RESULTS

Descriptive characteristics in the whole adolescent sample are shown in Table 1. ROC analysis showed a significant discriminatory accuracy of PA at all intensities for identifying unhealthy versus healthy CRF in adolescents (Table 2). The PA thresholds associated with a healthy CRF were 152, 33, 13, and 52 min/day in light, moderate, vigorous, and MVPA, respectively. In boys, the light PA cut-off did not significantly discriminate between CRF levels, whereas, in girls, a cut-off of at least 152 min/day of light PA significantly discriminated between unhealthy and healthy CRF. The AUC for vigorous PA showed higher values than the other PA intensities in all the analyses (Table 2).

Adolescents who met the calculated cut-offs of light, moderate, vigorous, and MVPA had significantly higher levels of CRF than those not meeting the PA cut-offs (all P < 0.05) after adjustments for age, sex, center, and BMI (Table 3). Odds ratios (ORs) and 95% CIs adjusted for the same potential confounders showed that adolescents who...
TABLE 1. Descriptive characteristics of the study sample

<table>
<thead>
<tr>
<th></th>
<th>All (n = 1808)</th>
<th>Boys (n = 844)</th>
<th>Girls (n = 964)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unhealthy CRF</td>
<td>Healthy CRF</td>
<td>Unhealthy CRF</td>
</tr>
<tr>
<td>Prevalence (%)</td>
<td>37.4</td>
<td>62.6</td>
<td>31.6</td>
</tr>
<tr>
<td>Age (year)</td>
<td>14.7 (1.2)</td>
<td>14.6 (1.2)</td>
<td>14.8 (1.3)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>164.5 (9.3)</td>
<td>166.2 (9.2)</td>
<td>169.4 (9.9)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>61.2 (14.1)</td>
<td>56.0 (10.3)</td>
<td>60.0 (15.8)</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>22.5 (4.3)</td>
<td>20.2 (2.6)</td>
<td>22.9 (4.6)</td>
</tr>
<tr>
<td>VO₂max (ml/kg/min)</td>
<td>34.9 (3.7)</td>
<td>45.7 (6.2)</td>
<td>37.4 (3.4)</td>
</tr>
<tr>
<td>20mSRT (stage)</td>
<td>2.8 (1.3)</td>
<td>6.7 (2.3)</td>
<td>3.8 (1.4)</td>
</tr>
</tbody>
</table>
| Weight (kg)    | 56, and 51 min/day for the whole sample, boys and girls, respectively. Likewise, the current PA recommendations (to be engaged in at least 60 min/day of MVPA) for adolescents were also significantly associated with high-CRF in European adolescents. These findings support the use of the current PA recommendations for preventive purposes related to a healthier CRF in adolescents.

The ROC analysis showed that spending more than 50 min/day at MVPA intensity was associated with high levels of CRF. Adolescents who met these thresholds had higher VO₂max and increased approximately twofold the likelihood for having a healthy CRF. The current PA guidelines suggest that adolescents should be active daily for at least 60 min in moderate and vigorous intensity (Strong et al., 2005). Several studies using accelerometers showed that moderate PA and vigorous PA are associated with high-CRF in children and adolescents, but no adjustments were performed for body fat measures (Gutin et al., 2005; Ruiz et al., 2006). Similarly to this study, Ortega et al. (2008c) showed that those adolescents meeting the PA guidelines were more likely to have a healthier CRF level independently of their adiposity status. Although the current PA guidelines suggest 60 min per day in MVPA, our findings showed that slightly lower doses of MVPA are also associated with a healthy CRF. Nevertheless, higher doses of MVPA may be necessary to prevent other health factors (Hallal et al., 2006). For example, Andersen et al. (2006) suggested that at least 90 min per day in MVPA was necessary to prevent cardiovascular and metabolic risk factors, mainly insulin resistance, in children and adolescents.

It must be noted that moderate PA showed weaker association with CRF than vigorous PA, which concur with previous studies (Gutin et al., 2005; Ruiz et al., 2006). Daily participation in more than 33 min in moderate PA was independently and positively associated with having a healthy CRF. The current PA guidelines (to be engaged in at least 60 min/day of MVPA) for adolescents were also significantly associated with high-CRF in European adolescents. These findings support the use of the current PA recommendations for preventive purposes related to a healthier CRF in adolescents.

The ROC analysis showed that spending more than 50 min/day at MVPA intensity was associated with high levels of CRF. Adolescents who met these thresholds had higher VO₂max and increased approximately twofold the likelihood for having a healthy CRF. The current PA guidelines suggest that adolescents should be active daily for at least 60 min in moderate and vigorous intensity (Strong et al., 2005). Several studies using accelerometers showed that moderate PA and vigorous PA are associated with high-CRF in children and adolescents, but no adjustments were performed for body fat measures (Gutin et al., 2005; Ruiz et al., 2006). Similarly to this study, Ortega et al. (2008c) showed that those adolescents meeting the PA guidelines were more likely to have a healthier CRF level independently of their adiposity status. Although the current PA guidelines suggest 60 min per day in MVPA, our findings showed that slightly lower doses of MVPA are also associated with a healthy CRF. Nevertheless, higher doses of MVPA may be necessary to prevent other health factors (Hallal et al., 2006). For example, Andersen et al. (2006) suggested that at least 90 min per day in MVPA was necessary to prevent cardiovascular and metabolic risk factors, mainly insulin resistance, in children and adolescents.

It must be noted that moderate PA showed weaker association with CRF than vigorous PA, which concur with previous studies (Gutin et al., 2005; Ruiz et al., 2006). Daily participation in more than 33 min in moderate PA was independently and positively associated with having a healthy CRF. The current PA guidelines (to be engaged in at least 60 min/day of MVPA) for adolescents were also significantly associated with high-CRF in European adolescents. These findings support the use of the current PA recommendations for preventive purposes related to a healthier CRF in adolescents.

The ROC analysis showed that spending more than 50 min/day at MVPA intensity was associated with high levels of CRF. Adolescents who met these thresholds had higher VO₂max and increased approximately twofold the likelihood for having a healthy CRF. The current PA guidelines suggest that adolescents should be active daily for at least 60 min in moderate and vigorous intensity (Strong et al., 2005). Several studies using accelerometers showed that moderate PA and vigorous PA are associated with high-CRF in children and adolescents, but no adjustments were performed for body fat measures (Gutin et al., 2005; Ruiz et al., 2006). Similarly to this study, Ortega et al. (2008c) showed that those adolescents meeting the PA guidelines were more likely to have a healthier CRF level independently of their adiposity status. Although the current PA guidelines suggest 60 min per day in MVPA, our findings showed that slightly lower doses of MVPA are also associated with a healthy CRF. Nevertheless, higher doses of MVPA may be necessary to prevent other health factors (Hallal et al., 2006). For example, Andersen et al. (2006) suggested that at least 90 min per day in MVPA was necessary to prevent cardiovascular and metabolic risk factors, mainly insulin resistance, in children and adolescents.
Intervention studies in youth showed significant improvements in CRF levels only when vigorous intensities were achieved (Baquet et al., 2003; Ortega et al., 2008b; Strong et al., 2005).

There is agreement among studies regarding the key role of vigorous PA on several health outcomes in children and adolescents. Vigorous PA measured by accelerometer is associated with body fat (Gutin et al., 2005; Ortega et al., 2007; Ruiz et al., 2006), cardiovascular disease risk factors (Ekelund et al., 2007; Rizzo et al., 2008), and other health-related physical fitness components in youth (Martínez-Gómez et al., 2009; Ortega et al., 2008b). In this study, around 15 min per day in vigorous PA was associated with higher CRF. Recent reviews stated that only interventions based on continuous vigorous PA for more than 30 min at least 3 days per week had success to improve CRF in young people (Ortega et al., 2008b).

The recently launched PA recommendations for youth from the U.S. Department of Health and Human Services

---

### TABLE 3. Associations of physical activity (PA) levels and intensities with cardiorespiratory fitness in adolescents

<table>
<thead>
<tr>
<th>Cut-off (min/day)</th>
<th>n</th>
<th>20mSRT, stage mean (SD)</th>
<th>P</th>
<th>VO_{max}, ml/kg/min mean (SD)</th>
<th>P</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light PA</td>
<td>&lt;152</td>
<td>668</td>
<td>5.1 (2.7)</td>
<td>0.123</td>
<td>40.7 (7.5)</td>
<td>0.107</td>
</tr>
<tr>
<td></td>
<td>≥152</td>
<td>1140</td>
<td>5.3 (2.7)</td>
<td>0.001</td>
<td>42.2 (7.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Moderate PA</td>
<td>&lt;33</td>
<td>653</td>
<td>4.6 (2.5)</td>
<td>0.001</td>
<td>39.8 (6.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>≥33</td>
<td>1155</td>
<td>5.6 (2.8)</td>
<td>&lt;0.001</td>
<td>42.7 (7.7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Vigorous PA</td>
<td>&lt;13</td>
<td>708</td>
<td>4.0 (2.1)</td>
<td>&lt;0.001</td>
<td>38.5 (6.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>≥13</td>
<td>1100</td>
<td>6.0 (2.7)</td>
<td>&lt;0.001</td>
<td>43.7 (7.7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MVPA</td>
<td>&lt;52</td>
<td>807</td>
<td>4.3 (2.3)</td>
<td>&lt;0.001</td>
<td>39.2 (6.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>≥52</td>
<td>1001</td>
<td>6.0 (2.8)</td>
<td>&lt;0.001</td>
<td>43.6 (7.8)</td>
<td>1.96</td>
</tr>
<tr>
<td><strong>Boys</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light PA</td>
<td>&lt;173</td>
<td>448</td>
<td>7.1 (2.5)</td>
<td>0.310</td>
<td>46.1 (7.0)</td>
<td>0.762</td>
</tr>
<tr>
<td></td>
<td>≥173</td>
<td>396</td>
<td>6.5 (2.8)</td>
<td>0.003</td>
<td>45.5 (7.4)</td>
<td>0.96</td>
</tr>
<tr>
<td>Moderate PA</td>
<td>&lt;37</td>
<td>344</td>
<td>6.5 (2.6)</td>
<td>0.001</td>
<td>44.6 (6.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>≥37</td>
<td>500</td>
<td>7.0 (2.7)</td>
<td>&lt;0.001</td>
<td>46.7 (7.3)</td>
<td>1.81</td>
</tr>
<tr>
<td>Vigorous PA</td>
<td>&lt;19</td>
<td>329</td>
<td>5.9 (2.5)</td>
<td>&lt;0.001</td>
<td>43.5 (6.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>≥19</td>
<td>515</td>
<td>7.4 (2.6)</td>
<td>&lt;0.001</td>
<td>47.3 (7.2)</td>
<td>2.27</td>
</tr>
<tr>
<td>MVPA</td>
<td>&lt;56</td>
<td>308</td>
<td>6.1 (2.6)</td>
<td>&lt;0.001</td>
<td>43.9 (6.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>≥56</td>
<td>536</td>
<td>7.2 (2.6)</td>
<td>&lt;0.001</td>
<td>47.0 (7.2)</td>
<td>2.13</td>
</tr>
<tr>
<td><strong>Girls</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light PA</td>
<td>&lt;152</td>
<td>388</td>
<td>3.8 (1.9)</td>
<td>0.008</td>
<td>37.1 (5.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>≥152</td>
<td>576</td>
<td>4.0 (2.0)</td>
<td>&lt;0.001</td>
<td>38.6 (5.7)</td>
<td>1.86</td>
</tr>
<tr>
<td>Moderate PA</td>
<td>&lt;34</td>
<td>433</td>
<td>3.6 (1.7)</td>
<td>&lt;0.001</td>
<td>37.1 (5.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>≥34</td>
<td>531</td>
<td>4.2 (2.1)</td>
<td>&lt;0.001</td>
<td>38.8 (6.0)</td>
<td>1.68</td>
</tr>
<tr>
<td>Vigorous PA</td>
<td>&lt;12</td>
<td>491</td>
<td>3.3 (1.6)</td>
<td>&lt;0.001</td>
<td>36.8 (4.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>≥12</td>
<td>473</td>
<td>4.5 (2.1)</td>
<td>&lt;0.001</td>
<td>39.3 (6.1)</td>
<td>2.32</td>
</tr>
<tr>
<td>MVPA</td>
<td>&lt;51</td>
<td>527</td>
<td>3.5 (1.7)</td>
<td>&lt;0.001</td>
<td>37.0 (5.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>≥51</td>
<td>473</td>
<td>4.4 (3.9)</td>
<td>&lt;0.001</td>
<td>39.2 (6.2)</td>
<td>1.90</td>
</tr>
</tbody>
</table>

CI, confidence interval; MVPA, moderate to vigorous PA; OR, odds ratio; SD, standard deviation; 20mSRT, 20 meter shuttle run test; VO_{max}, maximal oxygen consumption, estimated using the equation suggested by Leger et al. (1988). Data were adjusted for center, age, and body mass index. *Additionally adjusted for sex.

---

Fig. 1. Differences in cardiorespiratory fitness between physical activity levels according to current physical activity (PA) recommendations for youth. Footnotes: MVPA: moderate to vigorous PA. Data were adjusted for center, age, and body mass index. *Additionally adjusted for sex. *P ≤ 0.001 between PA groups.
suggest that children and adolescents should participate daily 60 min in MVPA, but it also states “and should include vigorous-intensity PA at least 3 days a week” (U.S. Department of Health and Human Services, 2008). Unfortunately, none specific dose of vigorous PA was added. A recommendation from Health Canada suggested a goal of 30 min per day in vigorous PA, even though the amount of daily-recommended PA reached 90 min per day in MVPA for young people (Public Health Canada, 2002). These recommendations showed to be unachievable goals for most adolescents, and, nowadays, they are promoting the every day 60 min in MVPA recommendation (Janssen, 2007).

An interesting finding from our study was the positive and significant association between light PA and CRF in girls. These results suggest a sex effect of light PA on CRF. On average, adolescent girls have lower CRF levels than boys. Moreover, CRF declines during adolescence, and this decline seems to be more attenuated in girls (Pfeiffer et al., 2007). Taken together, these findings may indicate that increasing light PA levels during adolescence in girls may be a suitable target for improving CRF, regardless of more efforts to increase MVPA. Nonetheless, the capacity to correctly identify an adolescent girl with a healthy CRF based on her light PA level was the lowest (AUC = 0.55), and, therefore, these results must be interpreted with caution.

Ekelund et al. (2007) also found positive and significant associations between objectively measured light PA and CRF in a large sample of 9- and 15-year adolescents. Conversely, other studies failed to detect significant associations between both variables (Kriemler et al., 2008). Recently, new postulates have highlighted the key role of light PA (also known as nonexercise activity thermogenesis) in obesity, cardiovascular disease, and metabolic abnormalities (Hamilton et al., 2007). With the help of new technology developments, several studies are emerging and show the importance of increase light PA and reduce sedentary behaviors—sitting time—on different health outcomes in children, adolescents, and adults.

This study shows notable strengths, such as the use of accelerometers to assess adolescents’ PA, the standardized, reliable, and valid test for assessing CRF (Castro-Piñero et al., in press; Ortega et al., 2008a; Ruiz et al., 2009), as well as a relatively large sample of adolescents from nine European countries. The study has however several limitations. First, a causal inference cannot be drawn due to the study design (i.e., cross-sectional). Second, CRF was estimated using a field-based test. Third, PA intensity thresholds obtained by the ROC curves provide maximal accuracy, but there is always a degree of error that should be assumed. Finally, assessments of PA by accelerometer have inherent limitations (e.g., water-based activities are not captured, and inability to detect horizontal movements as biking), which make comparisons between studies difficult due to the dissimilarities in the inclusion criteria, cut-offs to define PA intensities, epochs, and accelerometer models (Freedson et al., 2005; Martínez-Gómez et al., in press).

In conclusion, we have shown sex- and intensity-specific PA thresholds to discriminate between adolescents with a healthy CRF from those with a less favorable or unhealthy CRF level. To note is that the MVPA thresholds are rather similar to the current PA recommendations (i.e., 60 min/day). Identification of children who fail to meet these PA recommendations can help to detect the target population for pediatric prevention strategies.

ACKNOWLEDGMENT

We gratefully acknowledge all participating adolescents for their collaboration. We also acknowledge the support from the Swedish Heart and Lung-foundation, and from the European Commission, DG RESEARCH. The content of this article reflects only the authors’ views, and the European Community is not liable for any use that may be made of the information contained therein.

LITERATURE CITED


American Journal of Human Biology


Ortega FB, Ruiz JR, Hurtig-Wennlof A, Sjöström M. 2008c. Physically active adolescents are more likely to have a healthier cardiovascular fitness level independently of their adiposity status. The European youth heart study. Rev Esp Cardiol 61:123–129.


