Re-evaluation of Accelerometer Thresholds for MVPA at Age 16 in Subjects Previously Studied at Age 12

Alex Griffiths, Calum Mattocks, Andy Robert Ness, Kate Tilling, Chris Riddoch, and Sam Leary

Background: A study deriving a threshold for moderate- to vigorous-intensity physical activity (MVPA) in terms of accelerometer counts in 12-year-old children was repeated with a subset of the same children at 16 years. Methods: Fifteen girls and thirty boys took part in 6 activities (lying, sitting, slow walking, walking, hopscotch and jogging) while wearing an Actigraph 7164 accelerometer and a Cosmed K4b2 portable metabolic unit. Random intercepts modeling was used to estimate cut points for MVPA (defined as 4 METs). Results: Using a single model, the sex-specific thresholds derived for MVPA at 16 years were some way below the 3600 counts/minute used for both sexes at age 12, particularly for girls. However graphical examination suggested that a single model might be inadequate to describe both higher- and lower-intensity activities. Models using only lower-intensity activities close to the 4 METs threshold supported retention of the 3600 counts/minute cut point for both sexes. Conclusions: When restricting to lower-intensity activities only, these data do not provide sufficient evidence to change the previously established cut point of 3600 counts/minute to represent MVPA. However, further data and more sophisticated modeling techniques are required to confirm this decision.

Keywords: adolescent, gender, measurement, physical activity assessment

Accelerometry is widely considered to be an objective and reliable method of measuring physical activity intensity in children.1 There is evidence to suggest that moderate- to vigorous-intensity physical activity (MVPA), rather than total activity or average activity intensity, is particularly important for obesity prevention/reduction,2 so there is a need to define a threshold for MVPA in terms of accelerometer counts. Previous studies have derived several different cut points3–5 for children of various ages, using measurements made during a range of activities. However, as yet no study has incorporated repeated measures on the same children at different ages. The aim of this study was to determine whether the threshold for MVPA had changed substantially between the ages of 12 years, when our first study took place, and 16 years, when the study was repeated.

Methods

Children were recruited from the Avon Longitudinal Study of Parents and Children (ALSPAC). This is an ongoing geographically-based birth cohort which has been described in detail elsewhere.6 Briefly, 14,541 pregnant women living in 1 of 3 Bristol-based health districts in the former County of Avon, with an expected delivery date between April 1991 and December 1992, were originally invited to take part. Detailed information has been collected from pregnancy onward using self-administered questionnaires, data extraction from medical notes and linkage to routine information systems, and at a regular clinic lasting 3 hours, which the children have been invited to attend from the age of 7 years onward. Ethical approval for this study was obtained from the ALSPAC Law and Ethics Committee and Local Research Ethics Committees.

At 12 years, 246 children took part in a study (previously published7) to calibrate accelerometer counts against energy expenditure. This study concluded that an appropriate cut point for MVPA [defined as activity with an intensity equivalent to 4 times resting metabolic rate (4 METs)] was 3600 counts/minute for both sexes (sex-specific cut points were 3382 counts/minute for boys and 3731 counts/minute for girls; however, since the difference between girls and boys was small, a single cut point was used for convenience).
At 16 years, a randomly chosen subset of those who had provided data at 12 years were invited to take part in a repeat study, with data being collected between June 2008 and May 2009. The planned sample size was 50. Children were accompanied to the testing session by a parent, and, after the test protocol had been explained, written informed consent was given by either the parent (for children under 16) or by the child themselves, while children under 16 gave written assent.

The test protocol was identical to that used in the previous study at age 12. Height was measured to the nearest 0.1 cm (Leicester Height Meter, Invicta Plastics, Leicester, UK) and weight to the nearest 0.1 kg (Seca 770, Seca, Hamburg, Germany); body mass index (BMI) was then calculated in kg/m². Subjects took part in 6 consecutive 5-minute activities (lying flat, sitting, slow walking, walking, hopscotch and jogging) while wearing an Actigraph 7164 uniaxial accelerometer (Actigraph LLC, Pensacola, Florida) and a Cosmed K4b² portable metabolic unit (Cosmed, Rome, Italy). The accelerometer was positioned on the right hip and measured vertical movement in counts per minute, summing over 10-second epochs. Oxygen uptake (VO₂) in milliliters per minute was measured by the K4 unit, and converted to oxygen uptake per kg of body weight (ml·min⁻¹·kg⁻¹). For each activity, only data from minutes 3-1/2 to 4-1/2 were used, to allow oxygen uptake to stabilize. Slow walking, walking and jogging were conducted on an indoor running track, and the distance traveled during the 5 minutes was recorded (to the nearest 5 m) to allow the average speed during each activity to be calculated.

For each person, baseline VO₂ (=1 MET) was taken to be the minimum of sitting and lying VO₂; these values were used to calculate the mean oxygen uptake per kg equivalent to the 4 METs threshold for MVPA. To derive a threshold for MVPA in terms of accelerometer counts, oxygen uptake per kg was regressed on accelerometer counts using a random intercepts model, with sex, age and BMI as potential covariates. All analysis was carried out using Stata/IC v10.1.

Results

Forty-seven people attended a testing session. Two were excluded completely due to equipment failure, and 3 had no data for 1 of the activities, so the final sample size was 45 (15 girls, 30 boys). Table 1 summarizes the characteristics of these 45 participants. There were no apparent differences at age 12 between the group who were measured at both ages and the group measured at age 12 only in terms of exact age at measurement, height, weight, or BMI (data not shown).

Table 1 Characteristics of Study Participants

<table>
<thead>
<tr>
<th></th>
<th>Girls (n = 15)</th>
<th>Boys (n = 30)</th>
<th>All (n = 45)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at measurement (years)</td>
<td>16.1 (0.40)</td>
<td>16.0 (0.31)</td>
<td>16.0 (0.34)</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.66 (0.04)</td>
<td>1.77 (0.07)</td>
<td>1.73 (0.08)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>55.4 (50.1, 60.8)</td>
<td>63.2 (57.8, 77.7)</td>
<td>61.0 (54.5, 69.6)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>21.8 (17.6, 22.2)</td>
<td>20.6 (19.2, 22.6)</td>
<td>20.7 (19.0, 22.2)</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index.

Note. Values given are mean (SD) for normally distributed variables and median (IQR) otherwise.

Table 2 Accelerometry, Oxygen Uptake, and Speed During the 6 Test Activities

<table>
<thead>
<tr>
<th></th>
<th>Lying</th>
<th>Sitting</th>
<th>Slow walk</th>
<th>Walking</th>
<th>Hopscotch</th>
<th>Jogging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Counts per minute</td>
<td>–</td>
<td>–</td>
<td>2818</td>
<td>4585</td>
<td>5888</td>
<td>8695</td>
</tr>
<tr>
<td>(853)</td>
<td>(908)</td>
<td>(1652)</td>
<td>(1520)</td>
<td>(1652)</td>
<td>(2023)</td>
<td>(2023)</td>
</tr>
<tr>
<td>[1238–5270]</td>
<td>[3034–7088]</td>
<td>[2969–11,096]</td>
<td>[2062–12,589]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen uptake (VO₂) per kg (mL·min⁻¹·kg⁻¹)</td>
<td>5.23 (0.97)</td>
<td>5.48 (1.71)</td>
<td>15.93 (2.70)</td>
<td>22.08 (4.09)</td>
<td>35.00 (6.03)</td>
<td>48.98 (8.29)</td>
</tr>
<tr>
<td>Speed (km·h⁻¹)</td>
<td>–</td>
<td>–</td>
<td>4.23</td>
<td>5.71</td>
<td>–</td>
<td>9.03</td>
</tr>
<tr>
<td>(0.55)</td>
<td>(0.71)</td>
<td>(1.94)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. Values given are mean (SD) or mean (SD) [range].
very little difference in resting VO\textsubscript{2} per kg between girls and boys.

VO\textsubscript{2} per kg was logged before analysis, as models using the untransformed variable fitted poorly due to the variance increasing with the intensity of the activity. The final model contained age (centered at 16 years), sex, and the interaction between sex and accelerometer counts; inclusion of BMI was not found to improve the model fit. Residual plots from this model were consistent with normality, but there was a tendency toward overestimating oxygen uptake during the lower intensity activities and underestimating during higher intensity activities, suggesting that the model fit may still not be adequate. \(R^2\) values for this model were within-subjects, 0.81; between-subjects, 0.27; overall, 0.74.

Figure 1 shows the relationships between accelerometer counts and oxygen uptake for boys and girls predicted by this model, with dropped lines indicating the points at which these 2 curves cross the 4 METs threshold. The cut points predicted by this model were 2770 counts/minute (95% CI 2150–3389 counts/minute) for girls and 3333 counts/minute (95% CI 2986–3681 counts/minute) for boys. A Wald chi-squared test of the null hypothesis that boys’ and girls’ cut points were equal produced a \(P\)-value of 0.12, suggesting that there is some evidence of a true gender difference in cut points (the \(P\)-value should be interpreted in the light of the small samples tested, particularly for girls).

It should be noted, however, that the accelerometer counts threshold for MVPA is very sensitive to the choice of activities to be included in the regression model. For example, if we restrict to those activities requiring oxygen uptake close to the 4 METs boundary (ie, walking and slow walking), cut points of 3471 counts/minute for girls (95% CI 3079–3862) and 3875 counts/minute for boys (95% CI 3564–4187) are obtained, which tends to support retention of the earlier cut point of 3600 counts/minute. Conversely, using only hopscotch and jogging produces very low cut points. Figure 2 demonstrates this difference between high intensity, high variability and low intensity, low variability activities (logging the counts/minute variable did not improve the fit when the activities were separated in this way). \(R^2\) values for these 2 models were as follows—for the lower-intensity activities model: within-subjects, 0.83; between-subjects, 0.35; overall, 0.60; and for the higher-intensity activities model: within-subjects, 0.69; between-subjects, 0.30; overall, 0.51.

Clearly some better method of modeling the relationship between accelerometer counts and energy uptake is needed, rather than the standard linear or repeated measures regression generally used. One such approach was proposed by Crouter et al., who suggested splitting periods of activity into “walking/running” and “lifestyle/leisure” based on coefficients of variation, and applying different regression equations to each category. (This
approach unfortunately could not be applied to our data, as it requires the use of very short epochs for the accelerometer measurements.)

Conclusions

When activities of both higher and lower intensity are included in models, the sex-specific thresholds for MVPA derived from regression equations at 16 years were some way below the 3600 counts/minute derived for both sexes at age 12, particularly for girls. However models using only lower-intensity activities close to the 4 METs threshold supported retention of the 3600 counts/minute cut point used previously for both sexes. Future studies should recruit a larger sample (to enable detection of a true difference between boys and girls if it exists) and should include a wider range of activities close to the MVPA threshold. Care needs to be taken to ensure that modeling of the relationship between accelerometer counts and oxygen uptake/METs is adequate.

Acknowledgments

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References

