The energy expenditure of free-living physical activities in primary schoolchildren

Running Head: Energy expenditure of childhood activities

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Abstract

Background: The aim of this study is to establish the energy expenditure (EE) of a range of child-relevant activities and to compare different methods of estimating activity MET.

Methods: 27 children (17 boys) aged 9-11 years participated. Participants were randomly assigned to one of two routines of six activities ranging from sedentary to vigorous intensity. Indirect calorimetry was used to estimate resting and physical activity EE. Activity MET was determined using individual RMR, the Harrell-MET and the Schofield equation.

Results: Activity EE ranges from $123.7 \pm 35.7$ J/min/Kg (playing cards) to $823.1 \pm 177.8$ J/min/kg (basketball). Individual RMR, the Harrell-MET and the Schofield equation MET prediction were relatively similar at light and moderate but not at vigorous intensity. Schofield equation provided a better comparison with the Compendium of Energy Expenditure for Youth.

Conclusion: This information might be advantageous to support the development of a new Compendium of Energy Expenditure for Youth.
Introduction

A Compendium of Energy Expenditure for Youth was developed in 2008 with a list of over 200 activities that are usually performed by children and adolescents. Only 35% of the activities reported in the Compendium were based on activity data measured in youth, while the remaining were estimated by Compendium of Physical Activity in Adults. However, the resting EE for adults is lower than children and although activity EE could also be lower in adults, the MET is slightly higher compared to children. Likewise, EE in children can vary according to pubertal status. Furthermore, the MET values estimated in Compendium used predicted (Schofield equation) rather than measured resting metabolic rate (RMR) to calculate MET.

There is a need for an update to the Compendium of Energy Expenditure for Youth with accurate and direct measurements of physical activity from different ages. Therefore, the aim of this study was to provide information on EE of a range of playground and child-relevant activities in schoolchildren aged between 9 to 11 years old. The secondary aim was to compare the MET of these activities using different estimated methods including: individually measured RMR, the Harrell-MET, the Schofield equation and the previously established MET from the Compendium of Energy Expenditure for Youth.

Methods

Ethical approval

This study was approved by Teesside University, School of Health and Social Care Research and Governance Ethics Committee (protocol number: 056/13). Written informed consent was obtained from the Head Teacher and parental/guardian of the participating children as well as child assent prior to the study.
Energy expenditure of childhood activities

Participants
A total of 27 (10 girls, 17 boys) schoolchildren aged 9-11 from one primary school in the North East of England participated in the study.

Study Design
All testing procedures were conducted at the school. The testing consisted of two phases (separated by at least a day); 1) resting EE; 2) physical activities. In order to test as many activities as possible there were two different physical activity routines. The physical activities were selected based on common reported activities of schoolchildren within the North East of England.

Measurements
Height (cm) and weight (kg) were measured prior to testing. Children had to wear light clothing and removed shoes. Height was measured to the nearest 0.1 cm using a portable stadiometer (Leicester Height Measure, Child Growth Foundation, London, United Kingdom). Weight was measured to the nearest 0.1 kg using calibrated scales (Seca 761, Seca Weighing and Measuring Systems, Birmingham, England).

Indirect Calorimetry (Cosmed, K4 b²)
Prior to each test, the oxygen and carbon dioxide analysers and the flow turbine were calibrated according to the manufacturer's instructions for the Cosmed K4b². The child's information [height, mass (plus 2kg – to account for the weight of the Cosmed and shoes) and age] was inputted into the Cosmed software prior to testing. The children wore the Cosmed K4 b² for the duration of the resting measures and physical activity routine. The indirect calorimeter measured expired gases on a breath-by-breath basis.
Resting Energy Expenditure

The initial stage of the testing was the estimation of resting EE. Resting measures were taken on a different day to the physical activity trials. The children were informed to fast for a minimum of 2 hours before their respective test and were asked to avoid vigorous intensity activity 24 hour prior to testing. The testing was conducted in a quiet, darkened room at the school and distractions were prevented as much as possible. The children attached the heart rate monitor, and the face mask was placed for habituation for 5-10 minutes. The participants were told to lay comfortably in a supine position, on a mat with a pillow to rest the head. RMR was measured for 12 min which appears to be an acceptable duration for practical purposes.

Protocol

Children were randomly allocated to one of two routines by ‘names into a hat’ method. Table 1 displays a description of the activities performed in the two routines. Both routines consisted of two low-intensity, two moderate and two vigorous-intensity activities following the classifications in the Compendium of Energy Expenditure for Youth.

Table 1 here

The activities were performed for 5 minutes, followed by 5 minutes rest between each activity. We determined that the child had recovered once the HR was within 10% of the resting HR. All activities were performed standing, apart from playing cards, drawing and watching TV. To motivate and maintain the activity level, a member of the research team participated in the activities that involve team participation (soccer, tag and basketball). However, children were informed to conduct the activities at their own pace, apart from
walking which was controlled by a metronome. For the running activity, SmartSpeed
timing gates (SmartSpeed, Fushion Sport, United Kingdom) were placed in a 15 m square
area and two children performed the activity at the same time. Each child was given a
light to follow, when the light flashed, the child had to run and break the beam, this
continued over a 5 minute period. The children were encouraged to break as many beams
as possible but maintain a steady pace in order to complete the 5 minuutes of activity.
The light sequence was random in order to replicate the sporadic nature of running. VO$_2$
and VCO$_2$ were monitored continuously throughout all activities using the Cosmed and
the researcher recorded the exact time of each activity and marked the event button on
the Cosmed unit.

Data Analysis

Data were coded and downloaded using the respective software package for analysis. In
order to calculate the individual resting value the data were reduced to mid-5 minutes by
deleting the first 2 minutes and last 3 minutes of data. Resting EE was calculated as an
average across the remaining of 5 min. EE was calculated using the Weir equation$^5$.

The physical activity data were trimmed from 5 minutes to 2 minutes and 25 seconds by
deleting the first 2 minutes and the last 15 seconds of data. This was necessary to remove
the initial activity period (2-min) when the child had not reached steady state and the final
15-sec when the activity was terminating. Data were also filtered so that extreme outliers
(data with more than 3 standard deviations from the mean) caused by measurement error
were deleted. Once this editing stage had been completed the mean VO$_2$/kg, EE
(J/kg/min) and MET values were calculated for each physical activity. MET values were
determined by; 1) by dividing VO$_2$/kg by the individual metabolic resting value; 2) by
dividing VO$_2$/kg by 5.92 (ml/min/kg), the Harrell-MET$^3$; 3) Schofield predicted RMR. The
coefficient of variance of EE (J/min/kg) of activities was calculated by dividing the standard deviation by the mean.

Results

We recorded data from 32 participants, however we excluded all data from five participants due to equipment failure and measurement errors (N=27). The mean (SD) age (y), height (cm), weight (kg) and body mass index (BMI) of all participants was 10.3 (0.6) y, 146.4 (6.2) cm, 38.2 (7.9) kg and 17.6 (3) kg/m$^2$, respectively. According to the British growth reference (1990), 82% of the participants were classified as healthy weight (2$^{nd}$ – 85$^{th}$ centile), 11% were classified as overweight (85$^{th}$ – 95$^{th}$ centile) and 7% were classified as obese (≥95$^{th}$ centile). Although girls had similar height than boys (146.2 cm girls vs. 146.5 cm boys), girls weight and BMI were higher than boys (weight: 39.9 kg girls vs. 37.2 kg boys; BMI: 18.5 girls vs. 17.1 boys).

Resting Metabolic Rate

The mean results for the total sample and for each sex are shown in Table 2.

Table 2 here

The average resting VO$_2$ was 6.3 (ml.min$^{-1}$.kg$^{-1}$), with the boys having a slightly higher VO$_2$ than the girls. The mean absolute resting EE (kcal.min) was 1.14 (kcal.min) with the boys displaying lower EE than the girls.

Activity Energy Expenditure

Fourteen participants performed routine 1 and 13 participants performed routine 2 (Table 1). As shown in Table 3, the activity with the lowest EE (123.7 J/min/kg) was playing cards...
and the activity with the highest EE was basketball (823.1 J/min/kg). The MET values derived using the Compendium of Energy Expenditure in Youth\(^1\) are higher for most activities than the MET values derived from individual RMR or Harrell-MET. The discrepancy between the MET values appears to increase as the intensity of the physical activities increases. The MET values using the Schofield equation at vigorous intensity matches more closely to the Compendium. Table 3 also presents the inter-individual variability in all activities.

**Table 3 here**

**Discussion**

The study provides information of direct measurement energy costs in different playground and free-living activities in children aged 9 to 11 years old. When comparing the three methods of calculating METs (individual, Harrell-MET and Schofield), the predicting values at light and moderate intensity activities were fairly similar. However for activities above 5 MET, the individual MET and Harrell-MET appeared to underestimate the value when compared to Schofield and the Compendium of Energy Expenditure for Youth. The similarity of individual RMR and Harrell-MET equation on MET values throughout the range of activity intensities suggests that Harrell-MET equation may be a suitable option when measuring individual RMR is not possible. Schofield equation provided a better comparison in general with the Compendium of Energy Expenditure for Youth.

The main strengths of the study are the use of direct measurements of EE at rest and during the activities, the range in intensity of activities performed and the mixed weight population (18% overweight or obese). However, the sample size was small; therefore future studies with larger samples would be advantageous. Likewise, we did not measure
the different stage of maturation which could affect EE. Similarly, RMR was performed at school and not in a laboratory environment. Although we tried to control for light and noise there could be distractions in the environment that might have elevated children’s RMR. RMR has been previously reported as 5.92 ml/kg/min (95% CI: 5.67, 6.17) in a large sample of children (N=114) of the same age in a controlled laboratory environment. This RMR is considerably lower than the average value reported here 6.26 ml/kg/min (95% CI: 5.90, 6.62), which might, as a consequence, have underestimated the MET values of the activities. However, RMR appears to vary substantially according to the resting protocol applied. In the current study we used similar resting protocol as a previous study (i.e. 2-h fasting). Although the previous study was performed in a laboratory environment, their reported value (1.4 kcal/min, 95%CI: 1.03 to 2.1) was within the CI limits of our study (Table 2).

There was moderate inter-individual variability within the different activities. Some activities such as putting clothes away and walking presented lower variability (16% and 18% respectively) while activities such as hopscotch presented high variability (32%). This might reflect the nature of the activity in relation to variation in movement effort from each participant. However, this variability might also be inflated due the small sample size. Similar to our study, a previous study found no relationship between the intensity of the activity and the CV as higher CV was observed for lower intensity activities (e.g. playing computer games) and vigorous activities (e.g. biking).

This study provides an accurate estimation of the energy costs of a variety of commonly performed, child-relevant physical activities within a field-based setting, and also the associated MET values for the each activity. This information might be advantageous to support the development of a new Compendium of Energy Expenditure for Youth.
Acknowledgements

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Funding Source

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References


Table 1. Description of activities performed and intensity of similar activities from the Compendium of Energy Expenditures for Youth from the two physical activity routines.

<table>
<thead>
<tr>
<th>Routine 1 (n=14; 12 boys)</th>
<th>Routine 2 (n=13; 5 boys)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Activity</strong></td>
<td><strong>Description</strong></td>
</tr>
<tr>
<td>Playing cards</td>
<td>Sit at a bench and play cards</td>
</tr>
<tr>
<td>Hopscotch</td>
<td>Hopscotch, continuously</td>
</tr>
<tr>
<td>Activity</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Soccer</td>
<td>A competitive football match between participants and researchers (2 aside on a 5 aside pitch)</td>
</tr>
<tr>
<td>Basketball</td>
<td>A competitive basketball match between participants and researchers (2 aside on half a court)</td>
</tr>
<tr>
<td>Putting away</td>
<td>Untangle clothes from the floor, fold and place on a table.</td>
</tr>
<tr>
<td>Drawing</td>
<td>Sit at a table drawing a picture.</td>
</tr>
<tr>
<td>Playing Catch</td>
<td>Pass a basketball between each other on the basketball court, continuously</td>
</tr>
<tr>
<td>Overground Walking</td>
<td>Walk around school field (at 3mph) with pace controlled by a metronome (beat for each step)</td>
</tr>
<tr>
<td>Overground Running</td>
<td>Using the Smart Speed timing gates, the children were given a coloured light to follow, breaking the beam.</td>
</tr>
<tr>
<td>Tag</td>
<td>A game of tag between the children and the researchers.</td>
</tr>
<tr>
<td></td>
<td>VO₂ (ml/min/kg)</td>
</tr>
<tr>
<td>------------------</td>
<td>----------------</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>Total</td>
<td>6.26</td>
</tr>
<tr>
<td>Boys</td>
<td>6.39</td>
</tr>
<tr>
<td>Girls</td>
<td>6.04</td>
</tr>
</tbody>
</table>
Table 3. Estimated Energy Expenditure (J/min/kg) and METs for each activity (mean ± SD) estimated using the individual RMR, the Harrell-MET, Schofield equation and the predefined METs from similar activities from the Compendium of Energy Expenditures for Youth

<table>
<thead>
<tr>
<th>Activity</th>
<th>Energy Expenditure</th>
<th>METs Individual RMR</th>
<th>METs Harrell-MET</th>
<th>METs Schofield</th>
<th>METs Compendium</th>
<th>Energy Expenditure coefficient of variance (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watching TV</td>
<td>129.9 ± 35.8</td>
<td>1.1 ± 0.3</td>
<td>1.1 ± 0.3</td>
<td>1.3 ± 0.4</td>
<td>1.2</td>
<td>27.6</td>
</tr>
<tr>
<td>Drawing</td>
<td>149.1 ± 33.2</td>
<td>1.2 ± 0.3</td>
<td>1.3 ± 0.3</td>
<td>1.5 ± 0.3</td>
<td>1.4</td>
<td>22.2</td>
</tr>
<tr>
<td>Playing Cards</td>
<td>123.7 ± 35.7</td>
<td>1.0 ± 0.3</td>
<td>1.0 ± 0.3</td>
<td>1.2 ± 0.3</td>
<td>1.6</td>
<td>28.9</td>
</tr>
<tr>
<td>Putting away clothes</td>
<td>328.6 ± 51.8</td>
<td>2.7 ± 0.7</td>
<td>2.7 ± 0.4</td>
<td>3.3 ± 0.5</td>
<td>2.3</td>
<td>15.8</td>
</tr>
<tr>
<td>Nintendo Wii</td>
<td>243.7 ± 69.2</td>
<td>2.0 ± 0.7</td>
<td>2.1 ± 0.6</td>
<td>2.5 ± 0.8</td>
<td>3.4</td>
<td>28.4</td>
</tr>
<tr>
<td>Walking</td>
<td>334.6 ± 59.5</td>
<td>2.7 ± 0.5</td>
<td>2.9 ± 0.5</td>
<td>3.4 ± 0.6</td>
<td>3.8*</td>
<td>17.8</td>
</tr>
<tr>
<td>Playing Catch</td>
<td>492.3 ± 139.1</td>
<td>4 ± 1.1</td>
<td>4.2 ± 1.2</td>
<td>4.9 ± 1.2</td>
<td>3.3</td>
<td>28.2</td>
</tr>
<tr>
<td>Hopscotch</td>
<td>510.6 ± 162.3</td>
<td>4.2 ± 1.5</td>
<td>4.3 ± 1.4</td>
<td>5.1 ± 1.5</td>
<td>4.4</td>
<td>31.8</td>
</tr>
<tr>
<td>Tag</td>
<td>675 ± 108.7</td>
<td>5.5 ± 1.6</td>
<td>5.7 ± 1.3</td>
<td>6.7 ± 1.4</td>
<td>6.3</td>
<td>16.1</td>
</tr>
<tr>
<td>Activity</td>
<td>Energy Expenditure (kcal/min)</td>
<td>MET from Walking</td>
<td>MET from Running</td>
<td>MET from 26.1</td>
<td>21.6</td>
<td></td>
</tr>
<tr>
<td>------------</td>
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<td></td>
</tr>
<tr>
<td>Soccer</td>
<td>803.4 ± 139.5</td>
<td>6.6 ± 1.4</td>
<td>6.6 ± 1.1</td>
<td>8.0 ± 1.2</td>
<td>8.8</td>
<td></td>
</tr>
<tr>
<td>Basketball</td>
<td>823.1 ± 177.8</td>
<td>6.7 ± 1.7</td>
<td>6.8 ± 1.1</td>
<td>8.2 ± 1.3</td>
<td>8.2</td>
<td></td>
</tr>
<tr>
<td>Running</td>
<td>762.6 ± 198.8</td>
<td>6.2 ± 1.7</td>
<td>6.3 ± 1.3</td>
<td>7.5 ± 1.8</td>
<td>8.7 **</td>
<td></td>
</tr>
</tbody>
</table>

*MET from walking was calculated using the regression equation² at the walking speed of 1.34 m.s⁻¹ for a 10 years old child.

**MET from running was calculated using the regression equation² at the running speed of 2.92 m.s⁻¹ for a 10 years old child.