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

Running Head: Energy expenditure of childhood activities

Key Words: Indirect Calorimetry, METs, Playground, Individual RMR.

Abstract word count: 150 words

Manuscript word count: 2097 words

Date of submission: 11th May 2016

Submission for the 2016 NCCOR supplement

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± 35.7 J/min/Kg (playing cards) to 823.1 ± 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[1]. 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[2]. 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[3]. Likewise, EE in children can vary according to pubertal status[3]. Furthermore, the MET values estimated in Compendium used predicted (Schofield equation) rather than measured resting metabolic rate (RMR) to calculate MET[2].

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[3], the Schofield equation and the previously established MET from the Compendium of Energy Expenditure for Youth [1].

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.

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[4].

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 b^2)

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 K4b^2. 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 b^2 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[5].

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 [1].

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

79 walking which was controlled by a metronome. For the running activity, SmartSpeed
80 timing gates (SmartSpeed, Fushion Sport, United Kingdom) were placed in a 15 m square
81 area and two children performed the activity at the same time. Each child was given a
82 light to follow, when the light flashed, the child had to run and break the beam, this
83 continued over a 5 minute period. The children were encouraged to break as many beams
84 as possible but maintain a steady pace in order to complete the 5 minutues of activity.
85 The light squence was random in order to replicate the sporadic nature of running. VO_2
86 and VCO_2 were monitored continuously throughout all activities using the Cosmed and
87 the researcher recorded the exact time of each activity and marked the event button on
88 the Cosmed unit.

89

90 *Data Analysis*

91 Data were coded and downloaded using the respective software package for analysis. In
92 order to calculate the individual resting value the data were reduced to mid-5 minutes by
93 deleting the first 2 minutes and last 3 minutes of data. Resting EE was calculated as an
94 average across the remaining of 5 min. EE was calculated using the Weir equation[6].

95 The physical activity data were trimmed from 5 minutes to 2 minutes and 25 seconds by
96 deleting the first 2 minutes and the last 15 seconds of data. This was necessary to remove
97 the initial activity period (2-min) when the child had not reached steady state and the final
98 15-sec when the activity was terminating. Data were also filtered so that extreme outliers
99 (data with more than 3 standard deviations from the mean) caused by measurement error
100 were deleted. Once this editing stage had been completed the mean VO_2/kg, EE
101 (J/kg/min) and MET values were calculated for each physical activity. MET values were
102 determined by; 1) by dividing VO_2/kg by the individual metabolic resting value; 2) by
103 dividing VO_2/kg by 5.92 (ml/min/kg), the Harrell-MET[3]; 3) Schofield predicted RMR. The

104 coefficient of variance of EE (J/min/kg) of activities was calculated by dividing the
105 standard deviation by the mean.

106

107 **Results**

108

109 We recorded data from 32 participants, however we excluded all data from five
110 participants due to equipment failure and measurement errors (N=27). The mean (SD)
111 age (y), height (cm), weight (kg) and body mass index (BMI) of all participants was 10.3
112 (0.6) y, 146.4 (6.2) cm, 38.2 (7.9) kg and 17.6 (3) kg/m^2, respectively. According to the
113 British growth reference (1990), 82% of the participants were classified as healthy weight
114 (2^{nd} – 85^{th} centile), 11% were classified as overweight (85^{th} – 95^{th} centile) and 7% were
115 classified as obese (≥95^{th} centile). Although girls had similar height than boys (146.2 cm
116 girls vs. 146.5 cm boys), girls weight and BMI were higher than boys (weight: 39.9 kg girls
117 vs. 37.2 kg boys; BMI: 18.5 girls vs. 17.1 boys).

118

119 *Resting Metabolic Rate*

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

121

122 ***Table 2 here***

123

124 The average resting VO_2 was 6.3 (ml.min-^{1}.kg-^{1}), with the boys having a slightly higher
125 VO_2 than the girls. The mean absolute resting EE (kcal.min) was 1.14 (kcal.min) with the
126 boys displaying lower EE than the girls.

127

128 *Activity Energy Expenditure*

129 Fourteen participants performed routine 1 and 13 participants performed routine 2 (Table
130 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

159 the different stage of maturation which could affect EE[3]. Similarly, RMR was performed
160 at school and not in a laboratory environment. Although we tried to control for light and
161 noise there could be distractions in the environment that might have elevated children's
162 RMR. RMR has been previously reported as 5.92 ml/kg/min (95% CI: 5.67, 6.17)[3] in a
163 large sample of children (N=114) of the same age in a controlled laboratory environment.
164 This RMR is considerably lower than the average value reported here 6.26 ml/kg/min
165 (95% CI: 5.90, 6.62), which might, as a consequence, have underestimated the MET
166 values of the activities. However, RMR appears to vary substantially according to the
167 resting protocol applied. In the current study we used similar resting protocol as a
168 previous study[7] (i.e. 2-h fasting). Although the previous study[7] was performed in a
169 laboratory environment, their reported value (1.4 kcal/min, 95%CI: 1.03 to 2.1) was within
170 the CI limits of our study (Table 2).
171
172 There was moderate inter-individual variability within the different activities. Some
173 activities such as putting clothes away and walking presented lower variability (16% and
174 18% respectively) while activities such as hopscotch presented high variability (32%).This
175 might reflect the nature of the activity in relation to variation in movement effort from each
176 participant. However, this variability might also be inflated due the small sample size.
177 Similar to our study, a previous study[8] found no relationship between the intensity of the
178 activity and the CV as higher CV was observed for lower intensity activities (e.g. playing
179 computer games) and vigorous activities (e.g. biking).
180
181 This study provides an accurate estimation of the energy costs of a variety of commonly
182 performed, child-relevant physical activities within a field-based setting, and also the
183 associated MET values for the each activity. This information might be advantageous to
184 support the development of a new Compendium of Energy Expenditure for Youth.
185

Acknowledgements

The authors would like to thank the primary school and the schoolchildren for participating in the study. Also Christine Steel and Katy Weston for assisting with the data collection.

Funding Source

There was no financial support for this study. This study was part of the main authors PhD thesis.

References

1. Ridley K, Ainsworth B. E, Olds T. S. Development of a compendium of energy expenditures for youth. I*nternational Journal of Behavioral Nutrition and Physical Activity*. 2008; 5 (1):45.

2. Ainsworth B. E, Haskell W. L, Whitt M. C, et al. Compendium of physical activities: an update of activity codes and MET intensities. *Med.Sci.Sports Exerc*. 2000; 32 (9; SUPP/1): S498-S504.

3. Harrell J.S, McMurray R.G, Baggett C.D, et al. Energy costs of physical activities in children and adolescents. *Med.Sci.Sports Exerc.* 2005; 37: 329-336

4. Moore H.J, Ells L.J, McLure S.A, et al. The development and evaluation of a novel computer program to assess previous-day dietary and physical activity behaviours in school children: The Synchronised Nutrition and Activity Program (SNAP). *British Journal of Nutrition*. 2008; 99:1266-1274.

5. Ventham J. C, Reilly J. J. Reproducibility of resting metabolic rate measurement in children. *British Journal of Nutrition*. 1999; 81(6): 435-437.

6. Weir J.B. New methods for calculating metabolic rate with special reference to protein metabolism. *J Physio.* 1949; 109 (1-2): 1-9.

7. Corder K, Brage S, Wareham N. J. et al Comparison of PAEE from combined and separate heart rate and movement models in children. *Med.Sci.Sports Exerc*. 2005; 37(10): 1761-1767.

8. Pfeiffer K.A, Schmitz K.H, McMurray R.G, et al. Physical activities in adolescent girls: variability in energy expenditure. *Am J Prev Med*. 2006; 31(4):328-331.

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.

Routine 1 (n=14; 12 boys)			Routine 2 (n=13; 5 boys)		
Activity	**Description**	**Intensity similar activity to Compendium (MET, code)**	**Activity**	**Description**	**Intensity similar activity to Compendium (MET, code)**
Playing cards	Sit at a bench and play cards	Low (1.6 MET, 721220)	Watching TV	Sit in a chair watching a movie	Low (1.2 MET, 121130)
Hopscotch	Hopscotch, continuously	Moderate (4.4 MET, 341281)	Nintendo Wii	Wii Sonic Olympics performed in pairs. Games consisted of sprinting, jumping and throwing.	Moderate (3.4 MET, 732202)

Soccer	A competitive football match between participants and researchers (2 aside on a 5 aside pitch)	Vigorous (8.8 MET, 342182)	Basketball	A competitive basketball match between participants and researchers (2 aside on half a court)	Vigorous (8.2 MET, 342032)
Putting away clothes	Untangle clothes from the floor, fold and place on a table.	Low (2.3 MET, 641130)	Drawing	Sit at a table drawing a picture.	Low (1.4 MET, 420010)
Playing Catch	Pass a basketball between each other on the basketball court, continuously	Moderate (3.3 MET, 342773)	Overground Walking (3mph)	Walk around school field (at 3mph) with pace controlled by a metronome (beat for each step)	Moderate (3.8 MET, 240051)
Overground Running	Using the Smart Speed timing gates, the children were given a coloured light to follow, breaking the beam.	Vigorous (8.7 MET, 341480)	Tag	A game of tag between the children and the researchers.	Vigorous (6.3 MET, 342443)

Table 2. Mean, standard deviation and confidence interval (CI) of resting values in VO_2 (ml/min/kg) and energy expenditure (kcal/min)

	VO_2 (ml/min/kg)			Energy Expenditure (kcal/min)		
	Mean	SD	95% CI	Mean	SD	95% CI
Total	6.26	0.94	5.90,6.62	1.14	0.27	1.03,1.24
Boys	6.39	1.00	5.92,6.86	1.12	0.23	1.01,1.23
Girls	6.04	0.85	5.51,6.57	1.16	0.35	0.94,1.38

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

Activity	Energy Expenditure	METs Individual RMR	METs Harrell-MET	METs Schofield	METs Compendium	Energy Expenditure coefficient of variance (%)
Watching TV	129.9 ± 35.8	1.1 ± 0.3	1.1 ± 0.3	1.3 ± 0.4	1.2	27.6
Drawing	149.1 ± 33.2	1.2 ± 0.3	1.3 ± 0.3	1.5 ± 0.3	1.4	22.2
Playing Cards	123.7 ± 35.7	1.0 ± 0.3	1.0 ± 0.3	1.2 ± 0.3	1.6	28.9
Putting away clothes	328.6 ± 51.8	2.7 ± 0.7	2.7 ± 0.4	3.3 ± 0.5	2.3	15.8
Nintendo Wii	243.7 ± 69.2	2.0 ± 0.7	2.1 ± 0.6	2.5 ± 0.8	3.4	28.4
Walking	334.6 ± 59.5	2.7 ± 0.5	2.9 ± 0.5	3.4 ± 0.6	3.8*	17.8
Playing Catch	492.3 ± 139.1	4 ± 1.1	4.2 ± 1.2	4.9 ± 1.2	3.3	28.2
Hopscotch	510.6 ± 162.3	4.2 ± 1.5	4.3 ± 1.4	5.1 ± 1.5	4.4	31.8
Tag	675 ± 108.7	5.5 ± 1.6	5.7 ± 1.3	6.7 ± 1.4	6.3	16.1

Soccer	803.4 ± 139.5	6.6 ± 1.4	6.6 ± 1.1	8.0 ± 1.2	8.8	17.4
Basketball	823.1 ± 177.8	6.7 ± 1.7	6.8 ± 1.1	8.2 ± 1.3	8.2	21.6
Running	762.6 ± 198.8	6.2 ± 1.7	6.3 ± 1.3	7.5 ± 1.8	8.7**	26.1

*MET from walking was calculated using the regression equation[2] at the walking speed of 1.34 $m.s^{-1}$ for a 10 years old child.

**MET from running was calculated using the regression equation[2] at the running speed of 2.92 $m.s^{-1}$ for a 10 years old child.