Energy cost of free-play activities in 10-11 year old children

Brief Running Head: Energy Cost of Free-Play Activities

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Abstract

Objective: This study sought to ascertain the energy expenditure (EE) associated with different sedentary and physically active free-play activities in primary school-aged children. ***Methods:*** Twenty-eight children (13 boys; 11.4±0.3 years; 1.45±0.09 m; 20.0±4.7 $kg \cdot m^{-2}$) from one primary school in Northwest England engaged in six activities representative of children's play for 10 minutes (drawing, watching a DVD, playground games and free-choice) and 5 minutes (self-paced walking and jogging), with 5 minutes rest between each activity. Gas exchange variables were measured throughout. Resting energy expenditure was measured during 15 minutes of supine rest. ***Results:*** Child (Schofield-predicted) MET values for watching a DVD, self-paced jogging and playing reaction ball were significantly higher for girls ($p<0.05$). ***Conclusion:*** Utilising a field-based protocol to examine children's free-living behaviours, these data contribute to the scarcity of information concerning children's EE during play to update the Compendium of Energy Expenditures for Youth.

Introduction

In 2008, Ridley and colleagues[1] developed the Compendium of Energy Expenditures for Youth to enable researchers to understand the energy costs associated with commonly performed activities during daily living. However, two-thirds of the information listed was estimated using the adult compendium.[2] The compendium should be based on measured child-specific energy costs during both structured and unstructured activities across the intensity spectrum (i.e., sedentary, light, moderate, vigorous). However, the majority of previous research utilised highly structured protocol's to assess children's EE to standardise movement patterns and facilitate inter-individual comparisons. Such laboratory-based protocols may be limited in the assessment of free-living behaviours.[3] For example, the energy cost of pre-determined treadmill and/or running speeds are often examined, yet may have little ecological validity as these behaviours are self-paced by individuals and performed over-ground during daily living. In addition, given the sporadic and intermittent nature of children's physical activity (PA) there is a need to establish children's EE during play, with greater autonomy over mode, duration and intensity, which is more representative of their free-living behaviours. Unstructured free-play and playground games are examples of common behaviours children engage in, both at school and after school,[4] yet data on active free-play that informed the 2008 compendium were scarce. Indeed, the "unstructured outdoor play" MET value was based on one study that measured school quadrangle play in the 1920s.

The aim of this study was to ascertain the EE associated with different sedentary and physically active free-play activities in children.

Methods

Study Participants

Twenty-eight 10-11 year old children (13 boys, 15 girls) from one primary school in Northwest England participated in the study. Descriptive characteristics are shown in Table 1. Participants provided written assent and the primary caregiver provided informed written consent. The study was approved by the University Ethics Committee.

Activities

Resting energy expenditure (REE) was measured during 15 minutes of supine rest in a quiet, dimly lit room after at least one hour of fasting. Children subsequently took part in six different activities chosen to represent intermittent and continuous behaviours undertaken in free-play situations both on their own and with other people. The activities took place either in the classroom or in the school playground in a randomised order, with five minutes of seated rest between each activity. The six free-play activities that children participated in were:

a) Drawing/colouring: The child sat at a classroom table and was provided with materials to draw/colour pictures on their own;
b) DVD watching: The child sat inside the classroom and watched a DVD on their own;
c) Self-paced brisk walking: The child briskly walked around a marked circular track on the playground at a self-selected pace;
d) Self-paced jogging: The child jogged around the marked circular track at a self-selected pace;
e) Playground games: The child played three different games in a standardised order (hopscotch, Frisbee, and reaction ball) for 3.3 minutes each on the playground with a researcher, with no breaks in between;

f) Free choice games: The child was provided with the opportunity to play different games on their own or with a researcher. A Frisbee, soccer ball, tennis racquets and balls, skipping ropes, hula hoops, reaction ball, and a large dice were provided to facilitate the games. The child was able to freely change the game(s) played during this time.

All activities were 10 minutes in duration, with the exception of self-paced brisk walking and self-paced jogging which were 5 minutes in length. This was to ensure that children could sustain the self-selected pace for the whole activity duration.

Outcome Measures

EE was assessed using a portable, open-circuit indirect calorimetry system (MetaMax 3B, Cortex, Leipzig, Germany) that measured breath-by-breath oxygen consumption (VO_2). The MetaMax was calibrated before each trial using the manufacturer recommended procedure. Respiratory volume was calibrated using a 3-L syringe. Gas sensors were calibrated against known concentrations of gases (16% oxygen, 4% carbon dioxide). The MetaMax analyser unit was attached to the child around their upper body using a paediatric harness with adjustable Velcro straps. A facemask was secured over the child's nose and mouth using an adjustable nylon harness. A bi-directional digital turbine flow meter was inserted into the facemask to measure the volume of inspired and expired air. A sample line connecting the turbine and analyser unit to determine the content of oxygen and carbon dioxide. Data were retrieved at the end of each trial for analysis by manufacturer proprietary software (MetaMax, version 2.4, Statera Edition). Data were reduced to 10 second epochs for analysis due to the free-play nature of the activities being performed.

REE was calculated by removing the first five and last minutes and averaging the remaining data during the resting phase. For each activity VO_2 ($l \cdot min^{-1}$), relative VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) and EE ($J \cdot kg^{-1} \cdot min^{-1}$) were calculated by removing the first 2.5 minutes and last 0.5 minute and averaging the remaining data. As children can achieve steady state in 2-3 minutes[5], the individual playground games (hopscotch, Frisbee and reaction ball) were also examined separately. For these activities, the first 2.5 minutes were removed and an average across 50 seconds. After 2.5 minutes, EE values had reached steady state which was indicated by a plateau in VO_2 and VCO_2 where values varied by less than 15%. VO_2 was converted to EE using the values of 1L O_2 = 4.9 kcal.[6] All participants were assessed with the same calorimeter.

An estimate of daily RMR was calculated for each participant using the sex- and age- and mass- specific Schofield prediction equations.[7] Child metabolic equivalents (Child METs) were calculated by dividing activity EE by predicted RMR.[7]

Statistical Analyses

All data are expressed as means and standard deviations. One-way analyses of variance were conducted to examine sex differences for the descriptive characteristics and the energy cost of the free-play activities. All statistical analyses were conducted using PASW Statistics 22 (SPSS, Chicago, Il). Statistical significance was set at $p<0.05$.

Results

Technical issues with the MetaMax, resulted in three children's data (one boy, two girls) being fully lost. Incomplete data were recorded for eight children (two boys, six girls). All collected data were analysed for each activity. The energy cost of the sedentary and active

124 free-play behaviours, along with the sample sizes for each behaviour, are shown in Table 2
125 and Table 3, respectively.

126 There were no significant sex differences for any of the descriptive characteristics.
127 Self-paced walking and jogging speeds were 1.71 ± 0.1m·s^{-1} (range 1.31-2.00m·s^{-1}) and 2.59
128 ± 0.32m·s^{-1}, (range 1.31-2.00m·s^{-1}) for the whole sample, respectively. Specifically, boys and
129 girls speeds were 1.65 ± 0.2m·s^{-1} (1.31-2.00m·s^{-1}) and 1.86 ± 0.1m·s^{-1} (1.55-1.97m·s^{-1}) for
130 walking, and 2.5 ± 0.4m·s^{-1} (1.91-2.96m·s^{-1}) and 2.67 ± 0.3m·s^{-1} (2.19-3.3m·s^{-1}) for jogging,
131 respectively. In line with the adult compendium, the energy cost associated with various
132 speed ranges (1.31-1.80m·s^{-1}, 1.81-2.30m·s^{-1}, 2.31-2.80m·s^{-1} and 2.81-3.30m·s^{-1}) are shown
133 in Table 3. Girls expended more energy than boys for drawing ($p<0.05$). Child MET values
134 for watching a DVD, self-paced jogging and playing reaction ball were significantly higher
135 for girls ($p<0.05$).

136

137 **Discussion**

138 The activity that was least consistent with the 2008 compendium was self-selected brisk
139 walking, which has been used to describe moderate-intensity PA (MPA) in public health
140 recommendations. On average, children walked at 1.7m·s^{-1}, which was 0.2m·s^{-1} faster than
141 the identified 'hard' speed,[1] and elicited an EE of ≥4 METs. Notably, 4 METs is increasingly
142 used to quantify children's MPA in accelerometry studies,[8] which this study supports. For
143 jogging, children self-selected a speed that was consistent with moderate running in the
144 compendium, though the energy cost was closer to the MET value identified for light
145 jogging.[1] Despite this discrepancy, self-paced jogging exceeded the vigorous-intensity PA
146 (VPA) threshold of 6 METs, which is typically used to quantify children's VPA in
147 accelerometry studies.[8]

148 Little data were available to identify the energy cost of unstructured outdoor play in
149 the original compendium.[1] Using a protocol where children had autonomy over the intensity
150 they engaged in to play the different playground games, which were sporadic and intermittent
151 in nature, the energy cost was consistent with the original 5 METs value. This is a positive
152 finding and further supports the inclusion of active play as an example of PA in current
153 recommendations.[9] One of the playground games children played during this condition was
154 Frisbee, which was an activity where the energy cost was estimated using adult data.[2] This
155 study provides new information about the energy cost of this activity during unstructured
156 playground games for children, which on average had an average energy cost of ~5.5 METs.
157 There has been some recent debate about the classification of sedentary behaviour in
158 children, and whether a threshold of ≤1.5 or ≤2 METs should be used.[10] On average, both
159 drawing and DVD watching had energy costs that were consistent with the ≤1.5 MET
160 threshold, though there was some variability in individual values, and the current values
161 within the youth compendium.[1] It is postulated that reaching for different materials provided
162 will have resulted in small body movements equivalent to sit-stand transitions, which may
163 have increased the energy cost of the activity.[11]
164 This study utilised a field-based protocol to examine the energy cost of children's
165 free-living behaviours. These data contribute to the scarcity of information concerning
166 children's EE during play.
167
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175 **References**

176 1. Ridley K, Ainsworth BE, Olds TS. Development of a compendium of energy
177 expenditures for youth. *Int J Behav Nutr Phys Act*. 2008;5:45.
178 2. Ainsworth BE, Haskell WL, Whitt MC, et al. Compendium of physical activities: an
179 update of activity codes and MET intensities. *Med Sci Sports Exerc*.
180 2000;32(9):S498-S516.
181 3. Nilsson A, Brage S, Riddoch C, et al. Comparison of equations for predicting energy
182 expenditure from accelerometer counts in children. *Scand J Med Sci Sports*.
183 2008;18(5):643-650.
184 4. Stanley RM, Ridley K, Olds TS. The type and prevalence of activities performed by
185 Australian children during the lunchtime and after school periods. *J Sci Med Sport*.
186 2011;14(3):227-232.
187 5. Rowland TW. *Developmental Exercise Physiology.* Champaign, IL: Human Kinetics;
188 1995.
189 6. McArdle WD, Katch FI, Katch VL. *Exercise Physiology: Nutrition, Energy, and*
190 *Human Performance* (7th Ed). Philadelphia: Lippincott Williams & Wilkins; 2010.
191 7. Schofield WN. Predicting basal metabolic rate, new standards and review of previous
192 work. *Hum Nutr Clin Nutr*. 1985;39 Suppl 1:5-41.
193 8. Trost SG, Loprinzi PD, Moore R, Pfeiffer KA. Comparison of accelerometer cut-
194 points for predicting activity intensity in youth. *Med Sci Sports Exerc.*
195 2011;43(7):1360-1368.
196 9. Department of Health. *Everybody Active, Every Day. An evidence-based approach to*
197 *physical activity* London: Department of Health; 2014.

198 10. Saint-Maurice PF, Kim Y, Welk GJ, Gaesser GA. Kids are not little adults: what
199 MET threshold captures sedentary behavior in children? *Eur J Appl Physiol*. In press.

200 11. Júdice PB, Hamilton MT, Sardinha LB, Zderic TW, Silva AM. What is the metabolic
201 and energy cost of sitting, standing and sit/stand transitions? *Eur J Appl Physiol.* In
202 press.