Appropriateness of the Definition of 'Sedentary' in Young Children: Whole-Room Calorimetry Study

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Abstract

Objective: The present study aimed to measure the energy cost of three common sedentary activities in young children to test whether energy expended was consistent with the recent consensus definition of 'sedentary' as 'any behaviour conducted in a sitting or reclining posture and with an energy cost ≤1.5 metabolic equivalents (METs)' (Sedentary Behavior Research Network, 2012).

Methods: Whole-room calorimetry measures of television viewing, sitting at a table drawing and reading, and sitting on the floor playing with toys were made in 40 young children (mean age 5.3 years, SD 1.0).

Results: The energy cost of each sedentary activity was consistent with the recent consensus definition of sedentary: 1.17 METs (95% CI 1.07-1.27) for TV viewing; 1.38 METs (95% CI 1.30-1.46) for sitting at a table; and 1.35 METs (95% CI 1.28-1.43) for floor-based play.

Conclusions: Common sedentary activities in young children have energy costs which are consistent with the recent consensus definition of 'sedentary', and the present study is supportive of this definition.

Keywords: calorimetry; obesity; children; preschool; sedentary behaviour; measurement.

Introduction

Epidemiological studies have recently established that time spent in sedentary behaviour (sitting) influences several major health outcomes in adults[1,2]. There may also be measurable health effects of sitting behaviour during childhood and adolescence[3,4], and sitting behaviour during childhood and adolescence may influence adult sitting behaviour[5,6]. An international consensus has been reached recently on the definition of 'sedentary' as 'any behaviour conducted in a sitting or reclining posture and with an energy cost ≤1.5 metabolic equivalents (METs)'.[7]

Newton et al[8] recently demonstrated, in a whole-room calorimetry (WRC) study of 25 overweight and obese African-American adults, that the energy cost of common sedentary activities performed when sitting upright was clustered tightly around 1.0 MET, suggesting that a definition of sedentary might usefully incorporate an energy expenditure threshold below 1.5 MET. However, Newton et al[8] expressed a concern over the generalisability of their findings, noting the need to extend research of this kind to other populations. Evidence on the energy cost of sedentary behaviours in children has focused largely on older children and adolescents, notably the studies by Harrell et al in 8-18y olds[9] , Ridley and Olds in 6-18y olds[10], Puyau et al in 6-16y olds[11], and Evenson et al (mean age 7.3y)[12] . The energy cost of 5 common sedentary activities reported by Harrell et al was consistent with the consensus definition, with the 95% confidence intervals not exceeding 1.5 METs[9]. The mean energy cost of four common sedentary activities was reported by Ridley and Olds, and this approached 1.5 METs for only one of the four[10]. Puyau et al found that the range of energy expenditure exceeded 1.5 METs for one of the two sedentary activities studied[11]. Evenson et al reported the mean energy cost of two sedentary activities as well below 1.5 METs[12].

In pre-school-aged children (3-5 years), evidence on the energy cost of common sedentary behaviours is scarce. We have been able to find only a single study, in which Adolph et al[13] used WRC to measure the energy cost of two sedentary activities: reclining watching TV; sitting and colouring. The range of energy cost of watching TV did not exceed 1.5 METs, but the range of energy costs for

sitting and colouring did (mean 1.4, SD 0.2). The primary aim of the present study was therefore to test whether the energy cost of common sedentary activities was consistent with a '1.5 MET threshold'[7] definition of sedentary behaviour in a sample of young children.

Methods

The present study was based on a sample of forty healthy 4- to 6-year-old children and was part of a larger study that aimed to validate various objective methods of estimation of free-living energy expenditure and physical activity in young children. Children were recruited from childcare centers (pre-schools, long-day and family-day care) in the Illawarra region of New South Wales, Australia. Exclusion criteria included the child having a disease known to influence their energy balance (e.g. hypothyroidism), a physical disability, or claustrophobia. No children were excluded on these grounds. The study was approved by the University of Wollongong/ SESIAHS Health and Medical Human Research Ethics Committee and all participating parents provided informed written consent and their children assented to participation.

Whole-room calorimetry provides a criterion measure of physical activity, energy expenditure, by measurement of oxygen consumption and carbon dioxide production ('calorimetry') while study participants are confined within a room (the calorimeter). Moreover, WRC avoids the need for face masks for collection of expired air which can be problematic in young children, and the avoidance of facemask- based collection systems combined with the amount of space within the WRC allows young children to behave in a fairly natural way. In the present study all children had a familiarisation visit to the WRC before the measurement. On the morning of measurement, parents were asked to give their children a standardised breakfast provided by the researchers (170 kcal) at 07.00 h and only give them sips of water thereafter[14]. Children and their parents arrived at the laboratory at approximately 08.15 h before entering the WRC at around 08.30 h. For the present study of sedentary behavior children spent ~70 minutes in the WRC, but this was nested within a more extended protocol of ~150 minutes which included activities of light and moderate-vigorous intensity which are described elsewhere[14]. We have established that giving a small standardised breakfast has a negligible

impact on subsequent measures of energy expenditure within the WRC[14], and no decline in energy expenditure associated with declining diet-induced thermogenesis was detectable[14].

Children's height and weight were measured using standardised procedures. Height was measured to the nearest 0.1 cm using a portable stadiometer (PE87, Mentone Educational Centre, Victoria, Australia) and weight was measured to the nearest 0.1 kg using a calibrated electronic scale (Tanita BC-418A, Tanita Corporation of America, Illinois, USA). Children then entered the WRC and were asked to follow a protocol which consisted of: sitting watching TV/DVD, sitting at a table while talking on the phone, reading, colouring, drawing, and sitting playing with toys on the floor. According to the compendium of energy expenditure for children playing with toys was classified as a light physical activity [15]. However, in the current study it was completed while staying in a seated position and therefore it was included as a possible sedentary behaviour. The duration and order of the activities was pre-set and the same for each child (Table 1). Children were requested to complete one activity before moving on to the next. Children were not requested or instructed to sit still, but simply to complete the activity while in a seated position as they would do in a free-living situation. A degree of variation in the ways each behaviour in the protocol were carried out is inevitable, but energy expenditure data were only included in the present study if direct observation confirmed that they were sitting and carrying out the behaviour required at each stage of the protocol. All children were guided through the protocol by a research assistant who observed through a window and communicated via an intercom. The research assistant was able to encourage compliance with the protocol, and compliance was confirmed independently by filming and direct observation[16,17]. 'Compliance' as defined by the filmed record represented periods when the child was following the protocol (i.e. completing the activity while in a seated position).

Oxygen consumption (VO_2) and carbon dioxide production (VCO_2) were measured continuously (paramagnetic O_2 and infrared CO_2 analyzers, Sable System Inc, Las Vegas USA) and corrected to standard temperature, pressure and humidity in the room calorimeter (3m x2.1m x2.1m) at the University of Wollongong. Technical procedures are described in more detail elsewhere, along with

full details of the protocol which children followed in the present study[14]. Chamber air was sampled every two minutes and rates of O_2 consumption and CO_2 production were calculated from in- and outflow as described in the literature[18]. Rates of O_2 consumption and CO_2 production were then averaged over 10 min to produce stable measures of EE,[14,16] and rates of energy expenditure were calculated using the Weir equation[19].

Individualised MET values were calculated by dividing measured energy expenditure for each child by their predicted BMR. BMR was calculated using the following equations developed by Schofield et al.[20] in children aged 3- to 10-years:

BMR_{boys} = 0.082*weight (kg) + 0.545*height (m) + 1.736

BMR_{girls} = 0.071*weight (kg) + 0.677*height (m) + 1.553

The BMR was calculated as MJ/day and converted to kcal/kg/min. The Schofield equation was used because of the practical difficulties associated with obtaining BMR measures in children of this age[21-23], and in one study it had no bias relative to measured BMR in a small sample of young children[21].

Participants were filmed during the protocol. Video footage was coded using Vitessa 0.1 (Version 0.1, University of Leuven, Belgium) which generated a time stamp every time a change in posture or intensity was coded by the observer[24]. Every second following a given time stamp was coded as being at the same posture as that occurring at the point of the time stamp itself. Each second was coded in this way until a change in posture was indicated by the appearance of the next time stamp. This resulted in second-by-second coding. Children's postures were classified as sit/lie (i.e. sedentary) or non-sedentary. Postures were classified as sit/lie whenever the child's bottom touched the ground, a chair, or their legs (e.g. kneeling on both knees with their bottom touching the legs or heels)[25,26].The postural coding meant that, as far as possible, only sedentary behaviours were included in the energy expenditure data.

Average energy expenditure values collected during watching television, sitting at a table, and playing with toys on the floor were used for analyses. Ten-minute data points were defined as valid if during these 10 minutes children participated consistently in sedentary activity (i.e. watching television, sitting at a table, playing with toys on the floor) as confirmed by direct observation[14,16,17]. Repeated-measures ANOVA with Bonferroni adjustment was used to compare energy expenditure between each of the sedentary activities and predicted BMR using the Schofield equation. In addition, to compare the effect of using predicted BMR and measured REE on energy expenditure values during sitting at a table and playing with toys, paired sample *t*-tests were used.

Results

Of the 40 children who participated in the study, two had missing data due to calorimeter malfunction. For the remaining 38 children, 34 (92.1%), 28 (73.7%), and 35 (92.1%) had at least one 10-min block of watching television, sitting at a table, and playing with toys on the floor, respectively. Missing data were due to children breaking up the sedentary activity by moving to a non-sit/lie position. Descriptive characteristics for the study sample are presented in Table 2.

Energy expenditure data are shown in Table 3. Energy expenditure values for watching TV, sitting at a table and playing with toys were 0.037 kcal/kg/min (± 0.010), 0.044 kcal/kg/min (± 0.008) and 0.043 kcal/kg/min (± 0.009), respectively ($P<0.05$). Post-hoc analyses showed that measured energy expenditure while sitting at a table and playing with toys on the floor was significantly higher than while watching television ($P<0.05$).

For each of the three sedentary activities, average values were consistently <1.5 METs when predicted BMR was used to define 1 MET. The majority of the data points which exceeded 1.5 times predicted BMR were observed while sitting at a table (n = 8 out of 28) and playing with toys on the floor (n = 11 out of 35). The 95% confidence intervals for the three sedentary activities, expressed as

multiples of predicted BMR were as follows: 1.07 – 1.27; 1.30-1.46; 1.28 – 1.43 for watching TV, sitting at a table and playing with toys on the floor, respectively.

DISCUSSION

Consistency with the current '1.5 MET' definition of sedentary was high in the present study: the 95% confidence intervals for the energy cost of all three sedentary activities did not exceed 1.5 MET. The behaviours included in the present study were common early childhood activities which were sedentary on postural grounds, and on energy expenditure grounds, suggesting a high degree of concordance between the postural and energy expenditure components of the current consensus definition of 'sedentary'[7].

A few studies in older children and adolescents[7-10,27] suggested that some sedentary activities had mean energy costs which exceed 1.5 METs, or a range which greatly exceeded 1.5 METs, but generally the evidence from older children and adolescents is consistent with the current consensus definition of 'sedentary'[9-12]. The study of pre-school children (mean age 4.5y) by Adolph et al, which did not set out to test the appropriateness of the sedentary behaviour definition, found that the energy cost of sitting and colouring averaged 1.4 METs, with an SD of 0.2[13]. The 1.5 MET threshold to define sedentary behaviour is accepted as a mean, and a degree of inconsistency with it in certain populations, and for certain activities could presumably be tolerated.

The present study had a number of strengths. The use of a criterion method (energy expenditure) for validation of physical activity measures, the fairly natural setting, the combination of WRC with direct observation to confirm that activities within the WRC were occurring as instructed[14,16,17], and the inclusion of three common sedentary activities, were notable strengths. One weakness was our inability to obtain a measured BMR measure which led to the need to use predicted BMR values, a problem common to almost all studies of young children[22,22,28]. However, study conclusions did not differ whether predicted values BMR were used, or measured resting metabolic rate (reclining in a

beanbag watching TV) values were used. The WRC measures were made after an overnight fast followed by a small standard breakfast. We have shown that providing a small standardised breakfast has no marked impact on energy expenditure >90 minutes later within the WRC, and so the measurement conditions approximate measurement in the post-absorptive state[14]. Many free-living sedentary behaviours will be carried out in a post-prandial state, and so will have energy costs slightly higher than those measured in the present study. Sit- to -stand postural transitions are very common among pre-school children during sedentary activities[25,26,29] and the exclusion of these from the measures made in the WRC (using direct observation) in the present study means that the estimates of the energy cost of these behaviours in the present study may be conservative. The present study could not include all forms of sedentary behaviour which young children experience[30], and did not include screen-based gaming (some relatively new screen-based gaming devices appear to be particularly popular with young children)[31]. Finally, the dearth of evidence on the energy cost of common sedentary behaviours, with contemporary definitions of sedentary[7,32], in a range of contemporary populations, means that generalisability of the present study should not be assumed.

Conclusions

In conclusion, the present study suggests that common 'postural sedentary' activities in young children have an energy cost which would mean that they can be considered as 'sedentary' according to the current consensus definition which incorporates energy expenditure. The present study is therefore supportive of the use of the current definition of 'sedentary' in young children[7].

Practical Implications

- Defining sedentary behaviour in young children is important to evaluating interventions, understanding prevalence and trends, and assessing the health impact of sedentariness.
- The current consensus definition of sedentary behaviour is robust in young children and can be used with greater confidence as a result.

- Common sedentary behaviours in young children have energy costs between 1.2-1.4 METs, and energy expenditure during sedentary time can be estimated using these values.

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Conflicts of Interest: None Declared.

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Table 1. Whole room calorimetry protocol

Activity	Time (min)
Behaviour	
Watching TV–sitting in a beanbag	30
Talking on telephone with parents – sitting	2
Reading books with a cassette/CD – sitting	5
Drawing/colouring in – sitting	10
Playing with toys, blocks (Lego), dolls, puzzles, games – sitting on floor	20

344 **Table 2**. Characteristics of study participants, mean (SD).

	Total sample (n=40)	Boys (n=22)	Girls (n=18)
Age (years)	5.3 (1.0)	5.2 (1.0)	5.3 (1.1)
Height (cm)	112.7 (8.1)	114.3 (6.2)	110.9 (9.7)
Weight (kg)	20.6 (3.7)	21.5 (2.4)	19.4 (4.6)
BMI (kg/m^2)	16.1 (1.5)	16.5 (1.3)	15.5 (1.6)
BMI z-score	0.34 (1.07)	0.66 (0.88)	-0.05 (1.18)

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Table 3. Energy expenditure values for each sedentary activity, mean (SD).

	O_2 ml/kg/min	kcal/kg/min	METs[a]
Predicted BMR[b]		0.032 (0.003)	1.00
Watching TV	7.64 (2.47)	0.037 (0.010)†	1.17 (0.30) †
Sitting at a table	9.25 (1.82)*	0.044 (0.007)*†	1.38 (0.22)* †
Playing with toys	8.83 (2.10)	0.043 (0.009)*†	1.35 (0.23)* †

[a] METs defined as mutliples of predicted basal metabolic rate using the Schofield equation[19]; [b] predicted basal metabolic rate using the Schofield equation; *$p<0.05$ compared to watching television; † $p<0.05$ compared to predicted BMR