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Comparison of energy expenditure of tasks in standing and sitting in adolescent girls

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Abstract.
BACKGROUND: Adolescent girls are prone to increased sedentary behavior and are more sedentary than their male peers or younger girls. This study compared the energy required for identical tasks in standing and sitting.
METHOD: Energy expenditure (EE) was measured using indirect calorimetry ($n = 24$) in four tasks (sitting/standing quietly; reading; typing; sorting paper) under two postural conditions (sitting; standing). The currently accepted definition for sedentary behavior of energy expenditure of $\leq$1.5 metabolic equivalents (METs) and being in a seated or reclining position was used.
RESULTS: All seated tasks resulted in mean EE <1.5 METs with the exception of sorting paper. All standing tasks resulted in mean EE of >1.5 METs with the exception of standing quietly. Standing sorting paper was the only task with a mean EE significantly >1.5 METs. A significant interaction between task and posture found.
CONCLUSIONS: Active tasks in standing had significantly greater EE than in sitting, and sorting paper while standing was the only task with an EE significantly >1.5 METs. The difference between the two postures is likely too low to produce positive metabolic health benefits in the short term. Studies of the effects of long-term use of standing desks in the classroom are required.

Keywords: Sedentary behavior, calorimetry, METs

1. Introduction

Research links sedentary behavior with chronic disease, morbidity and mortality in adults [6, 9, 15, 31, 42]. Available evidence suggests that sedentary behavior is a health risk in children and young people [43]. In child populations, research has shown an association between a sedentary lifestyle and increased body weight [16, 23], poor metabolic health [5], low aerobic fitness [16] and reduced psychosocial functioning [45]. Perhaps more worrying is that a sedentary adolescent is likely to become a sedentary adult [17]. Adopting sedentary behaviors in adolescence can potentially put an individual at increased risk of chronic disease as an adult. The currently accepted definition of sedentary behavior stipulates two criteria to being sedentary; expending less than or equal to 1.5 metabolic equivalents (METs) and being in either a seated or reclining position [38]. Levels of sedentary behavior are high in children and generally increase with age [31] and evidence would suggest that sedentary behaviors are formed during adolescence [7, 29, 37]. Adolescent girls are particularly vulnerable to increased sedentary behavior and are more sedentary than their male peers or younger girls [11, 24, 35, 36]. Adolescents spend a significant proportion of their waking hours in school, and increased time spent engaging in schoolwork is implicated in

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increased sedentary behavior or decreased physical activity seen in this age demographic [35, 41]. Children typically spend half of their time at school seated [34], and standing desks have been proposed as a potential means of reducing sedentary behavior in offices for adults [18, 22, 25, 39] and in the classroom for children [2, 4, 19, 20, 27]. There appears to be a consensus that the addition of standing desks in a classroom results in increased standing time [20, 27] and benefits in neurocognitive function [26]. Thus, the use of standing desks appears to have the potential to reduce sedentary behavior among children without disrupting academic engagement [12].

Previous studies have indicated that mean energy expenditure, as measured by accelerometers/activity monitors, was significantly higher when children worked at standing desks compared to working at seated desks [2, 3, 4]. Accelerometers or activity monitors however have been demonstrated to underpredict the energy expenditure of sedentary behavior when compared to indirect calorimetry [33]. To date, no study has examined standing and seated posture in adolescents using indirect calorimetry, which provides a more accurate estimation of energy expenditure. The aim of the current study was to determine the energy expenditure of conducting identical tasks in standing and sitting. The objectives were to: (i) compare the energy expenditure of standing compared to sitting; (ii) determine the energy expenditure of the different tasks in standing and sitting and to (iii) determine the effects of BMI on energy expenditure in both postures.

2. Methods

2.1. Participants

A convenience sample of participants were recruited through local girl's schools. Participants were required to be under 18 years of age, provide written informed assent and written informed consent from their parent or guardian. Those with a history of metabolic disease or disease affecting metabolic rate were excluded, as were those with a musculoskeletal injury that affected their ability to sit or stand. Those with cognitive impairments, chronic infectious disease and active infections were also excluded. G*power software, Version 3.1.9.2 [14] was used to determine the sample size. An a priori power calculation revealed that with alpha = 0.05, an effect size of 0.25, and a power of 0.95, 22 participants were needed for this study. The effect size was calculated based on an estimated effect variance of 0.40 and an estimated error variance of 0.36, which resulted in a medium sized partial eta squared of 0.5. As there was little previous research from which to calculate the effect size and with the potential for dropouts, it was considered prudent to recruit 24 participants.

2.2. Procedure

Permission was sought from the principals of two local girl's schools to display recruitment posters with interested students requested to take an information leaflet as well as parental/guardian consent and assent forms from the school office. The year head then contacted the researchers to arrange suitable times for the testing to take place. Parents/guardians were advised that they should accompany their child on the day of testing or consent to have a chaperone present. A SMS message was sent to confirm participation and a reminder was given regarding fasting requirements. The institutional Ethics Committee granted ethical approval.

The study was conducted either in an exercise laboratory in the university or if more convenient for the participants, in a suitable designated venue within the school. The participants were asked to abstain from caffeine and moderate to vigorous exercise for 12 hours prior to testing, and to fast for four hours prior to testing. On arrival at the testing site, the participants were familiarized with the study protocol and equipment. They also had an opportunity to ask questions. Height and weight were measured using a calibrated stadiometer (Seca model 213) and scales (Tanita HD 352) respectively, with participants wearing light clothing and shoes removed.

Energy expenditure during the study was measured using the Cosmed K4b^2 portable indirect calorimeter (Cosmed, Rome, Italy). The Cosmed K4b^2 has been shown to be reliable [13] and valid [45] in the measurement of energy expenditure. Furthermore, the portable nature of this tool enabled participates to move naturally during testing. The Cosmed K4b^2 was calibrated prior to testing each participant.

2.3. Study design and testing protocol

A quasi-experimental study with a cross-sectional randomized cross over design was used. The protocol described here is the same as that reported in an earlier study on adults [8]. Participants were fitted with a heart rate monitor and the Cosmed K4b^2 and asked to lie supine for 15 minutes. This gave participants time to become comfortable wearing the equipment before the measurements of the tasks were taken. The tasks represented common seated/school-based activities and were as follows; sitting quietly, sitting and reading, sitting and typing, sitting and sorting paper, standing quietly, standing and reading, standing and typing, standing sorting paper. Each task was performed for 5 minutes with a one-minute break in between tasks, and task order was randomized using a random number generator. The tasks were standardized between participants who all read the same printed material, typed the same material and sorted the same collection of papers in the same way.

2.4. Data analysis

Weight categories were determined using the International Obesity Task Force (IOTF) BMI cut-off values for age and gender [10]. MET values were calculated using the standardised formula of METs = VO_2 of task in mL/min/kg divided by 3.5 [28]. As there is debate over the validity of MET values as multiples of 3.5 in children, results are also reported in VO_2 in ml/min/kg, but MET levels were used in analysis for ease of comparison with current guidelines for sedentary behavior (SBRN). VO_2 was calculated using the system software of the Cosmed K4b^2. Data were analysed using SPSS Statistics version 22.0. Statistical significance was set at $p < 0.05$. Data were checked for normality using the Kolmogorov Smirnov test. Mean and standard deviations were calculated for baseline data and for the energy cost of each activity in METs and VO_2. To determine whether the location of testing affected results, an independent *t*-test was conducted comparing results obtained from those who underwent testing in school with those who underwent testing in the university laboratory. Graphical interpretation of means with confidence intervals were used to enable comparison between METs expended during tasks with the cut-off criteria for sedentary behavior of 1.5 METs. This method was further supported by a single sample *t*-test. The overall difference between posture and tasks were analyzed using a 2 × 4 [posture (sitting, standing) × task (quietly, reading, typing, sporting paper)] repeated measures analysis of variance (ANOVA). Bonferroni tests were used for *post hoc* pairwise comparisons of significant effects. A paired *t*-test was used to examine the difference in energy cost of the same tasks in sitting compared to standing. Finally, to determine whether BMI affected the results an independent *t*-test was conducted between results of those with a healthy weight and those who were either overweight or obese.

3. Results

Twenty-four participants with a mean age of 15.6 ± 0.6 years were recruited for the study. Half of the participants (50%) had a healthy weight (mean BMI 21.2 ± 1.43) and the remaining participants were either overweight or obese (mean BMI 27.7 ± 3.25). Close examination of the data revealed one outlier point, which on further examination was found to have been caused by an isolated technical difficulty during the standing and typing task for this participant. This one outlier was removed from the standing typing data. All data was normally distributed.

There was no significant difference between the results obtained from those tested at their school ($n = 10$) and those tested at the university laboratory ([$n = 14$], $p > 0.1$ for all variables). Figure 1 shows the mean and 95% CI MET values for all tasks in both a seated and standing posture. A reference line at 1.5 METs is included for ease of comparison with the recognized energy expenditure cut-off point for sedentary behavior. Only one task (standing sorting paper) resulted in an energy expenditure which was statistically significantly higher than 1.5 METs, and only one task resulted in an energy expenditure statistically significantly lower than 1.5 METs (sitting reading).

The two-way analysis of variance comparing the effect of posture and task on energy expenditure revealed a significant difference between tasks [F (3, 66) = 15.36, $p < 0.001$, $n^2 = 1.692$], posture [F (1, 22) = 27.90 $p < 0.001$, $n^2 = 0.597$] and a significant interaction between task and posture F (3, 66) = 3.879, $p = 0.013$, $n^2 = 0.297$]. *Post hoc* tests revealed that overall standing resulted in a significantly greater energy expenditure than sitting (95% CI 0.069 to 0.159), and that sorting paper resulted in a significantly greater energy expenditure than reading, typing or being quiet ($p = 0.001$). There was no statistically significant difference between the energy cost of sitting quietly and standing quietly. There was a statistically significant difference between identical tasks (reading, typing

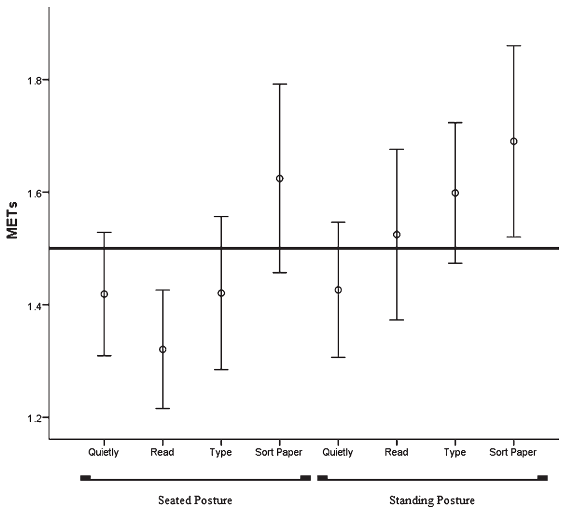

Fig. 1. Mean and 95%CI for each task compared with 1.5 METs.

and sorting paper) conducted in a different posture (seated versus standing). The MET and VO_2 values for each task in sitting and standing and the difference between postures is illustrated in Table 1.

Examining the effect of body composition on energy expenditure showed a significant difference ($p = 0.042$) in the mean energy cost (expressed in METS and mL/min/kg) of sitting while sorting paper between those of a healthy BMI (1.82 ± 0.36) and those categorized as either overweight or obese (1.48 ± 0.38). Those who were either overweight or obese expended significantly less energy per kilogram body weight than those of a healthy weight while sitting and sorting paper. There was no significant difference between these groups for any other task.

4. Discussion

The mean energy expenditure for most of the tasks in sitting was less than 1.5 METs, therefore meeting the currently accepted definition for sedentary behavior. There are no comparable studies in adolescent girls, but in adult populations similar results have been found with energy expenditure of less than 1.5 METS reported for similar seated tasks [8], sitting at a desk [21], typing [40], watching television or reading [30]. The only task in sitting that had a higher energy expenditure than 1.5 METs was sorting paper, with a value of 1.65 METs thus exceeding the cut-off point for sedentary behavior. Higher energy expenditure would be expected with tasks that involve movement of the upper limbs however, the energy expenditure of 1.65 METs was not statistically significantly different from an energy expenditure of 1.5 METs.

The mean energy expenditure values for tasks carried out in standing were all, except standing quietly, above 1.5 METs. As standing quietly had a MET value of 1.4 METs, which was similar to sitting quietly, substituting sitting with standing may not be sufficient to produce a beneficial effect in terms of metabolic health. The task being conducted must also be given some consideration. Even though all of the tasks except standing quietly were above 1.5 METs only one task, standing and sorting paper was significantly greater than 1.5 METs. The energy cost of the posture is therefore influenced by the task that is being conducted. With the exception of staying quiet, tasks conducted in a standing position resulted in a greater energy expenditure than identical tasks conducted while seated. The use of standing desks has been proposed as a strategy to improve and promote activity in the classroom [2, 4, 27] but the findings of

Table 1
MET and VO_2 values for each task in seated and standing posture and difference between postures

Task		Seated Mean (SD)	Standing Mean (SD)	Difference *P* (95% CI of difference)
Quietly	METs	1.44 (0.26)	1.44 (0.29)	0.797 (–0.081 to 0.063)
	VO_2; mL/min/kg	5.02 (0.91)	5.01 (0.99)	0.925 (–0.258 to 0.283)
Reading	*METs	1.35 (0.27)	1.54 (0.35)	0.003 (–0.320 to –0.074)
	*VO_2; mL/min/kg	4.71 (0.94)	5.40 (1.24)	0.003 (–1.119 to –0.257)
Typing	*METs	1.42 (0.31)	**1.60(0.29)	**0.002 (–0.282 to –0.074)
	*VO_2; mL/min/kg	5.07 (1.17)	**5.60(1.01)	**0.002 (–0.987 to –0.261)
Sorting Paper	*METs	1.65 (0.40)	1.73 (0.43)	0.020 (–0.147 to 0.014)
	*VO_2; mL/min/kg	5.78 (1.40)	6.06 (1.52)	0.021 (–0.514 to –0.047)

*Indicates statistically significant difference between seated and standing postures. **Indicates $n = 23$ due to removal of an outlier.

this study suggest that it is the task-related movement associated with using standing desks as well as the posture of standing that leads to an increased energy expenditure.

Although statistically significant, the energy difference seen between seated and standing tasks in this study was only measured over a short period of time. If however these energy differences occurred over many hours and days there could be positive health benefits. Long-term standing in the classroom using standing desks could have the potential to significantly increase energy expenditure in the classroom. Interventions that aim to improve health and promote wellness need to be sustained in order for the health benefits to materialize. The short-term use of standing workstations in elementary schools has been shown to be acceptable to children, parents and teachers [19]. Benden et al. [4)] and Alkhajah et al. [1] reported that energy expenditure was significantly increased by the use of standing desks in elementary school classrooms and at office workstations, respectively. However, in both studies the novelty value of the intervention was identified because the initial positive physiological [4] and behavioral [1] responses were not maintained over time. In order to achieve positive benefits, long term changes are required.

The effect of body weight on the energy cost was that sitting and sorting paper was significantly different between the groups, with overweight and obese participants using less energy (mL/min/kg) than those who had a healthy weight. In contrast to the findings, a previous study reported that overweight and obese participants expended greater energy than healthy weight participants [4]. The discrepancy in the results could be explained by the different measures used to collect data (Senswear armband versus portable indirect calorimetry) and in the reporting of results (expressed in relation to body weight or not).

This study explored the energy required by adolescent girls to do common tasks in sitting compared to standing. Previous studies of energy expenditure were classroom-based and data on energy expenditure was collected using fitness trackers worn on the arm [2, 3, 4], whereas the current study used indirect calorimetry, the gold standard for the measurement of energy expenditure over short periods of time in free-living conditions. This study adds to the current literature through a reduction in data variability gained from a repeated measures design, and in particular the addition of energy expenditure data collected through indirect calorimetry.

4.1. Limitations

Identical sitting and standing tasks were assessed, enabling a direct comparison between standing and seated postures. In order to get accurate measurements of energy expenditure the current study was conducted in a designated room or laboratory rather than a classroom, and this may limit ecological validity. Furthermore, subjects may have taken steps while in the standing position as the participants were not restricted in their movement at the workstation for the duration of testing, but this would be similar to behavior in a real world setting.

5. Conclusions

This study determined the energy expenditure of identical tasks in standing and sitting in school-aged girls. All but one task (standing quietly) carried out in standing had a mean MET value greater than 1.5 METs. Overall, standing resulted in significantly greater energy expenditure than sitting and the task of sorting paper while standing resulted in significantly greater energy expenditure than any other task, with an energy expenditure significantly higher than 1.5 METs. Long-term standing in the classroom using standing desks could have potential to significantly increase energy expenditure, but studies examining their long-term use are required.

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Conflict of interest

None to report.

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