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Energy utilization associated with regular activity breaks and continuous physical activity: A randomized crossover trial☆

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Abstract *Aims:* To quantify and compare energy utilization associated with prolonged sitting alone, or interrupted with regular activity breaks and/or an additional bout of continuous physical activity.
Methods and results: Thirty six adults (11 males, BMI 24.1 ± 4.6) completed four interventions: (1) prolonged sitting (SIT), (2) sitting with 2-min of walking every 30 min (RAB), (3) prolonged sitting with 30-min of continuous walking at the end of the day (SIT + PA), (4) a combination of the activities in (2) and (3) above (RAB + PA). All walking was at a speed and incline corresponding to 60% VO_{2max}. Energy utilization over 7 h for each intervention was estimated using indirect calorimetry. Compared to SIT, SIT + PA increased total energy utilization by 709 kJ (95% CI 485−933 kJ), RAB by 863 kJ (95% CI 638−1088 kJ), and RAB + PA by 1752 kJ (95% CI 1527−1927 kJ) (all $p < 0.001$). There was no difference in total energy utilization between SIT + PA and RAB, however, post-physical activity energy utilization in RAB was 632 kJ greater than SIT + PA (95% CI 561−704 kJ; $p < 0.001$).
Conclusions: Short frequent activity, results in greater accumulation of elevated post-physical activity energy utilization compared to a single bout of continuous activity; however the total energy utilization is similar. Combining activity breaks with a longer continuous bout of activity will further enhance energy utilization, and in the longer term, may positively affect weight management of a greater magnitude than either activity pattern performed alone.
Trial registration: ANZCTR12614000624684.

Introduction

The average American spends more than 8 h a day in sedentary behaviors [1]. These sedentary behaviors, defined as any waking behavior performed in a seated or lying position associated with an energy expenditure of less than or equal to 1.5 METs [2], are correlated with increased cardio-metabolic morbidity and all-cause mortality [3]. It appears that the pattern in which sedentary behavior is accumulated may also contribute to disease risk, with individuals who regularly interrupt their sedentary time having a more favorable cardio-metabolic risk profile than those who accumulate sedentary time in more sustained bouts [4,5]. However, the mechanisms that are responsible for this beneficial association between interrupting sedentary time and cardio-metabolic risk are not well understood. The results of a growing number of acute intervention studies have indicated that performing

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regular (every 20 or 30 min), short (1 min 40 s - 5 min) bouts of light or moderate activity can reduce postprandial glucose, insulin and triglyceride responses, and blood pressure, on the same or subsequent day [6–9].

Activity induced increases in energy utilization, and/or alteration in substrate metabolism may, at least in part, explain the association between increased sedentary time and increased morbidity and mortality [3]. Theoretical increases in daily energy utilization have been extrapolated from single exposures to an activity break (one activity break in a 30-min period of sitting) to accumulate an additional 100–669 kJ 8 h^{-1}, depending on the duration, intensity and modality of the activity break [10,11].

These previous investigations, however, assume that energy utilization of single break accurately represents the energy utilization of every single repetition of that activity, if performed repeatedly over the day. It has recently been proposed that the increased frequency of sit to stand transitions may elicit an independent effect on energy utilization above that of continuous standing, likely due to the increased skeletal muscle activation required during the transition in posture [12]. However, no study has described the energy utilization of repeated breaks when the activity during the break itself meets or exceeds the physiological demands of the transition between sitting and standing, nor have they directly compared this energy utilization to a similar amount of total activity performed continuously. Therefore, the aim of this study was to quantify and describe the energy utilization profiles of breaking up prolonged sitting with regular activity breaks, prolonged sitting followed by a similar amount of continuous physical activity, and a combination of regular activity breaks and continuous physical activity.

Methods

Participants

Participants (n = 36) were 18–40 years of age, had predominantly sedentary occupations, and did not self-report regular participation in more than 150 min of moderate to vigorous physical activity per week, nor did they have any medical conditions known to effect glucose or lipid metabolism, but were otherwise healthy.

Study design

This randomized, controlled, crossover trial was undertaken at the University of Otago, in Dunedin, New Zealand between June 2014 and November 2015. The University of Otago Human Ethics Committee approved the trial (approval number 13/112), and written informed consent was obtained from all participants before screening. This study was part of a larger, two-day intervention study, with detailed screening and testing procedures previously described [13]. The present analysis focuses on describing the energy utilization only on day one of each intervention. In brief, participants attended the laboratory for two preliminary visits (screening and aerobic fitness testing) before completing four intervention sessions in a randomized order, each separated by a minimum of 6 days. The randomization of intervention order was performed by one of the investigators (MCP) prior to participant recruitment using Stata software (version 11.2 for MAC; StataCorp, College Station, Texas), and concealed electronically. The sample size calculation was made based on the primary outcome of the larger study (glucose AUC). Based upon previous results [7] a 65% reduction in 5 h AUC for plasma glucose concentrations ($\alpha = 0.05$ and $\beta = 0.20$) required n = 32. The sample size was subsequently rounded to n = 36, to account for equal numbers of participants completing the 12 orders of intervention completion.

Experimental protocol

At the beginning of each intervention session, participants arrived at the laboratory having fasted for >10 h, having abstained from purposeful physical activity for three days and from alcohol consumption for 24 h. Participants replicated the food and drink consumed, including the amount and timing of caffeinated foods or drinks prior to their first intervention, at every subsequent intervention they completed.

The experimental protocol is presented in Fig. 1. Participants completed four interventions. Day one of each intervention comprised an observation period of seven hours, and is described below:

1) Prolonged Sitting (SIT): participants sat continuously.
2) Prolonged Sitting with Physical Activity (SIT + PA): participants sat continuously for 6.5 h then performed a 30-min bout of continuous walking.
3) Regular Activity Breaks (RAB): sitting was interrupted every 28 min by a 2 min bout of walking.
4) Regular Activity Breaks with Physical Activity (RAB + PA): sitting was interrupted every 28 min by a 2 min bout of walking for 6.5 h followed by a 30-min bout of continuous walking.

All prescribed walking was performed on a Stex 8020 treadmill (Stex, Anyang-Si, Korea) at a speed and incline to elicit 60% VO_{2max} (mean speed: 4.1 km h^{-1}, mean incline: 10%); determined at least 7 days prior to the initial intervention session using a modified version of the Bruce protocol [14]. This intensity was chosen as it has previously been shown to result in changes in postprandial glucose and insulin responses in young healthy individuals [7]. A combination of speed and incline was used to ensure all participants were walking, instead of running, at this intensity. Unless walking on the treadmill, participants were required to remain seated. When participants required the bathroom they walked slowly back and forth from the bathroom that was located 6 m away from their chair. An investigator was always present in the room with participants to ensure adherence to these protocols.

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