Journal of Science and Medicine in Sport 18 (2015) 294–298

Contents lists available at ScienceDirect

Journal of Science and Medicine in Sport

journal homepage: www.elsevier.com/locate/jsams

Original research

Breaking up prolonged sitting with light-intensity walking improves postprandial glycemia, but breaking up sitting with standing does not

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ARTICLE INFO

Article history:
Received 28 November 2013
Received in revised form 21 February 2014
Accepted 6 March 2014
Available online 20 March 2014

Keywords:
Exercise
Blood glucose
Sedentary lifestyle
Postprandial period

ABSTRACT

Objectives: To explore the effects of breaking up prolonged sitting time with standing or light-intensity walking on a range of cardiometabolic risk markers.
Design: A randomised three-period, three-treatment acute crossover trial.
Methods: Ten non-obese adults took part in three trials: (1) uninterrupted sitting; (2) seated with 2-min bouts of standing every 20 min; and (3) seated with 2-min bouts of light-intensity walking every 20 min. Two standardised test drinks (total 80.3 carbohydrate, 50 g fat) were provided after an initial 1-h period of uninterrupted sitting. Plasma glucose and blood pressure were assessed hourly to calculate area under the curve. Total cholesterol, HDL, and triglycerides were assessed at baseline and 5-h. ANOVAs were used to explore between-trial differences.
Results: Glucose area under the curve was lower in the activity-break condition compared to the uninterrupted sitting and standing-break conditions: mean area under the curve 18.5 (95% CI 17, 20), 22.0 (20.5, 23.5), and 22.2 (20.7, 23.7) mmol L/5-h, respectively, $p < 0.001$; no difference between uninterrupted sitting and standing-break conditions ($p > 0.05$). Systolic and diastolic blood pressure area under the curve did not differ significantly between conditions, nor did responses in lipid parameters ($p > 0.05$).
Conclusions: This study suggests that interrupting sitting time with frequent brief bouts of light-intensity activity, but not standing, imparts beneficial postprandial responses that may enhance cardiometabolic health. These findings may have importance in the design of effective interventions to reduce cardiometabolic disease risk.

1. Introduction

A modern day sedentary lifestyle (prolonged sitting) may be a significant contributor to hypokinetic disease risk.[1] Individuals with high levels of sedentary time may have a 112%, 147%, 90%, and 49% increased relative risk of diabetes, cardiovascular events, cardiovascular mortality, and all-cause mortality, respectively.[2] To reduce disease risk, interventions typically focus on engagement in moderate-to-vigorous physical activity (MVPA).[3] However, sedentary behaviour in itself is a risk factor for comorbidities and mortality regardless of physical activity level.[2,4]

Government guidelines recommend engagement in ≥150 min/wk of MVPA accumulated in bouts of ≥10 min.[5] However, improvements in postprandial glycemia occur following light-intensity activity similar to that observed following moderate- and vigorous-intensity activity.[6] Observational data show that frequent interruptions to sitting time (transition from sedentary to an active state for ≥1 min) are beneficially associated with metabolic risk.[4] The mean duration of these breaks was approximately 4 min, which was characterised by light-intensity physical activity.[4] Importantly, these relationships persisted after accounting for MVPA, suggesting that frequent short breaks in sitting time may impart unique benefit to health. Indeed, experimental data show interrupting prolonged sitting with short bouts of walking improves postprandial glucose and insulin levels.[7,8]

Interrupting sitting with standing could also impart health benefits,[9] although experimental studies in humans is lacking. A combination of 4-h standing and 2-h walking per day for four days improves fasting lipid levels and insulin sensitivity compared to vigorous-intensity exercise for 1-h per day.[10] However, the independent effects of standing were not explored and the potential for interrupting sitting with standing should be investigated.

This study therefore investigates the acute effects of interrupting sitting with standing or light-intensity walking on cardiometabolic risk markers in healthy adults.

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http://dx.doi.org/10.1016/j.jsams.2014.03.008
1440-2440/

2. Methods

The study was approved by the Sport Science and Physical Activity departmental ethics review board at the University of Bedfordshire and conformed to the Declaration of Helsinki. Written, informed consent was obtained from participants before any testing procedures following a verbal and written explanation of the nature and risks involved in the experimental procedures.

Ten healthy (free of any known metabolic or cardiovascular disease) participants with no contraindications to physical exercise took part (7 men, 3 women; mean age, 24.0 ± 3.0 y; mean BMI, 26.5 ± 4.3 kg/m^2) in this randomised repeated measures cross-over design study. Participants attended a familiarisation session where they became accustomed to the light-intensity walking speed and familiarised with use of the Borg Rate of Perceived Exertion (RPE).[11] During the familiarisation, RPE was recorded to ensure walking speed was equivalent to light-intensity activity for each participant (RPE of 6–9). Participants then made three separate visits to the laboratory to complete the 5-h trial conditions in a randomised order: (1) uninterrupted sitting; (2) sitting interrupted by standing breaks; and (3) sitting interrupted by light-intensity walking breaks. Because an acute bout of physical activity may enhance insulin sensitivity for up to 72 h,[12] a minimum wash-out period of 6 days between each condition was used to eliminate potential carryover effects of the activity conditions.

Participants were instructed to refrain from any exercise, alcohol, or caffeine for 24 h prior to each of the trial conditions. They attended the laboratory at 0900 h after an overnight fast and sat for 1-h to achieve a steady state before a resting blood sample and blood pressure measures were taken. Two standardised test drinks with a total of 80.3 g carbohydrate were then consumed: (1) 75 g carbohydrate (100% dextrose monohydrate powder; Thornton & Ross Ltd., UK) in 200 mL of water; energy, 273 kcal, and (2) 100 mL drink consisting of 50 g fat (Calogen; Nutricia, UK); nutritional components were energy, 467 kcal; fat, 50.0 g; saturated fat, 5.3 g; carbohydrate, 4.3 g; sugars, 4.0 g; protein, nil; fibre, nil; and sodium, 7.0 mg. The fat and protein content were included to (1) better simulate a mixed meal and (2) help slow the ingested glucose production to spread the plasma glucose responses over more of the 5-h treatment period.[13] Following consumption, the 5-h testing period commenced. Participants were guided through each trial and supervised at all times by a member of the research team to ensure full compliance with the protocols. Hourly blood samples were collected and hourly blood pressure readings taken prior to the standing or activity bouts during those respective conditions.

The trial conditions were as follows:

1. *Uninterrupted sitting*: participants remained seated throughout the experimental period and were instructed to minimise excessive movement, only rising from the chair to void.
2. *Sitting + standing breaks*: participants rose from the seated position every 20 min throughout the experimental period (three breaks per hour) and stood as still as possible for 2 min. They then returned to the seated position. This procedure was undertaken on 14 occasions, providing a total of 28 min standing.
3. *Sitting + light-intensity activity*: participants rose from the seated position every 20 min and completed 2-min bouts of light-intensity walking on a motorised treadmill (Woodway PPS55 Med-i, GmbH, Germany) with a level surface at 3.2 km/h, providing a total of 28 min activity. They then returned to the seated position.

Participants watched television or DVDs; read books, magazines, or newspapers; or worked on a laptop computer throughout the three conditions. Activity intensity during the sitting + activity breaks was monitored at the completion of each activity bout using the Borg RPE scale. Mean ± SD (range: min–max) RPE was 6.7 ± 0.9 (6–9).

Stature was measured to the nearest 0.1 cm using a stadiometer (Horltain Ltd., Crymych, UK) and body weight to the nearest 0.1 kg using electronic weighing scales (Tanita Corp., Tokyo, Japan). Blood pressure was measured in a seated position using an automatic device (Omron M5-I automated oscillatory device; Omron Matsusaka Co. Ltd., Matsusaka, Japan). Blood samples were obtained using a finger prick method and analysed immediately. Glucose was determined hourly using the YSI 2300 STAT plus glucose and lactate analyser (YSI Inc., Yellow Springs, OH, USA). The YSI uses a steady state measurement methodology, where membrane based glucose oxidase catalyses the oxidation of glucose to gluconic acid and hydrogen peroxide. The difference between the sample generated plateau current and the initial baseline current is proportional to the glucose concentration. The YSI was calibrated at the start of every day and every 45 min thereafter. Total cholesterol, HDL, and triglycerides were obtained at baseline and 5-h and determined using the Reflotron® Plus system (Roche Diagnostics, F. Hoffmann-La Roche Ltd., Burgess Hill, UK). Reflotron® plus is a compact reflectance photometer for fully automatic evaluation of Reflotron® tests. The instrument takes charge of all functions such as heating, automatic calibration, test execution and evaluation and calculation of results. The instrument has information on test principle and wavelength for each test and measuring ranges. The YSI and Reflotron® systems were maintained according to manufacturers' recommendations.

Sample size calculations were based on Dunstan et al.[7] who reported a 24% reduction in 5-h positive incremental AUC (iAUC) when interrupting sitting with 2 min of light-intensity walking every 20 min compared with uninterrupted sitting. Nine individuals were required to achieve 90% power to detect the minimum effect size between the three interventions, given a two-sided significance level = 5%.

Analyses were completed using SPSS version 19.0 (SPSS Inc., Chicago, IL). Data are presented as mean (95% CI). One-way ANOVA assessed between-trial condition differences in pre-trial weight and cardiometabolic risk variables. Total area under the curve (AUC) for each 5-h trial was calculated for glucose, systolic blood pressure, and diastolic blood pressure using the trapezoidal method and between-trial condition differences assessed using One-way ANOVA. Repeated measures ANOVA assessed differences across conditions for pre- and post-trial lipid parameters. Estimates of effect size for condition, partial eta squared (η^2), were calculated for each dependent variable. Statistical significance was accepted as $p < 0.05$. Graphical representations of results are presented as mean (SEM) to avoid distortion of the graphs.

3. Results

Biochemical and anthropometric data at baseline for each trial are shown in Table 1. There were no significant differences for baseline values between trials.

Fig. 1 shows glucose response over time during each of the trial conditions. A significant effect of condition with a large effect size was observed ($F = 8.59$, $p = 0.001$, $\eta^2 = 0.39$) for glucose AUC. As shown in Fig. 2, after sitting + activity breaks (mean AUC, 18.5; 95% CI 17.0, 20.0 mmol L/5-h) the glucose response to the test drink was 15.9% and 16.7% lower ($p < 0.001$) compared to uninterrupted sitting (22.0; 20.5, 23.5 mmol L/5-h) and sitting + standing breaks (22.2; 20.7, 23.7 mmol L/5-h), respectively.

There was no significant effect of condition and small effect size ($F = 0.45$, $p = 0.65$, $\eta^2 = 0.03$) for systolic blood pressure AUC: mean AUC, 601.5 (95% CI 565.5, 637.5), 585.3 (549.3, 621.3), and 608.1 (572.1, 644.1) mmHg/5-h for uninterrupted sitting,