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Original research

Effects of breaking up sitting on adolescents' postprandial glucose after consuming meals varying in energy: a cross-over randomised trial

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ABSTRACT

Objectives: To explore the impact of uninterrupted sitting versus sitting with resistance-type activity breaks on adolescents' postprandial glucose responses while consuming a diet varying in energy.
Design: Cross-over randomised trial.
Methods: Thirteen healthy participants (16.4 ± 1.3 years) completed a four-treatment cross-over trial: (1) uninterrupted sitting + high-energy diet; (2) sitting with breaks + high-energy diet; (3) uninterrupted sitting + standard-energy diet; and (4) sitting with breaks + standard-energy diet. For all four conditions, two identical meals were consumed; at 0 h and 3 h. A continuous glucose monitoring system (CGM) recorded interstitial glucose concentrations every five minutes. Linear mixed models examined differences in glucose positive incremental area under the curve (iAUC) and total AUC between the sitting and diet conditions for the first meal, second meal and entire trial period.
Results: Compared to the uninterrupted sitting conditions, the breaks condition elicited a 36.0 mmol/L/h (95%CI 6.6–65.5) and 35.9 mmol/L/h (95%CI 6.6–65.5) lower iAUC response after the first and second meal, respectively, but not for the entire trial period or for total AUC. Compared to the standard-energy diet, the high-energy diet elicited a 55.0 mmol/L/h (95%CI 25.8–84.2) and 75.7 mmol/L/h (95%CI 8.6–142.7) higher iAUC response after the first meal and entire trial, respectively. Similar response to the high-energy diet were observed for total AUC.
Conclusions: According to iAUC, interrupting sitting had a significant effect on lowering postprandial glucose for both dietary conditions, however, it was not significant when examining total AUC. Larger studies are needed to confirm these findings.
Clinical Trial Registration Number: ACTRN12615001145594.

1. Introduction

Chronic health conditions thought to develop during late adulthood, such as metabolic syndrome and type 2 diabetes, are now occurring at a younger age than in previous decades.[1] Some studies in youth,[2] but not all,[3] suggest that engaging in high volumes of sedentary time is associated with increased fasting blood glu-

Abbreviations: AUC, Area under the curve; CGM, Continuous glucose monitoring system.

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cose levels and insulin resistance which are key risk factors for developing these conditions. Thus, targeting reductions in sedentary time has the potential to improve an adolescent's metabolic profile and reduce their risk of developing metabolic syndrome or type 2 diabetes.

In the last decade, acute experimental trials have reported that interrupting sitting time with brief bouts of light- or moderate-intensity walking reduces postprandial glucose and insulin levels in healthy[4,5] and overweight/obese adults.[6,7] Moreover, two recent randomised cross-over studies have extended these findings into younger populations.[8,9] One study by Belcher et al. demonstrated that interrupting 3 h of continuous sitting with 3-min light-intensity walking breaks every 30 min reduced postprandial glucose by 7% and insulin levels by 32% in children aged 7–11 years.[8] However, the other study by Saunders et al. reported no significant differences in glucose or insulin responses in children aged 10–14 years when 8 h of prolonged sitting was interrupted with 2-min light- or moderate-intensity walking breaks every 20 min.[9]

The inconsistent findings between experimental studies may be explained in part by disparities in the energy content of the meals and by differences in blood sampling intervals. In the study by Saunders et al.,[9] although the meals were specifically developed for a young population, they may not have contained enough energy or the most suitable foods or beverages to raise glucose and insulin levels as has been demonstrated in adult studies.[4–6] In contrast, the findings by Belcher et al.[8] indicate that the use of meals containing a large amount of energy (e.g. a buffet style meal) may be necessary to elicit a sufficient glycaemic challenge to observe significant differences between intervention conditions. In addition, blood samples were collected at different time intervals (i.e. 30 min[8] versus 90 min[9]), which may not have been sufficiently regular to capture the fluctuations in glucose often seen in healthy, young populations. Continuous glucose monitoring systems (CGM) are minimally invasive and assesses interstitial glucose concentrations every 5 min. This provides the opportunity to assess the various temporal changes in blood glucose levels.[10] Although these devices are widely used clinically and in patients with type 1 or 2 diabetes,[10,11] no study to date has used a CGM to examine the acute effects of interrupting sitting on glucose responses in a healthy, young population.

Given the key role that dietary intake has on glucose metabolism,[12] it is surprising that no study to date has examined the effects of interrupting prolonged sitting on postprandial glucose when the dietary component is manipulated. Therefore, the aim of this pilot study was to explore the impact of uninterrupted sitting versus sitting with activity breaks on adolescents' postprandial glucose responses after consuming a diet varying in energy (e.g. high-energy versus standard-energy) across three time periods; (1) after the first meal; (2) after the second meal; (3) and the entire trial period. While we anticipated that the high-energy diet would elicit increased glucose responses overall, we hypothesised that the activity breaks would significantly attenuate postprandial glucose after the first meal, second meal and the entire trial period when compared to uninterrupted sitting for both diet conditions.

2. Methods

Ethical approval was obtained by Deakin University Human Research Ethics Committee in April 2015 (#2015-039). Study participants were recruited between September and December 2015 via flyers, local newspaper advertisement and word of mouth in Melbourne, Australia. Eligible participants were aged between 14 and 17 years, in good general health, not on any glucose lowering medications and had no dietary allergies. Eligibility criteria were assessed via phone screening interview with the participant or their parent. The recruitment stages are shown in Fig. S1. Written parental and participant consent was provided by 16 participants, with 15 participants completing the four trial conditions over the school summer holidays (November 2015 to January 2016). Participants who completed all four conditions received a FitBit® as compensation for their time.

The study was an acute, cross-over factorial randomised trial involving four experimental conditions each performed over a 6-h period: (1) uninterrupted sitting and high-energy diet; (2) interrupted sitting with 2-min activity breaks every 18-min and high-energy diet; (3) uninterrupted sitting and standard-energy diet; and (4) interrupted sitting with 2-min activity breaks every 18-min and standard-energy diet. For each condition, participants received two meals, consumed at 0 and 3 h. The 2-min activity breaks involved body-weight resistance exercises and included 30-s half squats, 30-s calf raises, 30-s knee lifts and 30-s step-ups. Resistance-type activities were selected as resistance-type activities utilises larger muscle groups,[13] and thus may promote an increased energy expenditure and higher glucose uptake. The study protocol and an example of one of the experimental conditions is shown in Fig. 1.

After enrolment, each participant was assigned one of the predetermined condition orders using a sequence which was randomly computer-generated by a research assistant. Participants were kept blinded to the order in which they completed each condition until the morning of each visit. Since moderate-intensity physical activity has been shown to have no residual effects on plasma glucose past a 17-h period,[14] a one-day minimum washout period was selected between trial conditions. The 24-h prior to each condition, participants were asked to refrain from participating in any moderate-to-vigorous physical activity (MVPA). Compliance to MVPA was self-reported using a checklist completed the morning on each condition day.

For all four experimental conditions, participants arrived at the laboratory between 0730 and 0800 after a 12-h overnight fast. At the first visit only, participants' height, weight, waist circumference, and blood pressure were measured using standard procedures.[15,16] Participants had access to a television, DVDs, sedentary video games, and computer and internet services. Participants were provided with a comfortable chair throughout the trial and were instructed to sit upright and minimise any movement when not performing the activity breaks. If participants needed to use the lavatory, they were escorted in a wheelchair. Research staff directly supervised the participants at all times to ensure compliance with the protocol. For descriptive purposes, participants completed a questionnaire about their usual MVPA[17] and sedentary behaviours levels[18] on the first condition day, and completed a 1-day food diary of food, beverages and medications consumed the day before each of the four experimental conditions. The food diaries were collected by researchers the morning of each condition to ensure compliance to the 12-h overnight fast and to calculate usual energy and macronutrient intakes.

Prior to the first and third condition, two researchers visited the participant's home to insert a CGM (Medtronic iPro2™, Northridge, USA) on the right side of the participant's lower back. After the CGM was inserted, an adhesive, waterproof strip was placed over the top of the CGM to minimise movement of the sensor and to allow participants to shower. Due to the CGM recorder having a battery life of seven days, a new sensor was inserted prior to the third trial condition to be worn during the final two conditions. To calibrate the CGM, two capillary blood glucose samples were taken from each participant by the researchers during the two home visits, and three during the trial days. The capillary blood samples were used to calibrate the CGM at the time of downloading the data. At the home visits, participants also received four standardised dinners to consume the night prior to each of the trial conditions. The

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