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The effect of brief intermittent stair climbing on glycemic control in people with type 2 diabetes: A pilot study

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ABSTRACT

We examined the effect of brief intermittent stair climbing exercise on glycemic control using continuous glucose monitoring in people with T2D (n=7; 5m 2f; 21-70 y). The protocol involved three, 60-s bouts of vigorously ascending and slowly descending a flight of stairs. Mean 24-h blood glucose was unchanged after an acute session (p=0.43) and following 18 sessions over 6 wk (p=0.13). The protocol was well tolerated by participants but seemingly insufficient to alter glycemic control.

Keywords: interval training, glycemia, exercise intensity

INTRODUCTION

Lack of time is a common barrier to regular physical activity in people with type 2 diabetes (T2D) (Korkiakangas et al. 2009). Interval training, which involves alternating bouts of relatively intense exercise and recovery, can improve indices of glycemic control despite reduced time commitment (Jelleyman et al. 2015). Protocols are often performed in a laboratory setting using specialized equipment, which limits translation to a 'real-world' setting. Stair climbing is an accessible mode of exercise that can be performed in an intermittent manner. Brief bouts of vigorously ascending and slowly descending a single flight of stairs improved cardiorespiratory fitness in young healthy individuals when performed 3 days per week for 6 weeks (Allison et al. 2017). Short continuous bouts of stair climbing acutely reduced postprandial glucose, assessed using finger stick blood sampling, in adults with impaired glucose tolerance (Honda et al. 2016; Takaishi et al. 2012). The present pilot study sought to advance this previous work through the novel assessment of brief intermittent stair climbing on indices of 24-h glycemic control using continuous glucose monitoring (CGM) in people with T2D. We tested the hypotheses that, compared to a control period involving no exercise, (i) an acute bout of stair climbing would reduce mean 24-h blood glucose; and (ii) mean 24-h glucose would be reduced after 18 sessions of stair climbing over 6 weeks.

METHODS

Participants

Inclusion criteria were: diagnosed T2D ($\geq$ 6 months); no insulin; no change in body weight (<5%) or diabetes medication (3 months); HbA1c < 9.0%; and no myocardial infarction, stroke or diagnosed coronary artery disease. Sample size was calculated with analyses powered to detect a 1 mmol/L change in 24-h mean glucose based on previous data in our lab (Little et al. 2011). Assuming a moderate to high correlation of 0.6, six participants were needed to detect a change at an alpha level of 0.05 with 80% power (G*Power 3.1). Data are reported for seven participants who ranged in age from 21-70, with a mean BMI, HbA1c, and disease duration of 31 ± 5 kg/m^2, 6.5 ± 7%, and 6 ± 9 years. The protocol was approved by the Hamilton Integrated Research Ethics Board and all subjects provided written informed consent.

Experimental Design

This study involved i) screening and baseline testing; (ii) the acute response to a single exercise session; iii) a 6-wk training intervention; and iv) post-training measurements. Identical procedures were employed to assess the acute and post-training responses under controlled dietary conditions. All food was provided while participants wore the CGM, with per-meal targets of ~55% carbohydrate, ~30% fat, and ~15% protein. Energy intake was estimated using the Harris Benedict equation, multiplied by a physical activity level of 1.4, and averaged 2329 ± 244 kcal/day during the CGM observation period.

Screening involved a physician-directed 12-lead electrocardiogram (ECG) exercise stress test using the Bruce Protocol on a treadmill at Hamilton General Hospital. Following clearance by a consultant physician, participants completed a 6-min walk test (6MWT) and 30-s chair stand test. Participants also performed a stair climbing familiarization session.

Fasting blood glucose, insulin, and fructosamine were determined and insulin sensitivity calculated using the quantitative insulin sensitivity check index (QUICKI) (Sarafidis et al. 2007). A CGM device was inserted for collection of 24-h non-exercise control data. Participants returned to the laboratory ~24-h later and performed the stair climbing exercise, with the CGM removed ≥ 24-h after the session.

Exercise training involved three sessions of stair climbing per week for 6 wk. At least 72-h following the final training session, participants returned in the fasted state to repeat the same procedures used for baseline testing and the acute response to exercise.

Stair Climbing

The protocol consisted of 3 x 1-min bouts of repeatedly ascending and descending a single flight of stairs. This was set within a 10-min period, which included a 2-min warm up, walking for 1-min in between bouts, and a 3-min cool-down. Participants were instructed to, "Climb up and down the stairs one step at a time for one minute. Ascend at a pace that you find challenging, and descend at a pace you find comfortable, such that you feel you can safely manage the three bouts of stair climbing. Use the railings for support if you wish." Rating of perceived exertion (RPE) using the Borg 0-10 Category-Ratio (CR-10) Scale was recorded after each interval. HR was monitored continuously. Blood pressure and a finger prick blood glucose sample were taken ~ 10-min before and 5-min post-exercise. All sessions were supervised and all participants completed all training sessions. The number of stairs climbed was recorded and enjoyment was assessed ~5-10 min after the final training session using the Physical Activity Enjoyment Scale (PACES) (Kendzierski & DeCarlo, 1991).

Continuous Glucose Monitoring

CGM measurements were performed as previously described (Little et al. 2011). Briefly, participants were given a glucose meter (OneTouch Ultra2, Lifescan, Inc., Burnaby, BC) while wearing the CGM (iPro™2 Professional CGM with Enlite™ Sensor, Medtronic Inc., Northridge, CA). CGM data was downloaded using CareLink™ Pro software (Medtronic Inc.) and exported to Microsoft Excel for analysis. Measurements included mean 24-h glucose, time spent in hyperglycemia (> 10 mmol/L), and postprandial hyperglycemia, which was calculated using the absolute and incremental area under the curve (AUC), and the postprandial spike (PPS) in glucose, over each 2-h post-meal period. Metrics of glycemic variability, including mean amplitude of glycemic excursions (MAGE) and standard deviation (SD) from mean glucose (Rodbard, 2011), were assessed using the EasyGV platform (http://www.phc.ox.ac.uk/research/technology-outputs/easygv). The acute 24-h post-stair climbing period was compared to the non-exercise control day. The training response compared the 24-h non-exercise control day before and after 6 wk of stair climbing.

Statistical Analysis

Data are presented as mean ± SD for n=7 except HR (n=6). Paired t-tests were used to analyze the acute differences between the CGM parameters, and all data collected pre- and post-training. Effect sizes (Cohen's d_z for repeated measures) were calculated for all t-tests. Data collected within the first training session and during selected training sessions across weeks were analyzed using a one-way repeated measures analysis of variance (ANOVA) with time as the within factor. The Greenhouse-Geisser correction was used when data did not meet the assumption of sphericity, and post-hoc analyses were completed using t-tests with a Bonferroni correction. Significance was set at $p < 0.05$.

RESULTS

Acute Response to a Single Session of Exercise

Exercise Characterization

Participants climbed 59 ± 3 stairs per bout. Mean HR over the 10-min session was 74 ± 5% and peak HR reached 90 ± 8% of age-predicted maximum (Fig. 1). Absolute HR increased ($p<0.05$) over the three bouts (140 ± 15, 146 ± 16, and 151 ±16 bpm). RPE increased ($p<0.05$)

over the three bouts (3.9 ± 1.9, 4.7 ± 1.6, and 5.6 ± 1.7) with mean ratings that corresponded to "moderate", "somewhat hard", and "hard".

Glycemic Parameters

Capillary blood glucose decreased from 11.3 ± 2.6 to 8.6 ± 2.3 mmol/L after the first stair climbing session (p=0.01, d_z= 1.3). Mean 24-h glucose was not different after a single stair climbing session compared to control (p= 0.43, d_z=0.32; Fig. 2a). There was no difference in time spent in hyperglycemia (147 ± 185 vs. 140 ± 146 min, p=0.84, d_z=0.08). The SD around the mean improved (1.6 ± 0.5 vs. 1.4 ± 0.5 mmol/L, p=0.03, d_z=1.04) but there was no change in the MAGE (4.1 ± 1.5 vs. 3.6 ± 1.1 mmol/L, p =0.09, d_z=0.76). There were no differences in the absolute or incremental meal responses (all $p \geq 0.05$).

Exercise Training Response

Exercise Characterization

Total stairs climbed averaged 188 ± 48 stairs per session. Mean RPE over the 3 bouts for all training sessions was 4.7 ± 2.0 ("somewhat hard"). Mean HR per session was 73 ± 2% and peak HR per session averaged 90 ± 5% of age-predicted maximum.

Glycemic Parameters

Capillary blood glucose decreased from 10.5 ± 1.6 to 8.2 ± 1.9 mmol/L (p<0.01, d_z = 2.03) after the final stair climbing session. Mean 24-h glucose was unchanged after 6 wk of training (p=0.13, d_z=0.65; Fig. 2b) and there was no change in time spent in hyperglycemia (147 ± 185 vs. 201 ± 249 min, p=0.36, d_z=0.37). Glycemic variability was not changed based on MAGE (4.1 ± 1.5 vs. 3.9 ± 1.9 mmol/L, p=0.80, d_z=0.10) or SD around the mean (1.6 ± 0.5 vs. 1.6 ± 0.6 mmol/L, p=0.85, d_z=0.08). There were no differences in the absolute or incremental glycemic responses to breakfast and dinner (all p values > 0.05) but lunch PPS was reduced (p=0.02, d_z= 1.20). There was no change in fasting insulin (p=0.07, d_z=0.82), glucose (p=0.83, d_z=0.09) and fructosamine (p=0.83, d_z=0.08) but QUICKI improved (p=0.03, d_z=1.08).

Performance and Psychological Measures

Total distance walked (617 ± 99 vs. 616 ± 113 m, p =0.92, d_z=0.04) and 30-sec chair stand (16 ± 4 vs. 15 ± 3 stands, p =0.69, d_z=0.16) were unchanged following training. The overall enjoyment score determined by the PACES was 94 ± 18.

DISCUSSION

The main finding from the present study was that mean 24-h blood glucose was unchanged in people with T2D after a single session of brief vigorous stair climbing and following 6 wk of training. The exercise protocol was well tolerated by participants, with mean overall enjoyment scores similar to that reported after interval cycling exercise (87 ± 14) in adults at an increased risk of diabetes (Little et al. 2014). The lack of acute change in glycemic parameters contrasts with favourable changes seen in our previous study in which people with T2D performed 10 x 1-min bouts of intermittent cycling (Gillen et al. 2012), and work by Terada et al. (2016) who studied the effects of 15 x 1-min bouts of treadmill exercise. We speculate that the lack of acute change in 24-h glucose in the present study was owing to a relatively low total volume of exercise performed, and/or the self-selected relative intensity was insufficient to elicit acute improvements.

Mean 24-h glucose (Fig. 2b), time spent in hyperglycemia, and glycemic variability were unchanged following 6 wk of stair climbing training. These findings are in contrast to the improved 24-h glucose we previously reported after six sessions of cycling-based interval cycling over 2 wk (Little et al. 2011). Again, we speculate that perhaps a minimum "threshold" dose of vigorous intermittent exercise may be needed to elicit measurable changes in 24-h glycemic control. Mean intensity in the present study, as reflected by heart rate, was lower compared to the study by Little et al. (2011), which also involved a more substantive total volume of exercise over a shorter period of time (2 versus 6 wk). The lack of performance change during the 6MWT is consistent with the notion that the exercise protocol was insufficient to elicit training adaptations.

In summary, we report that most CGM-derived indices of 24-h glycemic control were unchanged in people with T2D after a single session of brief vigorous stair climbing and after 18 sessions over 6 wk. While the protocol was well tolerated by participants, the mean intensity achieved was lower than in our previous study of healthy individuals, and we speculate that a higher total volume of exercise is likely needed to alter 24-h glycemic control in people with T2D.

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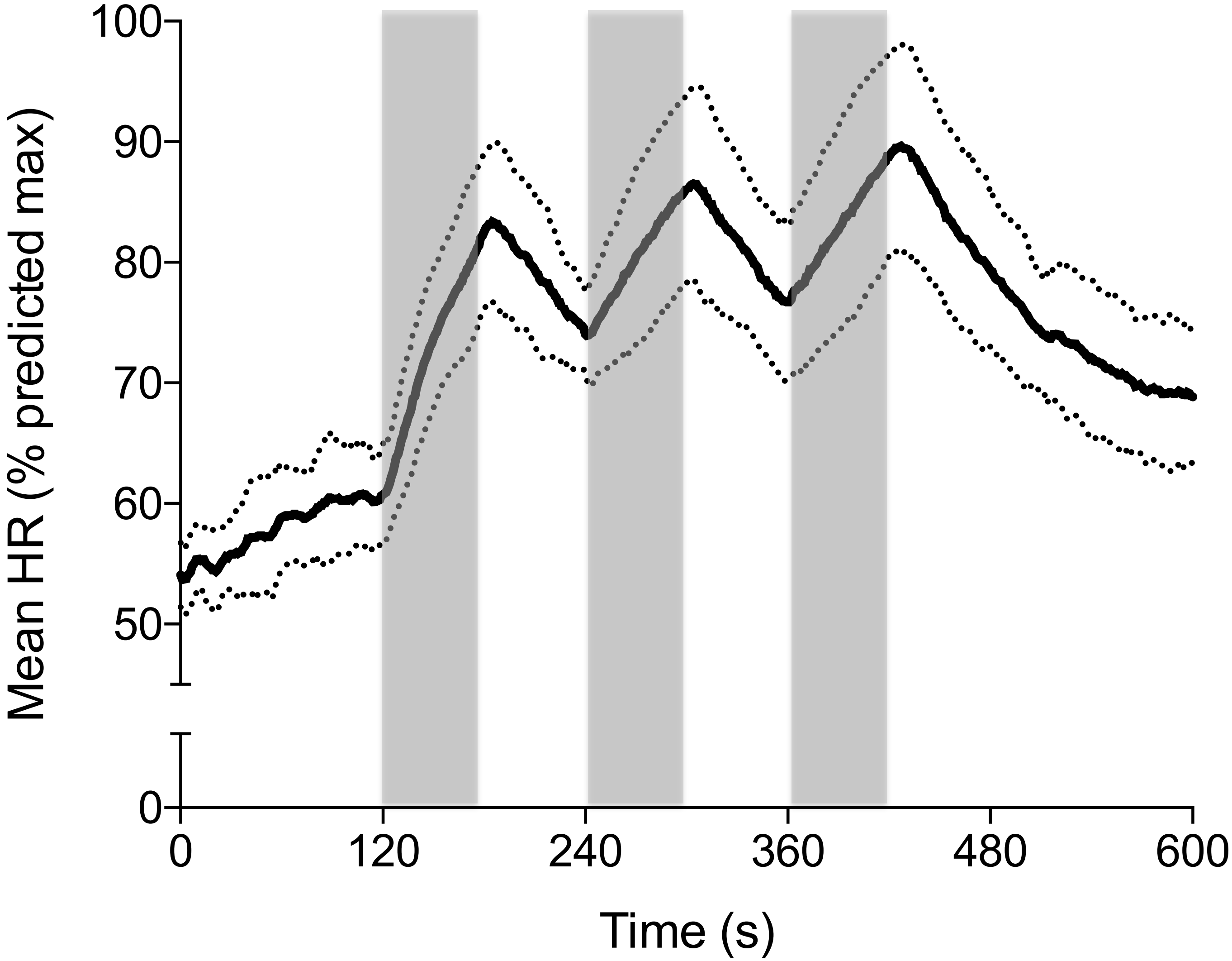
Figure 1. HR response to the acute 3 x 1-min stair climbing protocol. Values are from the acute session of stair climbing exercise, anchored to age-predicted heart rate maximum values (n=6). Values are mean ± SD. Shaded regions indicate stair climbing.

Figure 2. Mean 24-h blood glucose after a single session (A) and 6 wk (B) of stair climbing training. Panel A shows the 24-h non-exercise day (Baseline) and 24-h period after a single session of stair climbing (Acute). Panel B shows the 24-h non-exercise day before (Baseline) and after 6 wk of stair climbing training (Post-Training). Each line represents an individual participant. Values are mean ± SD.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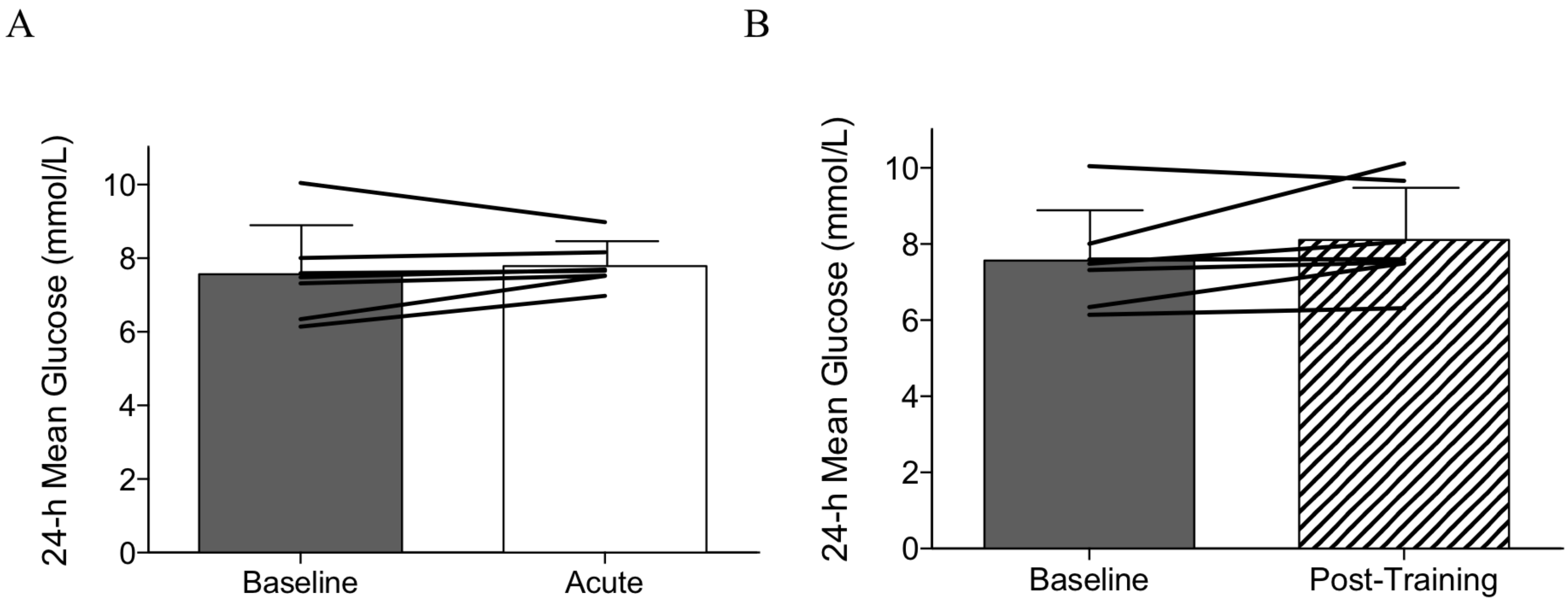
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