



Original Article

Repeated 3-minute stair climbing-descending exercise after a meal over 2 weeks increases serum 1,5-anhydroglucitol levels in people with type 2 diabetes

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Abstract. [Purpose] The purpose of this study was to examine the hypoglycemic effect of a postprandial exercise program using brief stair climbing-descending exercise in people with type 2 diabetes. [Subjects and Methods] Seven males with uncomplicated type 2 diabetes (age 68.0 ± 3.7 years) performed two sets of stair climbing-descending exercise 60 and 120 min after each meal for the first 2 weeks but not for the following 2 weeks. Each set of exercise comprised 3-min of continuous repetition of climbing briskly to the second floor followed by slow walking down to the first floor in their home. A rest period of 1–2 min was allowed between each set. [Results] Serum 1,5-anhydroglucitol level was significantly higher by 11.5% at the end of the 2-week exercise period than at the baseline. By contrast, the 1,5-anhydroglucitol level at the end of the following 2-week period did not differ from the baseline value. Fasting blood glucose level and insulin resistance index at the end of the exercise period did not differ from the baseline value. [Conclusion] Repeated 3-min bouts of stair climbing-descending exercise after a meal may be a promising method for improving postprandial glycemic control in people with type 2 diabetes.

Key words: Exercise, Glycemic control, Type 2 diabetes

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INTRODUCTION

Aerobic exercise (AE) is an important modality for controlling blood glucose (BG) level in people with type 2 diabetes (T2D). Although AE should be performed at least at moderate intensity, corresponding to 40–60% of maximum aerobic capacity, it is recommended that people who already exercise at a moderate intensity should undertake high-intensity AE to obtain additional beneficial effects on BG level¹. High-intensity AE effectively reduces the postprandial BG level^{2–4}, which is considered an independent risk factor for cardiovascular disease^{5–7}. However, the reported protocols for high-intensity AE (e.g., 6 bouts of 1 min of high-intensity incline walking², 10 bouts of 60 s of high-intensity cycling³, or repeated intervals of 3 min of slow and fast walking for 1 h⁴) are too strenuous and long, and/or need exercise equipment to be performed regularly by many people with T2D.

We have been conducting a series of original studies to demonstrate that brief stair climbing-descending exercise (ST-EX), which is a convenient method for performing high-intensity AE, is sufficient to reduce the postprandial BG level^{8–11}. ST-EX

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is easy to perform, needs no special exercise facility, and is not dependent on the weather. Typically, one set of ST-EX comprises 3–6 min of repeated brisk climbing up one flight of stairs followed by slow walking down to the starting point^{8–11}. In our most recent report, we have shown that a single brief bout of ST-EX for 3 min performed at 60 and 120 min after a meal hastened the postprandial decrease in BG level in people with T2D⁸. However, we have not examined whether a daily ST-EX program has a beneficial effect on glycemic control in people with T2D. In this study, we tested a home-based ST-EX program comprising two bouts of 3-min ST-EX performed 60 and 120 min after each meal for 2 weeks. We measured the changes in serum 1,5-anhydroglucitol (1,5-AG) level, as a sensitive index of postprandial hyperglycemia.

SUBJECTS AND METHODS

Seven Japanese males aged 60–75 years with T2D but no macrovascular or microvascular complications were recruited for this study (Table 1). Before enrollment, the methods of this study were approved by Toyooka Hospital Hidaka Medical Center Institutional Review Board, and written informed consent was obtained from all participants. The participants were being treated with oral hypoglycemic agents: glimepiride, metformin and voglibose (n=2); glimepiride, metformin and alogliptin (n=2); glimepiride, miglitol and sitagliptin (n=1); voglibose (n=1); or alogliptin (n=1). They also received medical nutritional therapy (energy intake: 1,400–1,800 kcal/day), which was continued during the experimental period. No exercise therapy except ST-EX was performed throughout the experimental period. No participant regularly climbed stairs in their daily life.

The total study period was 4 weeks. The participants performed ST-EX during the first 2 weeks at their home (ST-EX period) and did not perform this program during the following 2 weeks (REST period). The participants were instructed to perform two sets of ST-EX at 60 and 120 min after each meal (breakfast, lunch, and dinner) during the ST-EX period. Each set of ST-EX took about 3 min and comprised 8–10 continuous repetitions of stair climbing to the second floor of their home (13–15 steps, each 15–22 cm in height) at a rate of 80–110 steps/min followed by walking downstairs slowly to the first floor at a free step rate. The second set of ST-EX was started 1–2 min after the completion of the first set. The intensity of ST-EX was self-controlled to be in the range of 11–13 on the Borg rating of perceived exertion scale¹². Adherence to ST-EX was monitored through self-report. During the REST period, the participants were instructed not to perform ST-EX but were allowed to use stairs as necessary.

Blood samples were collected from an antecubital vein after an overnight fast from 9 pm at the baseline (before the ST-EX period), end of the first and second week of the ST-EX period, and end of the REST period. The measurement parameters were the fasting concentrations of BG, immunoreactive insulin (IRI), 1,5-AG, total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), and triglyceride (TG). The insulin sensitivity index (homeostasis model assessment of insulin resistance: HOMA-IR) was calculated according to the formula: fasting BG (mg/dl) × fasting IRI (μU/ml)/405¹³. Low-density lipoprotein cholesterol (LDL-C) concentration was calculated according to the formula: fasting TC – fasting HDL – fasting TG/5 (mg/dl)¹⁴.

The data were analyzed using SPSS software (version 15.0, SPSS Inc., Chicago, IL, USA). One-way repeated-measures analysis of variance (ANOVA) was used to identify differences in the changes of the parameters with time. For 1,5-AG, post hoc analysis was performed using Tukey's test to identify differences at each time point. The values are expressed as mean ± standard deviation (SD). Significance was set at p<0.05.

RESULTS

The blood analysis data are shown in Table 2. The fasting BG level and HOMA-IR did not change significantly during the study period. However, 1,5-AG level increased significantly by 11.5% at the end of the ST-EX period compared with the baseline (p<0.05), and this increase disappeared at the end of the REST period. LDL-C, HDL-C, and TG concentrations did not change during the study period. All participants completed the ST-EX program without clinical complications. Adherence to ST-EX estimated by the self-reported exercise performance rate (number of sets completed as scheduled/number of sets scheduled) was 73% ± 27%. The reasons for not completing all scheduled sets included leaving the house for personal reasons and forgetting to do ST-EX at the scheduled time.

Table 1. Baseline characteristics of the study participants

Age (years)	68.0 ± 3.7
Height (cm)	163.9 ± 4.9
Weight (kg)	58.9 ± 2.4
Body mass index (kg/m ²)	21.9 ± 1.1
Duration of diabetes (years)	11.6 ± 8.6
HbA1c (%)	6.9 ± 0.5

Values are the mean ± SD. N=7

DISCUSSION

In this preliminary study, we assessed the clinical effects of a 2-week program of ST-EX on postprandial hyperglycemia in people with T2D. We found that two sets of stair climbing exercise for as little as 3 min at 60 and 120 min after each meal significantly improved glycemic control, as indicated by the 1,5-AG level. 1,5-AG is tightly associated with BG fluctuations and is useful for evaluating postprandial glycemic control in the preceding several days to 1–2 weeks, unlike glycated hemoglobin which indicates glycemic control in the preceding 1–2 months^{15, 16}. A clinical study has suggested that 1,5-AG best reflects the 2-h postprandial BG level in the 2 preceding weeks in people with T2D¹⁷.

We have recently shown that a single bout of 3-min ST-EX performed at 60 and 120 min after a meal is sufficient to reduce the postprandial response in people with T2D⁸. This protocol significantly decreased the area under the curve for BG (0–180 min after a meal) by 18%⁸. However, in the present study, we used two bouts of 3-min ST-EX at 60 and 120 min after a meal to potentiate the hypoglycemic effect of ST-EX. We believe that this intensified protocol led to significant increases in serum 1,5-AG level despite the incomplete adherence, an inevitable outcome of home-based exercise programs.

The reasons for inactivity in people with diabetes includes perceived difficulty taking part in exercise, feelings of tiredness, being distracted by something interesting, and lack of time and exercise facilities¹⁸. Therefore, we used a brief, home-based exercise protocol that can be easily performed without needing exercise equipment or changing into specific clothing. The alternative repetition of ascending and descending stairs is a nonstrenuous method for performing high-intensity AE because the perception of exercise intensity is alleviated substantially during the decent and, thereby, the overall intensity can be increased without excessive effort^{8–11}. Additionally, we consider that the rest period between the first and second sets may also be important for reducing fatigue during the second set of ST-EX.

The fasting BG level and HOMA-IR did not change significantly after the ST-EX period (Table 2). In the absence of marked hyperglycemia (<180 mg/dl), HOMA-IR correlates with insulin sensitivity evaluated with the glucose clamp test in people with T2D¹⁹. HOMA-IR is set at 1.0 for healthy Caucasians, whereas the normal HOMA-IR value for Japanese people is <1.6, and a value >2.5 is interpreted as indicating insulin resistance (The Japan Diabetes Society, 2014). In the present study, the baseline HOMA-IR (Table 2) suggested that the study participants were not insulin resistant. This might be responsible for the observation that ST-EX did not significantly improve fasting BG level or HOMA-IR.

The major limitations of this study are the small sample size and the absence of a control group. A larger sample size and well-controlled studies are needed to confirm the hypoglycemic effect of the ST-EX program. In addition, we recruited lean patients whose T2D was well controlled and uncomplicated. Exercising on stairs may increase the risk of falling in older and/or obese people, particularly those with complications such as diabetic retinopathy (visual dysfunction), diabetic neuropathy (deterioration in the sensory, motor, and autonomic nervous systems), and cardiovascular and/or orthopedic disorders^{20, 21}. Further studies are required to evaluate the safety of ST-EX before clinical applications to diverse patient populations.

In conclusion, we found that repeated 3-min ST-EX starting 60 and 120 min after each meal for 2 weeks significantly increased serum 1,5-AG level in people with T2D. Although further studies are needed, we propose that postprandial ST-EX is a potentially useful method for improving postprandial glucose metabolism in people with T2D.

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Table 2. Time-course changes in fasting concentrations of blood parameters

Parameters	Baseline (pre-ST-EX period)	1 week (half-ST-EX period)	2 weeks (post-ST-EX period)	4 weeks (post-REST period)
BG (mg/dl)	146.0 ± 22.2	140.1 ± 31.1	135.3 ± 16.0	136.1 ± 19.7
1,5-AG (µg/ml)	11.2 ± 7.8	12.2 ± 8.1	12.5 ± 8.3*	11.6 ± 8.5
HOMA-IR	1.6 ± 0.8	1.4 ± 1.2	1.4 ± 0.5	1.2 ± 0.4
LDL-C (mg/dl)	118.3 ± 29.8	116.6 ± 35.5	106.4 ± 20.4	118.1 ± 29.1
HDL-C (mg/dl)	58.0 ± 14.8	56.9 ± 14.0	55.1 ± 14.5	57.7 ± 15.0
TG (mg/dl)	133.7 ± 65.0	135.4 ± 124.8	132.1 ± 84.8	176.9 ± 174.2

BG: blood glucose; 1,5-AG: 1,5-anhydroglucitol; HOMA-IR: homeostasis model assessment of insulin resistance; LDL-C: low-density lipoprotein cholesterol; HDL-C: high-density lipoprotein cholesterol; TG: triglycerides. Values are the mean ± SD. *p<0.05 vs. baseline. N=7

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