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Short Communication

Stair Climbing/Descending Exercise-Immediate Effect against Postprandial Hyperglycemia in Older People with Type 2 Diabetes Mellitus

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Abstract

The purpose of the present study was to examine whether a short bout of stair climbing/descending exercise (ST-EX) accelerates the decrease in postprandial blood glucose levels in older people with type 2 diabetes. Seven patients with no complicated type 2 diabetes (age 72±4 years, HbA1c 6.5±0.8%) performed ST-EX, walked on a flat floor, or sat on a chair for ~6.5 min starting 90 min after carbohydrate ingestion (30 g of starch hydrolysate), and then sat until 180 min after carbohydrate ingestion. ST-EX comprised 12 sets of stair climbing to the second floor at a rate of 90–120 steps/min followed by walking down to the first floor at a free step rate. The difference between capillary blood glucose levels at 90 min and 105 min was significantly greater when the subjects performed ST-EX (61±17 mg/dL) than when they walked (33±12 mg/dL, $P< 0.01$) or sat (21±10 mg/dL, $P< 0.01$). The area under the curve for blood glucose between 90 and 180 min was 15% lower when the subjects performed ST-EX than when they sat ($P< 0.05$).All the subjects completed ST-EX without distressing symptoms such as dyspnea or leg exhaustion, because of the reduction in perceived exertion during the descending and resting period. ST-EX may be a useful method for improving glucose excursion after a meal in people with type 2 diabetes.

ABBREVIATIONS

ST-EX: Stair Climbing/Descending Exercise; NEFA: Non Esterified Fatty Acids; %HRR: Percentage of Age-Predicted Heart Rate Reserve.

INTRODUCTION

Skeletal muscle is the major organ responsible for whole-body glucose uptake and utilization in humans. Exercise induces an insulin-like effect that activates the translocation of glucose transporter 4 in contracting skeletal muscle [1]. This phenomenon is considered to be responsible for the acute hypoglycemic property of exercise, whereby glucose in the blood is taken up by contracting skeletal muscles. Importantly, the exercise-mediated mechanisms for promoting glucose uptake remain intact in type 2 diabetes [2, 3].

Postprandial hyperglycemia is strongly linked to an increased risk for cardiovascular complications [4-6]. In studies of people with type 2 diabetes, Larsen et al. reported that moderate-intensity cycle ergometer exercise for 45 min [7] and four bouts of high-intensity cycle ergometer exercise for a total of 46 min [8] after a meal reduced the postprandial peak of blood glucose, while Manders et al. [9] showed that endurance-type exercise for 60 min at 35% of maximal work rate after a meal reduced the prevalence of hyperglycemia throughout the subsequent 24-h post exercise period. These results demonstrate the efficacy of exercise as a practical tool to control postprandial blood glucose levels. However, in practice, it is difficult to secure 45–60 min to perform exercise. Although Nygaard et al. [10] reported that post meal walking for 15–40 min is effective in reducing postprandial glucose levels in healthy middle-aged women; this effect has not been confirmed in type 2 diabetes patients. Therefore, it is desirable to develop an exercise that reduces blood glucose in a short time and is easy to perform.

The rate of glucose uptake in contracting skeletal muscle increases with exercise intensity [11,12]. Walking up stairs may be a convenient method, which is independent of weather conditions, for increasing the intensity of exercise in daily life without it taking an extended time. We reasoned that one could increase exercise intensity easily by performing an exercise that comprises alternately climbing and descending a flight of stairs, because the intensity is lessened when descending the stairs. In the present study, we examined whether a short bout of stair climbing/descending exercise (ST-EX) reduces the postprandial glucose response in older people with type 2 diabetes.

MATERIALS AND METHODS

Subjects

Seven people with type 2 diabetes but no microvascular or macrovascular complications (4 men and 3 women, age 72±4 years, duration of diabetes 13±8 years) volunteered for this study. Their mean±SD values measured prior to the experiment were as follows: body mass index (measured with a digital weight scale and a mechanical stadiometer) 21.8±3.2 kg/m2, fasting blood glucose concentration 98±20 mg/dL, HbA1c level 6.5±0.8%, and resting heart rate 67±7 beats/min (bpm). Five subjects were prescribed oral hypoglycemic agents as follows: metformin, glibenclamide, and miglitol (n = 1), metformin, gliclazide, and miglitol (n = 1), nateglinide and miglitol (n = 1), gliclazide (n = 1), and nateglinide (n = 1). These agents were discontinued on the experimental days. Written informed consent was obtained from all subjects before the experiments. The study protocol was approved by the institutional review board of Kyoto University, Graduate School of Human and Environmental Studies.

ST-EX and Walking Exercise

On separate days, 5–6 h after a Japanese-style breakfast (cooked rice, miso soup, and side dishes including broiled fish, rolled omelet, vegetables, and pickles; ~400 kcal), each subject ingested a test beverage containing 30 g of starch hydrolysate, and then sat for 180 min (REST); sat for 90 min, then walked on level ground (~75 m/min) for ~6.5 min, and then sat until 180 min total (WALK); or sat for 90 min then performed ST-EX for ~6.5 min, and then sat until 180 min total. ST-EX comprised 12 sets of stair climbing from the first to second floor (21 steps, each 18 cm in height) at a rate of 90–120 steps/min followed by walking down the stairs to the first floor at a free step rate. Heart rate was recorded using a heart-rate monitor (Polar Accurex Plus; Polar Electro, Kempele, Finland).

Blood Sampling and Analysis

Blood samples were drawn from a fingertip (for blood glucose and lactate concentrations) and the antecubital vein (other biochemical parameters). Glucose and lactate concentrations in capillary blood were measured using a glucose analyzer (Glutest Ace; Arklay, Kyoto, Japan) and a lactate analyzer (Lactate Pro; Arklay), respectively. C-peptide concentration was measured using an immunoassay kit (Mercodia, Uppsala, Sweden). Other biochemical parameters were assayed at Ikagaku Co. Ltd (Kyoto, Japan).

Statistics

All values are reported as the mean±SD. Two means were compared using Student's t test. Multiple means were compared by repeated-measures ANOVA. Post-hoc comparison with Fisher's PLSD test was performed as appropriate. Significance was set at $P < 0.05$.

RESULTS AND DISCUSSION

Results

The blood glucose level 90 min after carbohydrate ingestion (BG90) did not differ between the three exercise conditions (REST 237±34, WALK 228±47, ST-EX 225±34 mg/dL) (Figure 1a). However, the blood glucose level 105 min after carbohydrate ingestion (BG105) was significantly lower for ST-EX (163±32 mg/dL) than for REST (217±37mg/dL, $P < 0.05$). The difference between BG90 and BG105 was much greater for ST-EX (61±17 mg/dL) than for REST (21±12 mg/dL, $P < 0.01$) and WALK (33±10 mg/dL, $P < 0.01$). The area under the curve (AUC) for blood glucose between 90 min and 180 min of ST-EX (12421±2371 min·mg/dL) was 15% lower than the AUC of REST (14581±2716 min·mg/dL) ($P < 0.05$), but it was not significantly different from the AUC of WALK (13960±4347 min·mg/dL). Concentrations of nonesterified fatty acids (NEFA) (Figure 1b) and C-peptide (Figure 1c) did not differ between exercise conditions at any sampling time.

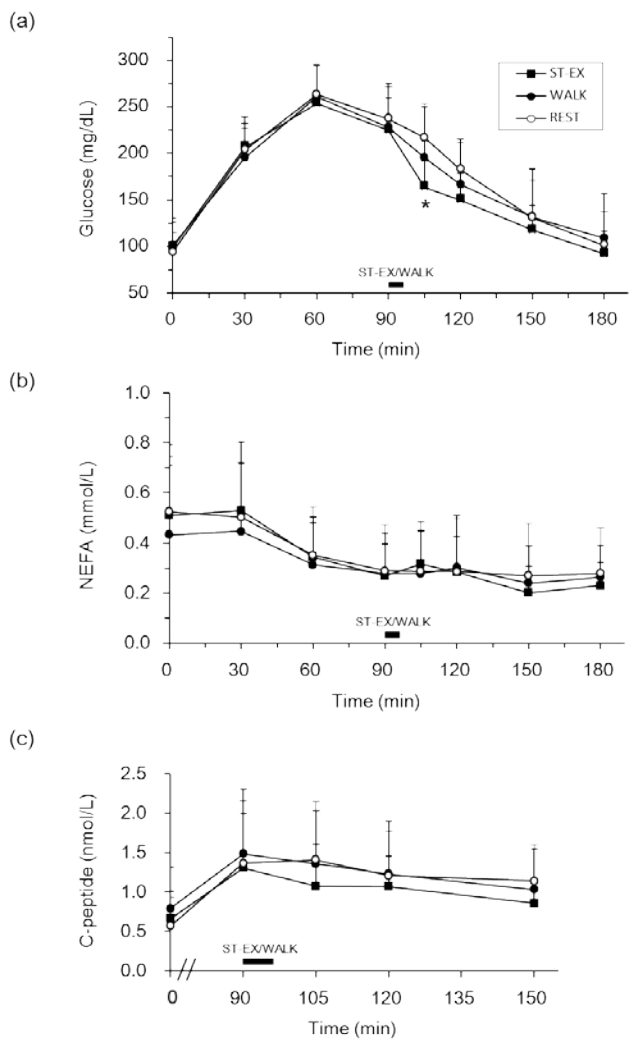

Figure 1 Changes in blood glucose (a), NEFA (b) and C-peptide (c) concentrations. Values are mean± SD. n = 7. * P<0.05 *vs.* REST.

Exercise intensity was significantly higher in ST-EX than WALK (Table 1). Based on the percentage of age-predicted heart rate reserve (% HRR) (13), the relative intensity of ST-EX was estimated as "hard" (60–84% HRR) and that for WALK was "light" (20–39% HRR). Nevertheless, all subjects completed ST-EX without obvious symptoms such as dyspnea or leg exhaustion because of the reduction in the perceived exertion during the descending phase of ST-EX.

Discussion

The important finding of the present study was the beneficial effect against postprandial hyperglycemia of exercise using stairs in older people with type 2 diabetes. ST-EX for as short a period as 6.5 min starting at 90 min after a meal significantly accelerated the decrease in postprandial blood glucose levels. We have reported that ST-EX after a meal hastened the decrease in blood glucose levels in people with impaired glucose tolerance (IGT) (14). As was observed in the present study, blood glucose levels at 90 min after a meal for REST, ST-EX, and WALK did not differ, but blood glucose decreased more rapidly after ST-EX than after REST ($P< 0.05$) and WALK ($P< 0.05$) [14]. Collectively, we demonstrated the glucose-lowering effect of ST-EX in people with both IGT and type 2 diabetes.

To obtain a significant decrease in blood glucose by ST-EX, we chose timing for ST-EX that did not result in a rebound of blood glucose concentration after exercise. Larsen et al. [7, 8] and Hostmark et al. [15] reported that bicycle ergometer exercise during the rising phase of blood glucose after a meal decreased blood glucose during exercise, but resulted in a rapid rebound in blood glucose after exercise. We also found in our preliminary experiments that ST-EX during the rising phase (< 60 min after ingestion), but not ST-EX starting at 90 min after ingestion, induced a rebound in blood glucose after exercise (data not shown). However, Larsen et al. [7, 8] demonstrated that cycle ergometer exercise during the rising phase significantly lowered the peak level and AUC of blood glucose, despite the rebound in blood glucose. Thus, ST-EX before the peak of postprandial blood glucose may improve glycemic control in people with type 2 diabetes. ST-EX starting more than 90 min later (e.g. 120 min after ingestion) may also be effective in attenuating postprandial hyperglycemia.

In the present study, C-peptide and NEFA levels did not change significantly during and after ST-EX. In contrast, Larsen et al. reported that moderate-intensity exercise for 45 min [7] and high-intensity exercise for a total of 46 min [8] after a meal robustly reduced insulin and C-peptide levels. They suggested that the reduction in insulin secretion was caused by both the decrease in blood glucose levels and the increase in sympathetic nervous activity elicited by exercise. Additionally, the combination of decreasing insulin levels and increasing sympathetic activity enhanced NEFA release rates [16], and in fact, Larsen et al. [7, 8] demonstrated that cycle ergometer exercise increased NEFA levels. Similar responses in C-peptide and NEFA levels may be evoked by ST-EX of higher intensities and/or longer durations.

We recruited a small number of subjects who are lean and maintain optimal HbA1c values, and thus the results may not be generalizable to obese patients or those with poorly controlled diabetes. It is also notable that in people with type 2 diabetes, body mass index and physical fitness are closely linked, with the heaviest subjects being the least fit [17]. Further studies are needed to determine whether there are differences in the effect of ST-EX according to age, adiposity, body composition, or aspects of metabolic control and physical fitness.

Table 1: Parameters of exercise intensity for ST-EX and WALK. Values are mean ±SD. n = 7/group. ** $P<0.01$ vs. WALK.

	ST-EX	WALK
End-HR (bpm)	121 ±15 **	95 ±16
End-%HRR (%)	70 ±24 **	39 ±17
End-Lactate (mM)	4.2 ±1.0 **	1.6 ±0.5

Abbreviations: ST-EX: stair climbing/descending exercise; HR: heart rate; %HRR: percentage of age-predicted heart rate reserve; End: measured at the end of exercise.

CONCLUSION

We believe that the observation that no strenuous ST-EX for as short a time as 6.5 min resulted in a substantial decrease in blood glucose level may help motivate sedentary people with type 2 diabetes to start exercising more frequently.

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