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## 学位論文要約

論文題目 Effects of stair climbing–descending exercise for a short time after a meal on postprandial hyperglycemia and glycemic control in people with type 2 diabetes

(食後に実施する短時間の階段昇降運動が2型糖尿病患者の食後高血糖および血糖コントロールに及ぼす影響)

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### Introduction

Postprandial hyperglycemia is recognized as an independent risk factor for cardiovascular events, and is highly prevalent throughout the day in people with type 2 diabetes (T2D), even among those with apparently good glycemic control according to their glycated hemoglobin level. High-intensity exercise (HIE) effectively reduces the postprandial blood glucose (BG) level. However, the reported protocols for HIE are too strenuous and long, and/or need exercise equipment to be performed regularly by many people with T2D. The lack of time, the lack of access to exercise facility, and the perceived difficulty in performing exercise are important barriers to regular participation in physical activity in people with T2D. Thus, it would be desirable to develop a time-saving and non-strenuous way of HIE that assures substantial improvements in glycemic control regardless of weather conditions without the need for dedicated exercise equipment.

A stair climbing–descending exercise (ST-EX) is a convenient method for performing HIE in daily life, needs no special exercise facility, and is not dependent on the weather. The intensity of climbing stairs is high, corresponding to that of running at 9.6 km/h. The energy cost for climbing stairs is also high, whereas that for descending stairs is lower. On the other hand, one can increase the overall exercise intensity without much effort by alternately climbing and descending stairs on a flight of stairs, because the subjective intensity is alleviated when descending the stairs. Typically, one set of ST-EX comprises less than 10 min of repeated brisk climbing up one flight of stairs followed by slow walking down to the starting point. Our lab previously examined the acute hypoglycemic effect of ST-EX, and found that a continuous bout of ST-EX for

6–6.5 min was more effective than level walking in reducing postprandial BG level in people with impaired glucose tolerance and T2D. However, it was still unknown: (1) whether the acute hypoglycemic effect of ST-EX occurs in people with T2D when taking oral hypoglycemic agents; (2) whether ST-EX for a short duration (~3 min) is also effective in reducing hyperglycemia in people with T2D; and (3) whether a daily exercise program using ST-EX has a beneficial effect on glycemic control in people with T2D.

Therefore, we conducted three studies in people with T2D without interrupting their use of oral hypoglycemic agents: to test the acute hypoglycemic effects of a single bout of ST-EX at 90 min after a meal (*Study 1*); to test the acute hypoglycemic effects of two separate ~3 min bouts of ST-EX at 60 and 120 min after a meal (*Study 2*); and to examine the changes in glycemic control status produced by a 2-week ST-EX program comprising two 3 min bouts at 60 and 120 min after each meal (*Study 3*).

## Objectives, Methods and Results

### *Study 1*

**Objective:** We examined whether one bout of ST-EX, a convenient method to increase physical activity in daily life, for a short time after a meal would acutely improve the postprandial BG response in people with T2D when taking oral hypoglycemic agents.

**Methods:** 10 people with T2D (age  $64.9 \pm 2.0$  years) participated in 2 separate sessions. After an overnight fast without interrupting the use of oral hypoglycemic agents, each participant consumed a test meal and then kept resting for 180 min, except when performing an 8–10 min bout of ST-EX at 90 min after the meal (ST-EX session), or kept resting for 180 min (REST session). One session of ST-EX comprised three repetitions of climbing to the second floor (21 steps) at a rate of 80–110 steps/min followed by walking down slowly to the first floor at a free step rate. The participants repeated 4–5 sessions of ST-EX with a short rest in a standing position for 30 sec between the sessions.

**Results:** The BG at 90 min after the meal during the ST-EX session (immediately before the ST-EX) did not differ from that during the REST session, but analysis of variance revealed a significant interaction between time and treatment ( $P < 0.05$ ). The BG at 120 min after the meal (30 min after the ST-EX) was significantly lower than that during the REST session ( $P < 0.01$ ). The area under the curve was also 14% lower during the ST-EX session than during the REST session, but not significantly. The heart rate and blood lactate levels indicated that the actual intensity of ST-EX was ‘hard’. In contrast, the rating of perceived exertion (RPE) indicated that the overall intensity of ST-EX was ‘moderate’ because of decreased RPE scores during descent.

### ***Study 2***

**Objective:** We examined whether two-separate bouts of ST-EX for a short time after a meal would acutely improve the postprandial BG response in people with T2D when taking oral hypoglycemic agents.

**Methods:** 16 people with T2D (age  $65.4 \pm 1.1$  years) participated in 2 separate sessions. After an overnight fast without interrupting the use of oral hypoglycemic agents, each participant consumed a test meal and then kept resting for 180 min, except when performing each 3 min bout of ST-EX at 60 and 120 min after the meal (ST-EX session), or kept resting for 180 min (REST session). ST-EX comprised 6 continuous repetitions of climbing to the second floor (21 steps) at a rate of 80–110 steps/min followed by walking down slowly to the first floor at a free step rate.

**Results:** The BG at 60 min after the meal during the ST-EX session (immediately before the first ST-EX) did not differ from that during the REST session, but analysis of variance revealed a significant interaction between time and treatment ( $P < 0.01$ ). The BG at 150 min after the meal (30 min after the second ST-EX) was significantly lower than that during the REST session ( $P < 0.01$ ). The area under the curve was also 18% lower during the ST-EX session than during the REST session ( $P < 0.05$ ). The heart rate and blood lactate levels indicated that the actual intensity of ST-EX was 'hard'. In contrast, the RPE indicated that the overall intensity of ST-EX was 'moderate' because of decreased RPE scores during descent.

### ***Study 3***

**Objective:** We examined whether a postprandial exercise program using brief ST-EX for 2 weeks has the hypoglycemic effect in people with T2D who takes oral hypoglycemic agents.

**Methods:** Seven men with uncomplicated T2D (age  $68.0 \pm 3.7$  years) performed two sets of ST-EX 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 at a rate of 80–110 steps/min followed by slow waking down to the first floor at a free step rate in their home. A rest period of 1–2 min was allowed between each set. Oral hypoglycemic agents were continued throughout the study periods.

**Results:** Serum 1,5-AG level was significantly higher by 11.5% at the end of the 2-week exercise period than at the baseline ( $P < 0.05$ ). By contrast, the 1,5-AG level at the end of the following 2-week period did not differ from the baseline value. Fasting BG level

and insulin resistance index at the end of the exercise period did not differ from the baseline value.

## Conclusion

*Study 1 and 2* showed that the ST-EX for a short time after a meal accelerated acutely the reduction in postprandial BG levels in people with T2D when taking oral hypoglycemic agents. In addition, *Study 3* showed that a home-based ST-EX program for 2 weeks improved the glycemic control in people with T2D who took oral hypoglycemic agents. Although further research, especially studies on the long-term effect in a variety of patient populations including obese people, is warranted, we strongly propose that the ST-EX is a clinically useful method for improving postprandial hyperglycemia and glycemic control in people with T2D.

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