Effects of a Post-meal Spot Marching Exercise on HbA1c and Functional Fitness in Patients with Type 2 Diabetes: A Pilot Study

ผลของการออกกำลังกายด้วยการยืนย่ำเท้าอยู่กับที่ต่อ HbA1c และสมรรถภาพทางกาย ในผู้ป่วยเบาหวานชนิดที่ 2: การศึกษานำร่อง

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ABSTRACT

This study aimed to evaluate the effect of a post-meal spot marching exercise (PMSME) on HbA1c and functional fitness, including aerobic fitness level (3 Minute Step Test [TMST]) and functional leg muscle strength (Five Times Sit To Stand Test [FTSST]) in patients with type 2 diabetes (T2DM). During the 8-week intervention period, 20 patients were randomly assigned to an experimental group who engaged both in the PMSME and a standard care program and a control group who received only standard care. The experimental group's improvements in HbA1c, TMST, and FTSST were significantly greater than the control group. The PMSME appeared to be effective in patients with T2DM, according to the results.

บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อประเมินผลของการออกกำลังกายด้วยการยืนย่ำเท้าอยู่กับที่ต่อ HbA1c และสมรรถภาพทางกายซึ่งประกอบด้วยความทนทานในการออกกำลังกาย (3 Minute Step Test [TMST]) และความแข็งแรงของกล้ามเนื้อขา (The Five Times Sit to Stand Test [FTSST]) ในอาสาสมัคร คือ ผู้ป่วยเบาหวานชนิดที่ 2 จำนวน 20 ราย (อายุเฉลี่ย 61.55±5.14 ปี) อาสาสมัครถูกสุ่มเข้ากลุ่มทดลองซึ่งได้รับการออกกำลังกายด้วยการยืนย่ำเท้าอยู่กับที่ร่วมกับการดูแลมาตรฐานสำหรับผู้ป่วยเบาหวาน และกลุ่มควบคุมซึ่งได้รับการดูแลมาตรฐานอย่างเดียว เป็นเวลา 8 สัปดาห์ พบว่า HbA1c, TMST และ FTSST ในกลุ่มทดลองหลังสิ้นสุดการศึกษามีค่าดีขึ้นมากกว่ากลุ่มควบคุมอย่างมีนัยสำคัญทางสถิติ จากผลการทดลองบ่งชี้ว่า PMSME สามารถนำมาปรับใช้ในผู้ป่วยเบาหวานชนิดที่ 2 ได้

Keywords: Post-meal exercise, Post-meal spot marching exercise, Type 2 diabetes mellitus
คำสำคัญ: ออกกำลังกายหลังอาหาร การออกกำลังกายด้วยการยืนย่ำเท้าอยู่กับที่หลังมื้ออาหาร เบาหวานชนิดที่สอง

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Introduction

Diabetes mellitus (DM) is characterized by elevated blood sugar levels and impaired metabolism induced by insufficiency of insulin secretion or insulin action (Wu et al., 2014). Insulin resistance is a major cause of type 2 diabetes mellitus (T2DM), which is responsible for about 90% of diabetes cases (Tao et al., 2015, IDF, 2019). The increasing prevalence of T2DM in developing countries appears to be due to high levels of inactivity and unhealthy eating behaviors (Sami et al., 2017). According to the International Diabetes Federation (IDF), there have been 463 million diabetes globally in 2019, with that number anticipated to increase to 700 million by 2045 (Saeedi et al., 2019). In addition, the National Health Examination Survey reported in 2014 that the prevalence rates of diabetes mellitus among people aged 30–44 and 45–59 years old were 3.4 % and 10.1 %, respectively (Chavasit et al., 2017). Exercise intolerance in Type 2 diabetes may be exacerbated by deficiencies in exercising muscle oxygen delivery caused by both cardiac and peripheral vascular dysfunction (Poitras et al., 2018). Cardiovascular disease (CVD) is the primary cause of death in persons with type 2 diabetes (T2DM). Dietary modifications, weight management, and increased physical activity are all important therapeutic modifiable factors for T2DM patients (Piché et al., 2020).

According to international guidelines, diabetic patients should engage in moderate intensity exercise for at least 150 minutes per week. At a minimum, resistance exercise should be performed 2 days per week. A systematic review in 2014 showed that moderate to high intensity aerobic exercise had greater beneficial effects than resistance exercise in attenuating HbA1c in patients with T2DM (Yang et al., 2014). The transport of vesicles containing glucose transporter-4 (GLUT4) from intracellular storage compartments to the cell surface is required for glucose uptake into peripheral skeletal muscle and adipose tissues. The canonical insulin signaling cascade in skeletal muscle and fat cells, as well as exercise-induced contraction in muscle cells, initiates trafficking of GLUT4 storage vesicles (Tunduguru et al., 2017). The ideal strategy for glycemic control in diabetes patients is to use glucose from meals as fuel for exercise (Chacko, 2014). Post-meal physical activity may be more effective than overall glycemic control in lowering the risk of post-prandial hyperglycemia (PPH) and CVD (Pahra et al., 2017). Possible mechanisms might be involved with a reduction of postprandial glycemic excursions by increasing GLUT-4 translocation on the cell surface of skeletal muscle, inhibiting hepatic fatty acid oxidation and hepatic glucose production, increasing blood flow to contracting muscle, and decreasing splanchnic blood flow, which slows digestion and absorption of nutrients from the gastrointestinal tract (Pahra et al., 2017; Chacko, 2016). The spot-marching exercise is considered a whole body aerobic exercise that may help patients manage their blood sugar levels and weight better than arm or leg aerobic exercise alone (Jones et al., 2018). However, no study has investigated the effects of the post-meal spot marching exercise (PMSME) on HbA1c and physical fitness in T2DM patients.

The objective of this study was to evaluate the effects of the PMSME on HbA1c and functional fitness, including aerobic fitness level and functional leg strength in patients with T2DM.

Methods

This clinical trial was a pilot study with a between-group experimental design and has been registered in the Thai Clinical Trials Registry (TCTR20210906003). All study protocols were approved by the Ethical Committee of Research in Human, Khon Kaen University, Thailand (HE632170). Informed consent was obtained from participants who agreed to enroll in this study.

Participants

Participants were patients with T2DM who had been attending the Diabetes Clinic at Waritchaphum Hospital in Sakon Nakhon province, Thailand. In total, 20 participants who met the following inclusion criteria were recruited to this study: those who had been diagnosed with T2DM for at least 1 year, those aged 50-70 years, those with a body mass index (BMI) of 18.5-29.9 kg/m^2, those who were able to understand and follow instructions and research protocols, and those whose sedentary behavior was below the threshold set for this study (Metabolic equivalent; METs ≤ 1.5). All patients had been receiving diabetes medications to control their blood glucose levels. Participants were excluded if they had a fasting blood sugar (FBS) of < 100 mg/dL and/or > 300 mg/dL, a blood pressure (BP) of < 90/60 mmHg and/or > 140/90 mmHg, any limitations with regards to capability to engage in exercises, such as neurological and/or orthopedic problems, pain in the trunk and upper or lower extremities (Visual Analogue Scale; VAS ≥ 3), or were at risk of falls (Timed Up and Go Test > 12 seconds).

Intervention

The participants with T2DM in experimental group engaged in the PMSME combined with a standard care program, including dietary modification and a foot care program. The control group received only standard care. Both interventions were conducted at the participant’s home. The experimental group received music rhythm control (80-90 beats/minute) during post-meal spot marching to achieve moderate intensity in which target heart rate should between 64% and 74% of maximum heart rate (American College of Sports Medicine, 2018) (Figure 1) Each session lasted 15 minutes and covered 1,400-1,600 steps. It was done three times a day following each meal (breakfast, lunch, and dinner), four days a week for eight weeks. A pedometer was placed in the pocket of participants’ pants during the PMSME. The standard care program for patients with T2DM included patient advice regarding dietary modification (American Diabetes, 2022) and diabetes foot care (Howarth, 2019). Baseline characteristics of the study population, including sex, age, duration of DM, BMI, HbA1c, vital signs, and underlying diseases/conditions were collected from their medical records. Interventions were initiated after baseline assessment. Each participant in the experimental group was trained to familiarize them with the PMSME by a physical therapist with 3 years of experience.

(A) (B)

Figure 1 Post-meal spot marching exercise with shoulder flexion at 90 degrees and hip flexion at 70 degrees, using tape to mark the required height on the wall.
(A) Lateral view; (B) Frontal view

Screening tools for neuropathy and risk of falls in diabetes patients

Diabetes patients were evaluated using the Michigan Neuropathy Screening Instrument (MNSI) for diabetic peripheral neuropathy of the lower extremities. This tool consists of a self-report questionnaire and a physical examination of the lower extremities, which includes a test of vibratory sensation and ankle reflexes. The cut-off for diabetic peripheral neuropathy is ≥ 7, and the cut-off for the physical examination is ≥ 2.5 (Abdissa et al., 2020). The Timed Up and Go Test (TUGT) was used to assess participants' risk of falling by measuring how long it took each participant to rise from a standard chair with armrests, walk straight ahead for 3 meters, turn around 180 degrees, walk back to the chair to sit, and lean back in the chair. In Thai elderly community living, the cut-off score is greater than 13.5 seconds (Jalayondeja, 2014).

Outcome measures

The outcome measures, HbA1c and functional fitness (exercise tolerance and lower-limb muscle strength), were assessed at the beginning and end of the 8-week intervention period by a research assistant who was blinded to the study procedure. HbA1c has been used as a biomarker for glycemic control over a 3-month period. The cut-off to diagnose diabetes is an HbA1c of more than 6.5%. In addition, the minimal clinically important difference (MCID) in HbA1c for diabetes is 0.5% (Lenters-Westra et al., 2014). The Three Minute Step Test (TMST) was used to evaluate participants' aerobic fitness level. First, participants' resting heart rate was measured for 3 minutes. Then, participants were asked to lift one foot at a time while stepping on and off a 12-inch step, keeping pace with an electronic metronome at 96 beats/minute. Every minute while participants were stepping, they were told, "You are doing well." After 3 minutes of stepping, participants sat down and relaxed without talking. Then, their pulse rate was measured using a pulse oximeter. Participants were asked to rate their perceptions of exertion with the Borg scale (from 6 to 20). Their accumulative pulse rate was evaluated within 1 minute (Bohannon et al., 2015). The Five Times Sit to Stand Test (FTSST) was used to measure functional leg muscle strength, balance control, fall risk and exercise capacity (Melo et al., 2019). The minimal detectable change (MDC) for the FTSST is 2.5 seconds (Muñoz-Bermejo et al., 2021).

Statistical analysis

Descriptive statistics were used to analyze participants' demographic data. The normality of the data set was assessed using the Shapiro-Wilk test. A student's t-test and paired t-test were used for between- and within-group analyses, respectively. Statistical significance was inferred at a value of $p < 0.05$. All analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 17.

Results

Four men and six women participated in each group. They were elderly, overweight, and had uncontrollable levels of HbA1c, low HDL and high triglycerides. All patients had being received insulin therapy and/or oral medications to control their blood glucose levels. No statistically significant between-group differences in baseline characteristics ($P > 0.05$) were shown in Table 1.

Table 1 Participants' baseline characteristics

Characteristics	Control group (n = 10)	Experimental group (n = 10)	Total (n = 20)	P-value
	Mean ± SD	Mean ± SD	Mean ± SD	
Age (yrs)	61.60 ± 5.19	61.50 ± 5.36	61.55 ± 5.14	0.967
Weight (kg)	60.20 ± 8.75	62.10 ± 8.30	61.15 ± 8.36	0.625
Height (cm)	158.50 ± 9.05	158.90 ± 6.39	158.70 ± 7.62	0.910
BMI (kg/m^2)	24.00 ± 2.97	24.58 ± 2.92	24.29 ± 2.88	0.656
T2DM duration (yrs)	5.60 ± 2.84	5.2 ± 3.52	6.45 ± 3.76	0.783
HbA1c (%)	9.59 ± 1.69	9.4 ± 1.15	9.50 ± 1.41	0.772
TMST (bpm)	111.80 ± 9.33	111.50 ± 8.97	111.65 ± 8.91	0.942
FTSST (sec)	9.98 ± 1.42	9.63 ± 1.76	9.81 ± 1.57	0.629

Note: BMI, Body mass index; HbA1c, Hemoglobin A1c; LDL, Low density lipoprotein; HDL, High density lipoprotein; TMST, Three Minute Step Test; FTSST, Five Times Sit to Stand Test; SD, Standard deviation.

Effect of the post-meal spot marching exercise on HbA1c

When compared to baseline, both experimental and control groups had statistically significant reductions in HbA1c after the 8-week intervention period (p<0.001). However, the decrease in HbA1c in the experimental group was significantly greater than in the control group post-intervention as shown in Table 2. The HbA1c of all participants in the experimental group decreases and reached the minimal clinically important difference of 0.5% (Lenters-Westra et al., 2014).

Effect of the post-meal spot marching exercise on functional lower limb muscle strength

In the experimental group, FTSST scores were attenuated post-intervention to a statistically significant degree compared to baseline measurements (P = 0.008), whereas the FTSST scores throughout the 8 weeks in the control group remained the same as at baseline (P = 0.211). Additionally, the decrease in FTSST score in the experimental group was significantly greater than in the control group post-intervention (P = 0.029) as shown in Table 2. The improvement in FTSST scores in the experimental group failed to reach the MDC of 2.5 seconds (Muñoz-Bermejo et al., 2021).

Effect of the post-meal spot marching exercise on exercise tolerance

The experimental group had a statistically significant reduction in TMST scores at post-intervention compared to baseline (P = 0.002), whereas the control group's TMST scores remained the same. Additionally, the decrease in TMST score in the experimental group was significantly greater than in the control group post-intervention (P = 0.003) as shown in Table 2.

Table 2 Comparison of HbA1c, TMST, and FTSST within and between groups

		Within-group analysis					Between-group analysis			
Outcome	Group	Baseline	Post-intervention	r	P-value	Effect size	Mean difference	95% CI	P-value	Effect size
HbA1c (%)	Control	9.59 ± 1.69	9.29 ± 1.53	0.997	0.001*	1.480	1.47 ± 0.60	0.22 to 2.72	0.024*	1.103
	Experimental	9.40 ± 1.15	7.82 ± 1.10	0.919	< 0.001*	3.469				
TMST (bpm)	Control	111.80 ± 9.33	113.20 ± 10.25	0.903	0.170	0.318	14.7 ± 4.27	5.72 to 23.68	0.003*	1.538
	Experimental	111.50 ± 8.97	98.50 ± 8.81	0.304	0.002*	1.239				
FTSST (sec)	Control	9.98 ± 1.42	10.18 ± 1.99	0.966	0.211	0.278	2.09 ± 0.69	0.64 to 3.53	0.004*	1.356
	Experimental	9.63 ± 1.76	8.09 ± 0.89	0.388	0.008*	0.942				

Note: Data shown as mean ± standard deviation. HbA1c, Hemoglobin A1c; LDL, Low density lipoprotein; HDL, High density lipoprotein; TMST, Three Minute Step Test; FTSST, Five Times Sit to Stand Test; * = statistically significant at P-value < 0.05.

Discussion and Conclusions

The aim of this study was to investigate the effect of the PMSME in patients with T2DM. Participants continued to take medications as prescribed before enrolling in this study, and diets were standardized during the intervention period, so the effects of the PMSME combined with standard care occurred independently of changes in medication, diet, and activities of daily living. Furthermore, there have been no adverse events such as hypoglycemia, hyperglycemia, chronic muscle pain, fall, or neurovascular impairment over the 8-week intervention period. The present study showed that the PMSME combined with standard care resulted in a significant improvement in HbA1c and functional fitness.

Several studies investigated the impact of exercise programs on blood sugar control in diabetes patients. A supervised exercise program was found to be more beneficial than counseling alone in encouraging physical activity and decreasing HbA1c and cardiovascular risk factors in patients with T2DM (Mendes et al., 2017). Furthermore, a systematic review of 12 trials revealed that aerobic exercise reduced HbA1c more than resistance exercise (Yang et al., 2014). Post-meal physical exercise is a safe and effective to improve postprandial glycemia in T2DM patients (Reynolds et al., 2016). Since the PMSME is a type of aerobic activity and a simple equipment-free work out that can be done at home. We chose a moderate-intensity PMSME for the experimental group in this study.

In the other studies, at least 20 minutes of walking after one meal or 10-15 minutes per each meal everyday has significantly improved glycemic control without hypoglycemia in patients with T2DM (Pahra et al., 2017, Reynolds et al., 2016, Li et al., 2018). For the management of T2DM, a reduction in HbA1c of about 0.51-0.89 % is cost effective (Sanda et al., 2017). The minimal clinically important difference (MCID) in HbA1c for diabetes is 0.5% (Lenters-Westra et al., 2014). Our findings revealed a 1.47% reduction of HbA1c, indicating that the PMSME combined with standard care program has clinically important impacts for elderly diabetic patients. This confirmed the previous findings of Pahra et al., who demonstrated that 15 minutes of post-meal brisk walking with moderate-intensity for 1,500-1,600 steps after breakfast, lunch, and dinner could significantly reduce the HbA1c levels by 0.9% at 8th weeks in T2DM patients (Pahra et al., 2017). Our study was conducted in a real-life context and allowed all participants to continue with their daily routines during the 8-week intervention period. Further, the amount of time and steps spent in moderate intensity whole-body PMSME after breakfast, lunch, and dinner was 15 minutes per session, covering 1,400-1,600 steps. Additionally, the participants in both groups were able to follow the protocols throughout the experimental period. Therefore, PMSME program in this study should be adequate in terms of HbA1c reduction based on the FITT principle (frequency, intensity, time, and type) (American Diabetes, 2022). Interestingly, a decrease in HbA1c is critical to reduce micro- and macro-vascular complications (Pozzilli et al., 2014). One explanation for the significant decrease in HbA1c in the current study could be increased peripheral glucose utilization and insulin-independent glucose uptake in skeletal muscle as a result of increased translocation of

GLUT-4 (glucose transporters) to the plasma membrane and transverse tubules via activation of 5'-AMP-activated protein kinase upon muscle contraction. Another potential mechanism underlying the effects of post-meal exercise on glycemic control is the inhibition of hepatic glucose synthesis after a meal (Pahra et al., 2017). In addition, a decrease in the splanchnic blood flow during post-meal exercise leads to the decelerating absorption of nutrients from the gastrointestinal tract and the consequent decreasing magnitude of postprandial glucose excursions (PPGEs) (Chacko, 2016). The proposed mechanisms for the short-term suppression of insulin release from β-cells as a result of post-meal exercise may optimize long-term glycemic control (Pahra et al., 2017).

This study also demonstrated that the PMSME combined with standard care for 8 weeks in T2DM patients could improve aerobic fitness level (TMST). Our finding was similar to previous studies in overweight patients with chronic kidney disease who engaged in home-based aerobic exercise (Aoike et al., 2015). Regular aerobic exercise not only enhances cardiac contractility (Powers et al., 2018) but also improves endothelial function by lowering oxidative stress and maintaining nitric oxide (NO) bioavailability. Further, regular aerobic exercise is the most evidence-based treatment to reduce the risk of cardiovascular disease in elderly people (Seals et al., 2019).

In this study, functional leg muscle strength as measured by the FTSST was significantly improved after 8 weeks of the PMSME when compared with the control group. Our finding appears to be consistent with a previous study by Janyacharoen et al., 2018 who found that FTSST was significantly improved in healthy senior adults following 12-weeks of modified ancient Thai boxing exercise (moderate intensity, 40 minutes per session, 3 sessions per week) (Janyacharoen et al., 2018). PMSME and ancient Thai boxing exercise are both considered whole-body aerobic exercises that contribute to activating mitochondrial biogenesis, decreasing catabolic gene expression, and increasing muscle protein synthesis. All of these molecular factors may help to delay the progression of age-related sarcopenia, which is characterized by a progressive loss of skeletal muscle mass and function in the elderly, particularly those with diabetes (Erlich et al., 2016; Konopka et al., 2014; Seals et al., 2019; Seo et al., 2016; Buscemi et al., 2021). However, simply using the participants' bodyweight to provide resistance during the PMSME) in this study did not reach a minimal detectable change (MCD) in FTSST which is 2.5 seconds (Kanaley et al., 2022).

In conclusion, this study has shown that 8-week of PMSME (15 minutes per session, 3 sessions per day, 4 days per week) is an effective home-based exercise program for improving HbA1c, exercise tolerance, and lower limb muscle strength in the elderly with type 2 diabetes. Additionally, weekly reminder phone calls and step counts, as well as counselling at each visit every two weeks, can help to increase compliance with 8-week PMSME program in this study. Finally, our suggestion was a longer duration of follow-up, larger-sample-size randomized controlled trial is required to further confirm the efficiency and effectiveness of PMSME combined with standard care in improving HbA1c, exercise tolerance, and lower limb muscle strength in elderly people with T2DM.

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