Journal of Associated Medical Sciences 2023; 56(2): 39-46

JAMS
Journal of Associated Medical Sciences

Scopus indexed & Thai-Journal Citation Index Centre (TCI)

Journal of Associated Medical Sciences

Journal homepage: https://www.tci-thaijo.org/index.php/bulletinAMS/index

Impact of post-meal spot marching exercise in individuals with type 2 diabetes mellitus: A randomized clinical trial

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ARTICLE INFO

Article history:
Received 11 November 2022
Accepted as revised 12 January 2023
Available online 23 January 2023

Keywords:
Type 2 diabetes mellitus, glycemic control, physical activity, post-meal exercise

ABSTRACT

Background: For meaningful HbA1c reduction, improvement of cardiovascular risk profile, and weight loss, the current recommendation for people with type 2 diabetes mellitus (T2DM) is a minimum of 150 min/week of physical exercise. Post-meal exercise was both safe and effective in improving glycemic profiles in people with T2DM. However, the effects of post-meal spot marching exercise (PMSME) on glycemic control, exercise tolerance, leg muscle strength, and quality of life (QoL) in individuals with T2DM have not yet been investigated.

Objectives: Aim of this study was to investigate the effect of PMSME on glycemic control, exercise tolerance, leg muscle strength, and QoL in individuals with T2DM.

Materials and methods: Participants aged 50-70 were randomly allocated to the exercise or control groups (N=12 each). Participants in both groups received standard treatment following the Standards of Medical Care in Diabetes 2019. Only the exercise group performed moderate-intensity PMSME for 15 minutes per set, 3 sets per day, 4 days per week for 8 weeks. All participants underwent fasting plasma glucose (FPG), hemoglobin A1c (HbA1c), Three-Minute Step Test (TMST), Five Times Sit to Stand Test (FTSST), and the 36-item Short Form Survey (SF-36) at baseline and at the end of this study.

Results: At baseline, there were no differences in outcomes between the two groups. At post-intervention period, the exercise group showed significant improvements in HbA1c (7.99 vs. 9.16%), heart rate recovery in the first minute after completion of the TMST (99.83 vs 113.58 bpm), FTSST (8.44 vs 10.02 sec), and SF-36 (physical function [82.50 vs. 67.50 scores], physical role [75.00 vs. 50.00 scores], vitality [75.00 vs. 57.50 scores], and total score [76.19 vs 62.81 scores] domains) compared to the control group (p<0.05).

Conclusion: PMSME could be used as an alternative home-based exercise to improve glycemic control, exercise tolerance, functional leg muscle strength and QoL in T2DM patients.

Introduction

In emerging nations, inactivity and bad eating habits accelerate the incidence of type 2 diabetes (T2DM).[1] According to the International Diabetes Federation (IDF), there were 463 million cases of diabetes worldwide in 2019, and the number is expected to rise to 700 million by 2045.[2] Dietary modifications, weight management and increased physical activity are essential for T2DM patients.[3]

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doi: 10.12982/JAMS.2023.015
E-ISSN: 2539-6056

Either aerobic activity or strength training can be used to decrease hemoglobin A1c (HbA1c) levels.[4,5] Using glucose from each meal for exercise is the ideal method of glycemic control for diabetes because the blood glucose-lowering benefits can be seen immediately.[6] Previous studies revealed that post-meal exercise in T2DM patients was both safe and able to improve glycemic profiles, hence reducing the risk of cardiovascular disease.[7-10] As post-meal blood glucose levels peak within 90 min, post-meal exercise could attenuate this peak in diabetes patients.[11,12] Spot marching was determined to be a safe and effective home-based exercise for people with chronic obstructive pulmonary disease to improve exercise endurance and quality of life.[13] Compared to arm or leg aerobic exercise alone, spot marching is a whole-body aerobic exercise that may be more beneficial in improving blood sugar levels and physical fitness.[9,14] However, there is insufficient evidence regarding the feasibility of PMSME in enhancing glycemic control, physical fitness, and quality of life in T2DM patients. Therefore, this study aimed to investigate the effect of 8-week home-based post-meal spot marching exercise (PMSME) on glycemic control, exercise tolerance, leg muscle strength, and quality of life (QoL) in individuals with T2DM.

Materials and methods

Study design and participants

The participants were recruited at Waritchaphum Hospital, Sakon Nakhon Province, Thailand, between October 2020 and January 2021. Before recruitment, each participant was screened for eligibility. A flow chart of the study enrolment is demonstrated in Figure 1. The sample size was calculated based on fasting plasma glucose (FPG) from a previous study.[15] The significant level α=0.05 and the test efficiency 1-β=0.8 were set for bilateral test.[16] As a result, each group required 9 participants. Given a 20% rate of lost to follow-up, each group would require 12 participants.[17]

The inclusion criteria were as follows: (1) those diagnosed with T2DM, (2) age between 50 and 70 years, (3) body mass index (BMI) of 18.5-29.9 kg/m2, (4) sedentary behavior (metabolic equivalent; METs ≤1.5), and (5) capable of reading and communicating in Thai and achieving the Mini-Mental State Examination (MMSE) in Thai, depending on the participant's level of education: ≥22 scores for secondary school graduation or above ≥17 scores for elementary school graduation, and ≥14 scores for non-study.[18] The exclusion criteria were as follows: (1) FPG >300 mg/dL, (2) blood pressure <90/60 mmHg or >140/90 mmHg, (3) neurological and/or orthopedic problems, (4) risk of falls (Time Up and Go test >12 s),[19] and (5) participation in other exercise programs during this study period.

This study was a double blinded randomized controlled trial. The protocol was registered in Thai Clinical Trial Registry (ID 20210906003). Each participant was randomly allocated to the exercise group (EG) or the control group (CG) using stratified block randomized allocation with block sizes of 4 and 6 (www.sealedenvelope.com). Ages (50 to 60 years and 61 to 70 years) and gender were set as the stratified variables.

Intervention

Both groups were required to maintain doses and

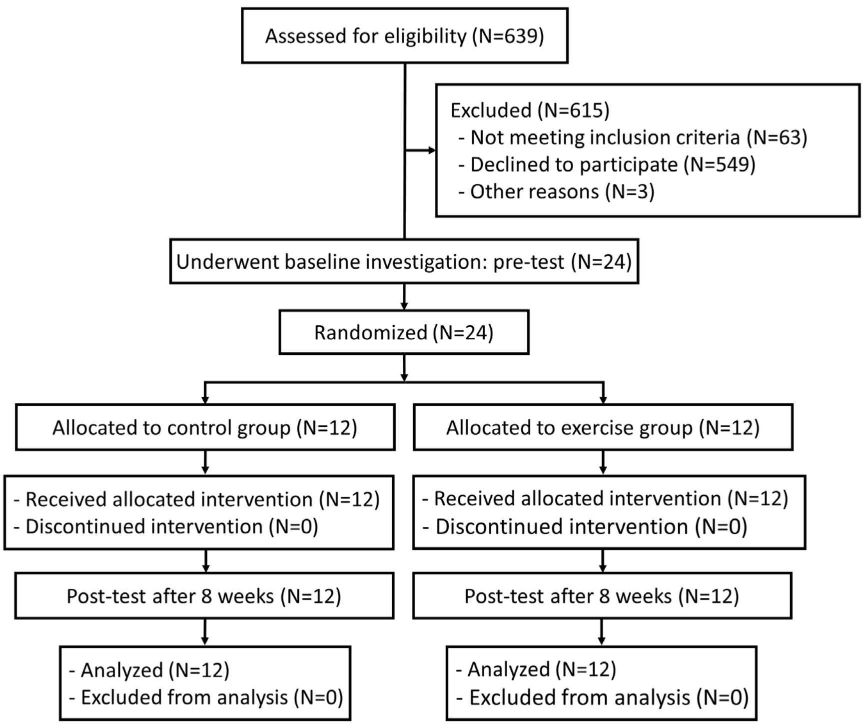

Figure 1 *Flow of participants in the study.*

medications during the intervention. The EG received home-based PMSME in addition to standard treatment following the Standards of Medical Care in Diabetes 2019.[20] The CG received only standard treatment. The intensity, time, and duration of PMSME in this study were derived from Pahra *et al*.[9] Participants in the EG underwent moderate-intensity PMSME with shoulder flexion ≥90° and hip flexion ≥70° (Figure 2) covering 1,400-1,600 steps for 15 min starting 30 min after each meal (breakfast, lunch, and dinner) 4 day/week for 8 weeks. Exercise intensity was achieved by using music with a rhythm of 80 to 90 beats/min, which was adjusted every 2 weeks. After each session, subjects were asked to record their step counts and any adverse events.

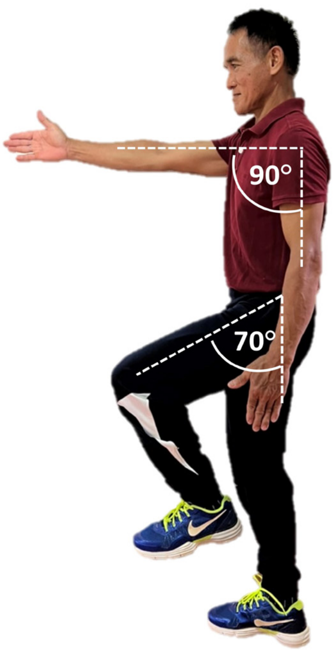

Figure 2 *Post-Meal Spot Marching Exercise (PMSME).*

Outcome measures

Five outcomes were evaluated at baseline and week 8 by a research assistant who was blinded to the study procedure.

Glycemic control

FPG and HbA1c tests were used to monitor glycemic control. After 8-12 hours of fasting, 5 ml of blood sample was collected in the next morning. FPG was determined using a glucose oxidase-peroxidase method, whilst HbA1c was assessed by high performance liquid chromatography (HPLC).[9,21] The FPG test determines the amount of free glucose in the blood, whereas the HbA1c test determines the amount of glycosylated hemoglobin. In addition, HbA1c is a key indicator of long-term glycemic management in T2DM patients.[22]

Exercise tolerance test

The Three-Minute Step Test (TMST) was used to determine cardiovascular fitness. First, all participants' resting heart rates (RHR) were determined. The participants then stepped on and off a 12-inch step at 96 beats/min for 3 min. The participants sat down, and their pulse rate was measured with a pulse oximeter immediately. Auscultation using a stethoscope was then performed to determine their cumulative heart beats (heart rate recovery [HRR]) in the first minute after completion of the test.[23]

Lower extremity muscle strength

Five Times Sit to Stand Test (FTSST) was used to measure functional lower extremity strength.[24] Participants sat on conventional armless chairs (43 cm seat height) with their arms crossed over their chests, backs straight, and feet flat on the floor 10 cm behind their knees. The participants had to stand with their hips and knees fully extended and sit down five times without moving their arms. From "Go" to the fifth repetition, Time was recorded in seconds. Data analysis used two attempts' average time.[25]

Quality of life

Self-Report Short Form-Series (SF-36) was used to monitor physical function, physical role, bodily pains, general health, vitality, social functioning, emotional role, and mental health. Each domain was scored 0-100, with higher scores indicating greater health.[26]

Statistical analysis

All analyses were carried out using SPSS version 28.0 (SPSS Inc., Chicago, IL, USA). The demographic data of the participants were analyzed using descriptive statistics. A Shapiro-Wilks test was used to determine the normality of the data set. The data of FPG, FTSST, HbA1c, and HRR had a normal distribution, whereas the data of SF-36 did not. Pre- and post-intervention data were compared using the paired t-test for normal distributed data and the Wilcoxon singed-rank test for non-normal distributed data. A comparison of pre- and post-intervention data between the groups was conducted using the independent t-test for normal distributed data and the Mann-Whitney U test for non-normal distributed data. The significance level for all inferential test was set at 0.05.

Results

Table 1 shows the participants' demographics and health status. Baseline characteristics were comparable in the EG and CG. Each group had four men and eight women. The CG and the EG had 7±3.8 years and 6±3.7 years diabetes diagnoses, respectively. The majority of the participants were elderly, overweight, and had diabetic dyslipidemia with high plasma triglyceride, low HDL cholesterol, and increased LDL cholesterol levels. These lipid alterations are linked to diabetes mellitus because of the increased free fatty acid flux caused by insulin resistance.[27] The intervention completion was 100%. During the 8-week intervention, both groups had no hypo- or hyperglycemia, muscle soreness or other complications.

Table 1 Baseline characteristics of participants in control and exercise groups.

Variable	Control group (N=12)	Exercise group (N=12)	*p* value
Age (years)	61 (5.74)	62.33 (5.33)	0.561
Weight (kg)	60.83 (8.45)	60.25 (10.29)	0.881
Height (cm)	159.08 (8.82)	158.92 (5.79)	0.957
BMI (kg/m^2)	24.17 (3.40)	24.17 (3.07)	0.999
Lipid profile			
- Cholesterol (mg/dL)	196.50 (54.10)	178.75 (36.06)	0.355
- Triglyceride (mg/dL)	154.25 (52.22)	172.83 (55.22)	0.406
- LDL (mg/dL)	128.42 (45.98)	110.33 (26.70)	0.251
- HDL (mg/dL)	37.47 (11.49)	37.58 (8.60)	0.978

Note: Values are presented in mean (standard deviation), BMI: body mass index, LDL: low density lipoprotein, HDL: high density lipoprotein.

The effect of post-meal spot marching exercise on glycemic control

Fasting plasma glucose

There was a significant reduction in FPG levels from baseline to the end of the intervention period in the CG (%change = -11.58%, p<0.05) and the EG (%change = -7.42%, p<0.001). At the end of the study, there was no significant difference in FPG levels between the CG and the EG (p>0.05) as shown in Table 2.

Hemoglobin A1c

There was a significant decrease in HbA1c after the intervention period in both the CG (%change = -2.97%, p<0.001) and the EG (%change = -15.98%, p<0.001) compared to baseline (Table 2). In addition, the decrease in HbA1c at the end of the study in the EG was significantly greater than in the CG (p<0.05).

The effect of post-meal spot marching exercise on functional lower extremities muscle strength

At the end of week 8, the EG had a significant decrease in the FTSST time scores compared to baseline (%change = -14.31%, p<0.05), whilst there was no difference in the CG (p>0.05). In addition, the EG demonstrated greater improvement in the FTSST scores than the CG at the end of the study (p<0.05).

The effect of post-meal spot marching exercise on exercise tolerance

At the end of the trial, HRR in the first minute after completion of the TMST in the EG had decreased significantly (%change = -11.20%, p=0.001) from the baseline, whereas there was no difference in the CG (p>0.05). In addition, the decrease in HRR in the EG was significantly greater than in the CG (p<0.05) after 8 weeks of intervention (Table 2).

Table 2 Comparison of FPG, HbA1c, FTSST, and HRR between control and exercise groups at week 0 and week 8th.

Variable	Group	Week 0	Week 8th	*p* value ^{a}	*p* value ^{b}
FPG (mg/dL)	Control	175.17 (20.93)	162.17 (12.92)	0.001*	0.224
	Exercise	175.50 (14.27)	155.17 (14.43)	<0.001*	
HbA1c (%)	Control	9.44 (1.71)	9.16 (1.58)	<0.001*	0.045*
	Exercise	9.51 (1.11)	7.99 (1.06)	<0.001*	
FTSST (s)	Control	9.95 (1.35)	10.02 (1.89)	0.741	0.029*
	Exercise	9.85 (1.78)	8.44 (1.37)	0.009*	
HRR (bpm)	Control	112.75 (9.98)	113.58 (11.94)	0.592	0.004*
	Exercise	112.42 (8.91)	99.83 (8.58)	0.001*	

*Note: Values are presented in mean (standard deviation). ^{a}comparison between week 0 and week 8th using the Paired t-test, ^{b}comparison between groups at week 8th using Independent t-test, *statistically significant at p<0.05, FPG: fasting plasma glucose, HbA1c: hemoglobin A1c, FTSST: five time sit to stand test, HRR: heart rate recovery in the first minute after completion of the TMST.*

The effect of post-meal spot marching exercise on quality of life

After completing the intervention, only the EG had significantly improved QoL (p < 0.05), including the physical function (%change =26.92%), physical role (%change =50.00%), bodily pain (%change =61.32%), vitality (%change =15.38%), mental health (%change =50.00%), and total score domains (%change =29.05%). At the end of the study, the increase in SF-36 scores in the physical function, physical role, vitality, and total score domains were significantly greater than in the CG (p<0.05), as shown in Table 3.

Table 3 Comparison of quality of life in control and exercise groups at week 0 and week 8th.

Domain	Group	Week 0	Week 8th	*p* value a	*p* value b
Physical function	Control	65.00 (28.75)	67.50 (30.00)	0.812	0.017*
	Exercise	65.00 (28.75)	82.50 (21.25)	0.026*	
Physical role	Control	50.00 (37.50)	50.00 (43.75)	0.655	0.004*
	Exercise	50.00 (25.00)	75.00 (25.00)	0.002*	
Body pain	Control	58.50 (12.00)	57.75 (41.88)	0.533	0.111
	Exercise	53.00 (11.00)	85.50 (30.50)	0.010*	
General health	Control	55.00 (10.00)	47.50 (34.75)	0.504	0.118
	Exercise	57.50 (12.50)	60.00 (27.00)	0.540	
Vitality	Control	57.50 (15.00)	57.50 (21.25)	0.944	0.036*
	Exercise	65.00 (12.50)	75.00 (18.75)	0.029*	
Social function	Control	75.00 (34.38)	75.00 (25.00)	0.257	0.067
	Exercise	75.00 (18.38)	87.50 (21.88)	0.055	
Emotional role	Control	50.00 (33.34)	66.67 (33.34)	0.655	0.187
	Exercise	66.67 (33.34)	66.67 (0.00)	0.083	
Mental health	Control	56.00 (19.00)	78.00 (23.00)	0.105	0.727
	Exercise	52.00 (10.00)	78.00 (14.00)	0.003*	
Total score	Control	59.47 (4.11)	62.81 (14.04)	0.136	0.003*
	Exercise	59.04 (9.49)	76.19 (11.51)	0.002*	

*Note: Values are presented in median (interquartile range). acomparison between week 0 and week 8th using the Wilcoxon Signed-Rank test, bcomparison between groups at week 8th using the Mann-Whitney U test, *statistically significant at p<0.05.*

Discussion

The present study demonstrated that the PMSME in combination with standard treatment significantly improved glycemic control, exercise tolerance, functional leg muscle strength and QoL in T2DM patients. FPG in the CG and EG decreased significantly from baseline at the end of this study. Our result is similar with previous studies that reported a decrease in FPG in T2DM patients who received dietary education.[28,29]

T2DM management is cost-effective when HbA1c decreases by 0.51%–0.89%.[30] Reduced HbA1c prevents micro- and macrovascular complications.[31] Additionally, the diabetic minimal clinically important difference (MCID) is a 0.5% HbA1c reduction.[32] Therefore, the decrease in HbA1c by 1.52% after 8 weeks of PMSME indicating it was cost-effective and clinically meaningful advantages for T2DM patients. Increased translocation of GLUT-4 (glucose transporters) to the plasma membrane during muscular contraction may explain the decrease in HbA1c.[33] Compared to Pahra *et al*,[9] our study showed a greater HbA1c reduction (0.9% vs 1.52%). A possible explanation is that the PMSME was a total-body workout, whereas brisk walking mostly targeted the lower limbs. In our study, however, neither FPG nor Hba1c returned to normal range after 8 weeks of the PMSME program.

This study also demonstrated that the PMSME can improve HRR in the first minute after completion of the TMST. Our finding was similar to a previous study on overweight patients with chronic kidney disease who engaged in home-based aerobic exercise three times per week for 12 weeks.[34] This could be explained by the fact that aerobic exercise enhances myocardial contractility and endothelial function by reducing oxidative stress and preserving nitric oxide bioavailability.[35]

After 8 weeks of PMSME, functional leg muscle strength improved significantly. In diabetics, increased functional leg muscular strength could delay age-related sarcopenia.[36,37] In addition, increased muscle mass and strength in T2DM patients can improve insulin sensitivity and glycemic control.[38,39] Since the PMSME is an accumulating aerobic exercise, its efficacy in achieving the MCID of FTSST (2.5 s) may be limited.[40]

The improvements in HbA1c, exercise tolerance and functional muscle strength observed in this study may contribute to an improvement in QoL (physical function, physical role, vitality, and total score domains of SF-36). Additionally, an increase in SF-36 scores in these domains was found to meet the MCID of SF-36.[41] The mechanism by which PMSME improves QoL in people with T2DM is unclear. The improvement in QoL is probably due to the result of a decrease in FPG and HbA1c as well as an increase in functional leg muscle strength an exercise tolerance. Our findings are consistent with previous studies suggesting that aerobic exercise training can increase QoL in sedentary, healthy men and T2DM patients.[42,43]

As far as the limitations are concerned, our study's findings may not be generalizable to other racial or regional groups due to the limited sample size and participants from only the Northeast Thailand. Therefore, the results should be interpreted with caution. Further, we only instructed the participants to regulate their mealtime before exercise. Dietary intake before exercise has been observed to affect the exercise-induced blood glucose response.[44] Additional research should include dietary pattern measurements, e.g., eating frequency, nutritional composition, mealtime and employ dietary records to collect dietary information of the participants. Despite these limitations, the current study has several strengths including that it is a double-blind RCT with individual supervised exercise instruction and excellent 8-week intervention compliance (100% complete).

Conclusion

According to our study, PMSME is simple to implement and highly compliant. T2DM patients can improve glycemic control, exercise tolerance, functional leg muscle strength and QoL by using the PMSME as an alternative home-based exercise program.

Conflicts of interest

None

Ethics approval

The study was approved by Ethics Committee of Center for Ethics in Human Research, Khon Kaen University (HE632170). All subjects provided their informed consent prior to participation.

Acknowledgments

We sincerely thank all participants in the study. This study was support by Faculty of Associated Medical Sciences, Khon Kaen University.

References

[1] Jakicic JM, Otto AD. Physical activity considerations for the treatment and prevention of obesity. Am J Clin Nutr. 2005; 82(1 Suppl): S226-9. doi: 10.1093/ajcn/82.1.226S.

[2] Saeedi P, Petersohn I, Salpea P, Malanda B, Karuranga S, Unwin N, et al. Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045: results from the International Diabetes Federation Diabetes Atlas, 9th edition. Diabetes Res Clin Pract. 2019; 157: 107843. doi: 10.1016/j.diabres.2019.107843.

[3] Piché M-E, Tchernof A, Després J-P. Obesity phenotypes, diabetes, and cardiovascular diseases. Circ Res. 2020; 126(11): 1477-500. doi: 10.1161/CIRCRESAHA.120.316101.

[4] Balducci S, Zanuso S, Nicolucci A, De Feo P, Cavallo S, Cardelli P, et al. Effect of an intensive exercise intervention strategy on modifiable cardiovascular risk factors in subjects with type 2 diabetes mellitus: a randomized controlled trial: the Italian diabetes and exercise study (IDES). Arch Intern Med. 2010; 170(20): 1794-803. doi: 10.1001/archinternmed.2010.380.

[5] Church TS, Blair SN, Cocreham S, Johannsen N, Johnson W, Kramer K, et al. Effects of aerobic and resistance training on hemoglobin A1c levels in patients with type 2 diabetes: a randomized controlled trial. JAMA. 2010; 304(20): 2253-62. doi: 10.1001/jama.2010.1710.

[6] Goodyear LJ, Kahn BB. Exercise, glucose transport, and insulin sensitivity. Annu Rev Med. 1998; 49: 235-61. doi: 10.1146/annurev.med.49.1.235.

[7] DiPietro L, Gribok A, Stevens MS, Hamm LF, Rumpler W. Three 15-min bouts of moderate postmeal walking significantly improves 24-h glycemic control in older people at risk for impaired glucose tolerance. Diabetes Care. 2013; 36(10): 3262-8. doi: 10.2337/dc13-0084.

[8] Gaudet-Savard T, Ferland A, Broderick TL, Garneau C, Tremblay A, Nadeau A, et al. Safety and magnitude of changes in blood glucose levels following exercise performed in the fasted and the postprandial state in men with type 2 diabetes. Eur J Cardiovasc Prev Rehabil. 2007; 14(6): 831-6. doi: 10.1097/HJR.0b013e3282efaf38.

[9] Pahra D, Sharma N, Ghai S, Hajela A, Bhansali S, Bhansali A. Impact of post-meal and one-time daily exercise in patient with type 2 diabetes mellitus: a randomized crossover study. Diabetol Metab Syndr. 2017; 9: 64. doi: 10.1186/s13098-017-0263-8.

[10] Reynolds AN, Mann JI, Williams S, Venn BJ. Advice to walk after meals is more effective for lowering postprandial glycaemia in type 2 diabetes mellitus than advice that does not specify timing: a randomised crossover study. Diabetologia. 2016; 59(12): 2572-8. doi: 10.1007/s00125-016-4085-2.

[11] Daenen S, Sola-Gazagnes A, M'Bemba J, Dorange-Breillard C, Defer F, Elgrably F, et al. Peak-time determination of post-meal glucose excursions in insulin-treated diabetic patients. Diabetes Metab. 2010; 36(2): 165-9. doi:10.1016/j.diabet.2009.12.002.

[12] Erickson ML, Little JP, Gay JL, McCully KK, Jenkins NT. Postmeal exercise blunts postprandial glucose excursions in people on metformin monotherapy. J Appl Physiol (1985). 2017; 123(2): 444-50. doi: 10.1152/japplphysiol.00213.2017.

[13] Jones C, Phimphasak C, Pukdeechat M, Jones D. Spot marching exercise for home-based pulmonary rehabilitation in COPD: physical performance and quality of life. Eur Respir J. 2018; 52(suppl 62): PA3651. doi: 10.1183/13993003.congress-2018. PA3651.

[14] Leelayuwat N, Tunkumnerdthai O, Donsom M, Punyaek N, Manimanakorn A, Kukongviriyapan U, et al. An alternative exercise and its beneficial effects on glycaemic control and oxidative stress in subjects with type 2 diabetes. Diabetes Res Clin Pract. 2008; 82(2): e5-8. doi: 10.1016/j.diabres.2008. 08.010.

[15] Lunde MS HV, Høstmark AT. Slow post meal walking reduces the blood glucose response: an exploratory study in female Pakistani immigrants. J Immigr Minor Health. 2012; 14(5): 816-22. doi: 10.1007/s10903-012-9574-x.

[16] Jirawatkul A. Statistics for health science research. Bangkok: Witthayaphat, Ltd.; 2009: 174-88 (inThai).

[17] Gupta KK, Attri JP, Singh A, Kaur H, Kaur G. Basic concepts for sample size calculation: Critical step for any clinical trials!. Saudi J Anaesth. 2016; 10(3): 328-31. doi: 10.4103/1658-354X.174918.

[18] Sriburi C, Mausikarat P, Silsupadol P, Srisupornkornkool K. Effects of backward and forward walking training on balance, spatiotemporal gait characteristics and risk of fall in elderly. Thai J Phys Ther. 2021; 44(1): 12-28 (in Thai).

[19] Lusardi MM, Fritz S, Middleton A, Allison L, Wingood M, Phillips E, et al. Determining risk of falls in community dwelling older adults: a systematic review and meta-analysis using posttest probability. J Geriatr Phys Ther. 2017; 40(1): 1-36. doi: 10.1519/JPT.00000 00000000099.

[20] American Diabetes A. Microvascular complications and foot care: standards of medical care in diabetes-2019. Diabetes Care. 2019; 42(Suppl 1): S124-38. doi: 10.2337/dc19-S011.

[21] Tabesh MR, Abolhasani M, Zali MR, Bagheri R, Alipour M, Cheraghloo N, et al. The impact of bariatric surgery procedures on the modulation of cardiometabolic risk factors in patients with severe obesity: a 12-month follow-up. J Int Med Res. 2022;50(10):3000605221119657.doi:10.1177/030 00605221119657.

[22] Almutairi N, Hosseinzadeh H, Gopaldasani V. The effectiveness of patient activation intervention on type 2 diabetes mellitus glycemic control and self-management behaviors: a systematic review of RCTs. Prim Care Diabetes. 2020; 14(1): 12-20. doi: 10.1016/j.pcd.2019.08.009.

[23] Bohannon RW, Bubela DJ, Wang YC, Magasi SS, Gershon RC. Six-minute walk test vs. three-minute step test for measuring functional endurance. J Strength Cond Res. 2015; 29(11): 3240-4. doi: 10. 1519/jsc.0000000000000253.

[24] Bohannon RW, Bubela DJ, Magasi SR, Wang YC, Gershon RC. Sit-to-stand test: performance and determinants across the age-span. Isokinet Exerc Sci. 2010; 18(4): 235-40. doi: 10.3233/ies-2010-0389.

[25] Thaweewannakij T, Wilaichit S, Chuchot R, Yuenyong Y, Saengsuwan J, Siritaratiwat W, et al. Reference values of physical performance in Thai elderly people who are functioning well and dwelling in the community. Phys Ther. 2013; 93(10): 1312-20. doi: 10.2522/ptj.20120411.

[26] Lins L, Carvalho FM. SF-36 total score as a single measure of health-related quality of life: scoping review. SAGE Open Med. 2016; 4: 2050312116671725. doi: 10.1177/2050312116671725.

[27] Mooradian AD. Dyslipidemia in type 2 diabetes mellitus. Nat Clin Pract Endocrinol Metab. 2009; 5(3): 150-9. doi: 10.1038/ncpendmet1066.

[28] Aliha JM, Asgari M, Khayeri F, Ramazani M, Farajzadegan Z, Javaheri J. Group education and nurse-telephone follow-up effects on blood glucose control and adherence to treatment in type 2 diabetes patients. Int J Prev Med. 2013; 4(7): 797-802.

[29] Shab Bidar S, Fathi B, Shirazifard N. Effects of clinical nutrition education on glycemic control outcomes in type 2 diabetes. Int J Diabetes Dev Ctries. 2006; 26(4): 156-59. doi: 10.4103/0973-3930.33181.

[30] Sanda S, Mamilla R. A comparative study of effect of short walk after meals to that of single daily half an hour walk in type 2 diabetes. J Evid Based Med Healthc. 2017; 4: 5339-41. doi: 10.18410/jebmh /2017/1067.

[31] Pozzilli P, Strollo R, Bonora E. One size does not fit all glycemic targets for type 2 diabetes. J Diabetes Investig. 2014; 5(2): 134-41. doi: 10.1111/jdi.12206.

[32] Lenters-Westra E, Schindhelm RK, Bilo HJ, Groenier KH, Slingerland RJ. Differences in interpretation of haemoglobin A1c values among diabetes care professionals. Neth J Med. 2014; 72(9): 462-6.

[33] Colberg SR, Sigal RJ, Fernhall B, Regensteiner JG, Blissmer BJ, Rubin RR, et al. Exercise and type 2 diabetes: the American College of Sports Medicine and the American Diabetes Association: joint position statement executive summary. Diabetes Care. 2010; 33(12): 2692-6. doi: 10.2337/dc10-1548.

[34] Aoike DT, Baria F, Kamimura MA, Ammirati A, de Mello MT, Cuppari L. Impact of home-based aerobic exercise on the physical capacity of overweight patients with chronic kidney disease. International Urology and Nephrology. 2015; 47(2): 359-67. doi: 10.1007/s11255-014-0894-8.

[35] Powers SK, Howley ET. Exercise physiology: theory and application to fitness and performance. New York: McGraw-Hill Education; 2018: 298-9.

[36] Buscemi C, Ferro Y, Pujia R, Mazza E, Boragina G, Sciacqua A, et al. Sarcopenia and appendicular muscle mass as predictors of impaired fasting glucose/type 2 diabetes in elderly women. Nutrients. 2021; 13(6): 1909. doi: 10.3390/nu13061909.

[37] Konopka AR, Harber MP. Skeletal muscle hypertrophy after aerobic exercise training. Exerc Sport Sci Rev. 2014; 42(2): 53-61. doi: 10.1249/jes.0000000000000007.

[38] Gordon BA, Benson AC, Bird SR, Fraser SF. Resistance training improves metabolic health in type 2 diabetes: a systematic review. Diabetes Res Clin Pract. 2009; 83(2): 157-75. doi: 10.1016/j.diabres.2008.11.024.

[39] Qadir R, Sculthorpe NF, Todd T, Brown EC. Effectiveness of resistance training and associated program characteristics in patients at risk for type 2 diabetes: a systematic review and meta-analysis. Sports Medicine - Open. 2021; 7(1): 38. doi: 10.1186/s40798-021-00321-x.

[40] Kanaley JA, Colberg SR, Corcoran MH, Malin SK, Rodriguez NR, Crespo CJ, et al. Exercise/physical activity in individuals with type 2 diabetes: a consensus statement from the American College of Sports Medicine. Med Sci Sports Exerc. 2022; 54(2): 353-68. doi: 10.1249/mss.0000000000002800.

[41] Wee H-L, Li S-C, Cheung Y-B, Fong K-Y, Thumboo J. The influence of ethnicity on health-related quality of life in diabetes mellitus: A population-based, multiethnic study. Journal of Diabetes and its Complications. 2006;20(3):170-8. doi: 10.1016/j.jdiacomp.2005.06.010.

[42] Amini M, Mirmoezzi M, Salmanpour M, Khorshidi D. Effect of 8-week of selected aerobic exercises on improving the quality of life in healthy aged sedentary men. Int J Sport Stud Hlth. 2018; In Press. doi: 10.5812/intjssh.67514.

[43] Myers VH, McVay MA, Brashear MM, Johannsen NM, Swift DL, Kramer K, et al. Exercise training and quality of life in individuals with type 2 diabetes: a randomized controlled trial. Diabetes Care. 2013; 36(7): 1884-90. doi: 10.2337/dc12-1153.

[44] Ferland A, Brassard P, Lemieux S, Bergeron J, Bogaty P, Bertrand F, et al. Impact of high-fat /low-carbohydrate, high-, low-glycaemic index or low-caloric meals on glucose regulation during aerobic exercise in type 2 diabetes. Diabet Med. 2009; 26(6): 589-95. doi: 10.1111/j.1464-5491.2009.02734.x.