ISSN: 2345-2897; Health Education and Health Promotion. 2022;10(3):509-515.

Continuous Moderate-Intensity Exercise: Effects on Diabetic Ulcers in Type 2 Diabetes Mellitus

ARTICLE INFO

Article Type
Original Research

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How to cite this article
Mawarti S, Rohmansyah N A, Hiruntrakul A. Continuous Moderate-Intensity Exercise: Effects on Diabetic Ulcers in Type 2 Diabetes Mellitus. Health Education and Health Promotion. 2022;10(3):509-515.

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Article History
Received: April 23, 2022
Accepted: June 26, 2022
ePublished: July 10, 2022

ABSTRACT

Aims The purpose of this study is to look at the influence of continuous moderate-intensity exercise on the risk of diabetic ulcers in people with type 2 diabetes.
Material & Methods This study employed a randomized control trial design, with 30 participants divided into 15 in the intervention group and 15 in the control group. Continuous moderate-intensity exercise was done three times per week for a total of twelve sessions each month. The covariance was performed to analyse the data using SPSS 22.
Findings The intervention group had a much lower risk of diabetic ulcers than the control group, according to the findings. Furthermore, covariance revealed that Continuous Moderate-Intensity Exercise had a significant influence on the risk level of diabetic ulcers in individuals with type 2 diabetes mellitus.
Conclusion Continuous Moderate-Intensity Exercise is predicted to be used as an intervention to reduce diabetic ulcer complications in people with diabetes mellitus.
Keywords Type 2 Diabetes Mellitus; Exercise; Ulcer; Risk

CITATION LINKS

[1] Global and regional diabetes prevalence ... [2] Potret sehat indonesia dari riskesdas ... [3] Diabetic foot ulcers: part I. pathophysiology ... [4] Do patients with diabetes mellitus want wearable ... [5] Update on prevention of diabetic foot ... [6] Depth and combined infection is important predictor ... [7] Therapeutic effects of medicinal plants on ... [8] Effect of intensive nursing education on the prevention ... [9] Emerging diabetic foot ulcer microbiome ... [10] Severe vitamin D3 deficiency in the majority of patients ... [11] The incidence of confounding factors in ... [12] Tinea pedis and onychomycosis frequency in diabetes ... [13] Association between peripheral arterial disease ... [14] Reliability and credibility analysis of ... [15] Age-related and disease-related muscle ... [16] Obesity management for the treatment ... [17] Management of type 2 diabetes ... [18] Physical activity advice only or structured ... [19] Screening for identification of patients at high risk for ... [20] Impaired quality of life and diabetic ... [21] Exercise in obesity, metabolic syndrome ... [22] Low-intensity exercise reduces the prevalence ... [23] Consideration of insurance reimbursement ... [24] Effects of 7 days of exercise training ... [25] Seven days of aerobic exercise training improves ... [26] Low-volume high-intensity interval training ... [27] Exercise as a therapeutic intervention for the ... [28] Effects of prior high-intensity exercise on glucose ... [29] Independent and combined effects of ... [30] Nutrition therapy for diabetes: Implications ... [31] Obesity in young men, and individual ... [32] Effectiveness combination of foot care with ...

Introduction

Diabetes mellitus (DM) is a group of metabolic diseases marked by hyperglycemia that primarily endangers human health in the twenty-first century. Type 2 Diabetes Mellitus (T2DM) is caused by defects in insulin secretion, insulin action, or both, and accounts for 90-95% of all types of diabetes. According to data on the incidence of diabetes mellitus, 537 million adults (20-79 years) have diabetes; this figure is expected to rise to 643 million by 2030 and 783 million by 2045 [1]. According to Riskesdas 2018, the prevalence of diabetes mellitus in Indonesia in 2007 was 5.7 percent, then rose to 6.9% in 2013, and then rose again to 8.5% in 2018 [2].

The most serious complication of diabetes mellitus is Diabetic Foot Ulcer (DFU). DFU occurs in diabetic patients, accounting for nearly 25% of all diabetic patients [3–5]. During the course of the disease, DFU accounts for 14 to 24% of lower extremity amputations [6]. DFU develops as a result of peripheral neuropathy, ischemia, and neuro-ischemia. The loss of protective sensation and muscle coordination in the feet caused by neuropathy affects mechanical stresses during ambulation [7, 8]. Furthermore, the decreased oxygen supply in the lower limb causes ischemia and can result in a wound.

DFU can be caused by a combination of ischemia and neuropathy, both of which deteriorate the patient's skin integrity. DFU is a DM complication that can be treated. Appropriate dietary, activity, and therapy changes can all have an impact on DFU healing. DFU will heal at a rate of 60-80%. However, 10-15% will remain germinate, and 5-24% will have an amputation within 6-18 months [9,10]. According to Miranda *et al.* [5], more than half of DFUs addressed the sign of healing with proper DFU management.

In Indonesia, the prevalence of diabetic ulcer patients is around 15%, the amputation rate is 30%, and the 1-year post-amputation mortality rate is 14.8%. This is supported by data from Riskesdas [2] which shows an 11% increase in the number of diabetic ulcer sufferers in Indonesia.

A history of hypertension (BP 130/80 mmHg), a history of smoking habits (not smoking), physical exercise (less than 3 times a week for 30 minutes), obesity (BMI: women 23 kg/m^2, men 25 kg/m^2), non-adherence to dietary changes, poor blood sugar levels (GDS 200 mg/dL), poor foot care, and improper use of footwear are the most diabetic ulcer risk factors that can affect patients with diabetes mellitus [11–13].

A preliminary study conducted at hospitals in Yogyakarta and Semarang found 59 type-2 diabetes patients and 35 type-2 diabetes patients with diabetic ulcers. On 28 T2DM patients who visited the hospital, researchers examined the risk of diabetic ulcers using Inlow's 60-second diabetic foot screen screening tool observation sheet [14]. These patients met the researcher's inclusion and exclusion criteria, and the results showed that 16 patients were at high risk of developing diabetes mellitus, with 50% at high risk of developing diabetic ulcers.

Insulin resistance and impaired insulin secretion are two major insulin-related issues that patients with type 2 diabetes face. Diabetes mellitus duration >10 years, cholesterol levels >200 mg/dl, HDL levels 45 mg/dl, non-adherence to diabetes mellitus diet, lack of physical exercise, irregular foot care, and improper use of footwear were all found to be risk factors for ulcers by Kalyani *et al.* [15]. Diabetes ulcers are associated with education level, age, HbA1c >8%, obesity, and hypertension, but not with gender or smoking history [8, 15].

Diabetes mellitus management requires four main pillars: education, meal planning, physical activity, and pharmacological intervention. Physical activity is one of the recommendations in the management of diabetes mellitus. Many recreational teams or field sports, such as soccer, basketball, or football, as well as some training regimens (such as Fartlek or interval training), combine steady-state continuous moderate-intensity exercise with short bursts of higher intensity effort. Long periods of continuous moderate-intensity exercise activity (i.e. between 55–75% of maximum heart rate (HRmax)) are typically interspersed with intermittent bouts of high-intensity exertion (i.e. > 90% HRmax). Several studies [16–18] recently reported that a brief sprint, or a series of intermittent high-intensity exercise bouts, typically in the form of sprints, reduces the typical drop in blood glucose concentration associated with continuous moderate-intensity aerobic exercise.

Although intermittent high-intensity exercise may protect against acute exercise-induced hypoglycemia, the effects of intermittent high-intensity exercise on glucose levels during recovery are unknown. On the one hand, because intermittent high-intensity exercise uses muscle glycogen as a primary fuel source (due to the higher intensity of the exercise), recovery blood glucose levels may fall even further with this type of exercise due to an increased need for muscle glycogen restoration. Increases in glucose counter-regulatory hormones, such as catecholamines and cortisol, or elevations in other metabolites (such as free fatty acids), on the other hand, may lower glucose clearance and be associated with higher blood glucose concentrations during recovery. The purpose of this study was to determine the effect of continuous moderate-intensity exercise on the risk of developing diabetic ulcers with Type 2 Diabetes Mellitus.

Material and Methods

A randomized control trial was used in the study. In this study, participants were divided into two groups: the treatment group and the control group.

The study commenced in January 2021 with the baseline measurements and ended in March 2021. Thirty patients met the requirements. The following were the inclusion criteria for this study: 1) Between the ages of 40 and 65; 2) Capable of carrying out independent activities; 3) No signs of hypoglycemia (shaking, precipitation, headache, hunger, weakness, difficulty concentrating, emotional changes); 4) Blood Sugar Levels not exceeding 300 mg/dL and not falling below 70 mg/dL. The following patients were excluded from this study: 1) T2DM patients with diabetic ulcers and gangrene; 2) T2DM patients with complications that could interfere with the study (chronic kidney failure, heart failure, visual impairment, deafness, etc.); 3) The patient does not participate in all activities or resigns. There are several methods used to calculate the sample size depending on the type of data or study design. The sample size is calculated using the following formula:

$$n = \frac{2(Z\alpha + Z1 - \beta)}{\Delta 2}$$

where n is the required sample size. For Zα, Z is a constant (set by convention according to the accepted α error and whether it is a one-sided or two-sided effect), For Z1-, β, Z is a constant set by convention according to the power of the study.

The two elements of the Michigan Neuropathy Screening Instrument were the main outcomes evaluated (MNSI). The first part of the MNSI is a self-report, 13-item questionnaire that looks at peripheral neuropathy symptoms such as foot feeling, foot pain, and foot temperature sensitivity. Two of the questions were eliminated since they dealt with non-neuropathy issues. Observation sheet for Inlow's 60-second Diabetic Foot Screen Screening Tool [14]. The observation sheet includes 12 indicators, each with a different score. The lowest possible total score was 0 and the highest possible total score was 25. The second part is a brief clinical examination of the foot that assesses hallux appearance, ulceration, ankle reflexes, and vibration perception. The outcome is an eight-point score. Higher scores indicate poorer loss of feeling. The MNSI clinical symptoms component is validated to screen for peripheral neuropathy indicators. Subjects were informed about all experimental procedures and signed written informed consent, following Universitas PGRI Semarang's ethics policy.

Starting in week nine and continuing through the 12-week program, continuous moderate-intensity cycling on an ergometer. Age HRmax was predicted for two consecutive workloads and increased to nearly 85% of HRmax by using three protocols or 3-minute consecutive workloads designed to increase HR between 110bpm; 50rpm was set as the initial pedaling speed, and 150kpm×min^{-1} (25W) was set as the initial workload. It is used to measure HR to determine the next workload at 15 seconds at the last minute. For example, if HR was around 80-89bpm or 90-100bpm in the first stage, the workload increased to 600 or 450kpm×min^{-1} in the second stage.

The statistical analysis was carried out with the aid of IBM SPSS software (Version 22.0. IBM Corp., Armonk, NY, USA). For ratio data, group data were reported as mean standard deviation, and for nominal data, proportions. The cut-off for statistical significance was p=0.05. In order to compare participant characteristics, independent sample t-tests for ratio data or chi-square testing for nominal data were used (Table 1). For anthropometry, primary and secondary outcome variables, mixed-model repeated measurement ANOVAs (between factor: intervention group; within factor: timing) were conducted. If the sphericity assumption was broken, Mauchly's test was examined and the Greenhouse-Geisser correction was used. The intervention was considered to have an impact on the pattern of response if a significant p-value for the interaction effect (intervention X timing) was found. If the interaction effect failed to approach significance, the primary effects of intervention and timing were considered.

Findings

The average age of the respondents was 56.59 years, according to the findings of the study of the distribution of research respondents (n=30) based in Table 1. An average of 69.53 months may be determined from extended experience with DM. The average blood sugar level in diabetic people is 219.91mg/dl. The average BMI in diabetes patients is 24.482. The average ankle-brachial index (ABI) value was 1. In terms of gender, it was clear that more than half of the 17 responders were male. The entire respondents' average education level is more than half, with 19 respondents in elementary school. Data on job status can be found, with half of the 14 respondents working as entrepreneurs. All respondents do not smoke, and the majority of the 27 respondents use prescription medicines.

According to Table 2, there was a 2.6 point drop in the probability of developing diabetic ulcers, from 6.73 points before continuous moderate-intensity exercise to 4.13 points after continuous moderate-intensity exercise. The negative sign in the difference column shows that the respondents have a lower risk of diabetic ulcers. According to Table 2, there was a 0.53 point drop in the probability of developing diabetic ulcers in the control group, from an average pre-test of 6.46 points to 5.93 points at the time of the post-test. The negative sign in the difference column shows that the respondents had a lower risk of diabetic ulcers.

The combined cohort, the treatment and control groups, and the mean difference in the major and secondary outcome indicators are shown in Table 3. Similar patterns of change were observed in the neuropathic signs, neuropathic symptoms, and VPT following the treatment and control interventions. The patients in both lifestyle regimens did, however, significantly improve neuropathic symptoms, indicators, and VPT. The pattern of change in maximum oxygen uptake was comparable when contrasting treatment and control, which is consistent with the major outcome measures. Similar results from sit to stand showed no variation in the pattern of change between groups. The tandem stance's interaction and temporal effects did not achieve significance. The mean differences for the auxiliary variables are shown in Table 3.

The exercise and education sessions had acceptable mean attendance of >80%. During the trial, there were no adverse events such as foot ulcerations, medical problems, or other occurrences like increased pain. At the recommended relative exercise intensity, the aerobic component's duration and intensity ranged from 7 to 20 minutes in week 1 to 15 to 45 minutes in week 8. (50–70% heart rate reserve). Beginning with two sets of 10 repetitions on each exercise, the strengthening exercise program advanced to three sets of 10-15 repetitions at an RPE of 7-8 out of 10.

Table 1) Distribution of Respondents

Variable	Group treatment		Group control		p-value
	Mean±SD	N (%)	Mean±SD	N (%)	
Age (years)	56.46±6.42	-	56.73±6.48	-	0.53
BMI	25.71±3.87	-	23.25±4.68	-	0.56
Resting heart rate (bpm)	69±10.3	-	72.7±8.3	-	0.35
Resting systolic blood pressure (mm Hg)	127.9±15.3	-	123.2±14.6	-	0.25
Resting diastolic blood pressure (mm Hg)	73.4±7.9	-	76.2±9.6	-	0.31
Waist circumference (cm)	109.5±18.5	-	105.3±11.6	-	069
Duration of diabetes	70.39±77.85	-	68.67±81.79	-	0.38
Current KGD score (mg/dl)	218.60±55.87	-	221.23±48.31	-	0.31
ABI	0.98±0.23	-	1.02±0.14	-	0.62
Method of control	-	-	-	-	-
Oral medication	-	5 (17.3)	-	9 (31.6)	0.67
Insulin	-	5 (17.3)	-	5 (17.5)	
Diet	-	10 (32.1)	-	7 (24.2)	
Combination	-	7 (24.1)	-	5 (17.8)	
Adhered to exercise recommendations	-	16 (52.4)	-	16 (53.2)	0.56
Michigan Neuropathy Screening Instrument. signs (/8)	5.4±0.8	-	5.1±0.9	-	0.03
Michigan Neuropathy Screening Instrument. symptoms (/13)	5.6±2.4	-	4.7±2.9	-	0.24
VPT (/50)	38.6±7.3	-	35.8±8.7	-	0.08
Balance: tandem stance (s)	36.1±24.8	-	41.3±23.5	-	0.68
Maximum oxygen uptake ($Ml \times kg^{-1} \times min^{-1}$)	18.6±4.3	-	21.4±5.8	-	0.52
Sit to Stand (number 30 s)	17.5±13.4	-	15.6±11.3	-	0.76

Table 2) Data on the Risk of Diabetic Ulcers in both groups

Code of samples	Treatment					Control				
	Pre-test		Post-test		Difference (Δ)	Pre-test		Post-test		Difference (Δ)
	Score	Categories	Score	Categories		Score	Categories	Score	Categories	
S.1	8	Low	6	Very low	-2	9	Low	8	Low	-1
S.2	7	Low	4	Very low	-3	6	Very low	6	Very low	0
S.3	6	Very low	3	Very low	-3	7	Low	6	Very low	-1
S.4	7	Low	3	Very low	-4	5	Very low	5	Very low	0
S.5	8	Low	6	Very low	-2	9	Low	8	Low	-1
S.6	8	Low	5	Very low	-3	7	Low	6	Very low	-1
S.7	6	Very low	5	Very low	-1	5	Very low	4	Very low	-1
S.8	9	Currently	8	Low	-1	6	Very low	6	Very low	0
S.9	6	Very low	2	Very low	-4	4	Very low	4	Very low	0
S.10	7	Low	3	Very low	-4	7	Low	6	Very low	-1
S.11	6	Very low	3	Very low	-3	6	Very low	6	Very low	0
S.12	5	Very low	4	Very low	-1	6	Very low	6	Very low	0
S.13	7	Low	4	Very low	-3	7	Low	6	Very low	-1
S.14	5	Very low	3	Very low	-2	6	Very low	5	Very low	-1
S.15	6	Very low	3	Very low	-3	7	Low	7	Low	0
Total	101		62		-39	97		89		-8

Table 3) Pre- and post-test outcome scores for the combined cohort, the exercise, and intervention groups with mean±SD and 95% confidence intervals.

Variable	Group	Pre-test	Post-test	Mean difference	95% CI
MNSI Signs (0–8)	Treatment	4.9±0.8	3.5±1.5	-0.43	-1.67 to 0.91
	Control	5.1±0.7	3.4±1.6		
MNSI Symptoms (0–13)	Treatment	4.9±2.3	3.6±1.7	-0.37	-1.95 to 1.3
	Control	4.6±2.1	3.5±1.4		
VPT (0–50)	Treatment	38.7±6.7	34.3±12.5	-4.34	-13.83 to 3.56
	Control	34.5±6.8	32.6±7.6		
Maximum oxygen uptake (mL×kg^{-1} ×min^{-1})	Treatment	18.3±3.5	24.7±7.4	1.58	-2.68 to 6.11
	Control	18.6±3.6	23.6±6.7		
Tandem Stance (s)	Treatment	36.7±24.3	37.7±23.6	-0.89	-12.3 to 8.75
	Control	37.5±24.2	41.6±23.5		
30s sit-to-stand (repetitions)	Treatment	14.5±11.3	23.2±13.2	0.67	-8.77 to 12.53
	Control	14.3±10.5	22.4±12.2		

Mean variations presented for the combined effects of time and group interactions between the exercise and education groups (time effect). A drop in scores for primary outcome metrics indicates improvement. An increase for secondary outcome measures denotes improvement. MNSI stands for the Michigan Neuropathy Screening Instrument.

Discussion

The risk of ulcers in the therapy group dropped considerably after conducting the continuous moderate-intensity exercise. This reduction was caused by constant moderate-intensity exercise activities performed 12 times per week and the respondents' healthy lifestyle. According to Al-Mohaithef [19], in this study, a therapy from one of the pillars of diabetes management was carried out. It was discovered that before diabetes mellitus exercise was carried out, 74.3% of respondents were in the very low group. 94.3% of responders fell into the extremely low group after undertaking continuous moderate-intensity exercise.

Diabetes mellitus exercise was performed in line with the standards of the American Diabetes Association in this study [16]. The American Diabetes Association principles are used to optimize the outcomes of continuous moderate-intensity exercise. The American Diabetes Association consists of continuous, in this study, the implementation of the continuous moderate-intensity exercise was carried out for 30 minutes per session and was carried out three times per week for one month. As a result, persons with diabetes should pick a workout that primarily works big muscles, has rhythmic (rhythmic) motions, and is continuous for an extended time. The portion of exercise must be set such that the aims and objectives of DM sufferers' exercise deliver good advantages.

This reduction in the incidence of diabetic ulcers suggests that diabetes mellitus exercise has a good influence on the risk of diabetic ulcers. Continuous moderate-intensity exercise, according to AlSadrah [20], has a significant impact on the treatment of type 2 diabetes mellitus. In T2DM, insulin production is not disrupted, but insulin cannot assist since the response of insulin receptors on cells (resistance) is still inadequate. Glucose transport into cells During exercise, the condition of membrane permeability to glucose rises in contracting muscles, resulting in decreased insulin resistance and increased insulin sensitivity. Respondents who receive exercise training are reported to have 40% lower insulin needs and feel healthier than those who do not exercise [18, 21–29]. Exercise not only reduces the body's requirement for insulin but can also boost blood circulation, particularly in the legs.

However, there were respondents in this study who had a constant value and there was no drop since the respondents could not regulate their daily eating, were not frequent users of medicines and did not routinely exercise. Diet is a type of diabetes management that is based on the nutritional regulation idea of a balanced diet and in line with each individual's calorie and nutritional demands [30]. Setting the timetable, kind, and amount of meals is a critical issue to consider. Regular medicine usage can improve the condition of patients with diabetes. Oral hyperglycemic medications (OHO) are classified into five classes based on how they work: insulin secretagogue triggers (insulin secretagogue): Insulin sensitivity improvers: metformin and thiazolidinediones, gluconeogenesis inhibitors: metformin, glucose absorption inhibitors: alpha-glucosidase inhibitors and DPP-IV inhibitors Age is one of the factors that influence a person's capacity to care for themselves. The ability to lead and assess oneself improves as one grows older [15, 31]. The active engagement of clients, families, and communities, as well as the health team that aids patients in healthy behavior modification, is required for the empowerment of DM responses. Comprehensive education and motivational efforts are required for successful habit change.

Physical activity (exercise) that is insufficient (3x or more/week for 30 minutes) increases the chance of getting diabetic ulcers by 9.4 times compared to those who exercise regularly (3x or more/week for 30 minutes) [18, 21, 22, 32]. The statement was issued by 11 doctors and 38 physiotherapists who observed

DM patients with different criteria obtain a prescription for a physical activity program, the three profiles of DM patients were developed and the results obtained were they were lazy to exercise because they were fat and costs based on the focus of the discussion obtained, they have a 4x higher risk of blood [18].

Physical activity or exercise has the purpose of increasing insulin sensitivity, preventing obesity, improving blood flow, stimulating glycogen production, and preventing additional difficulties. By maintaining a balance of right and left muscles, the notion of continuous moderate-intensity exercise leverages the concept of cardiopulmonary endurance training (endurance). Continuous moderate-intensity exercise will benefit diabetes patients' health by lowering the risk of diabetic ulcers. Continuous moderate-intensity aerobic exercise raises the oxidative capacity of skeletal muscle via increasing the utilization of plasma fatty acids and fatty acid transport proteins. Exercise raises the number of mitochondria and the work of lipoprotein lipase, which is responsible for the rise in fat catabolism during sports activities.

The confounding variable cannot be well controlled in this study. Respondents to the survey Because the respondents' homes are far apart, it is impossible to gather and attend to each respondent who does not come for exercise. Weather considerations considerably affected the limits of this research during the time it was conducted. Because some respondents were unavailable due to weather considerations and personal activities during the exercise, the researchers chose another opportunity, namely the next day, to visit each respondent's house and offer exercises independently at the respondent's residence.

Conclusion

The reduction in the likelihood of diabetic ulcers in the treatment group compared to the control group demonstrates that regular moderate-intensity exercise can enhance blood flow, sensitivity, and circulation in the feet, preventing numbness or disturbances in the feet. The control group also saw a decline, not as a result of ongoing moderate-intensity exercise, but because the respondents already had enough knowledge to manage their diabetes.

Acknowledgments: None declared by the authors.
Ethical Permissions: Under Universitas PGRI Semarang's ethics policy.
Conflicts of Interests: None declared by the authors.
Authors' Contributions: Mawarti S (First Author), Assistant Researcher (33%); Rohmansyah NA (Second Author), Introduction Writer/Main Researcher/Discussion Writer (34%); Hiruntrakul A (Third Author), Methodologist (33%)
Funding/Support: None declared by the authors.

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