Original Article

The effect of 12-weeks foot exercise on blood glucose levels, ankle brachial index, and sensation of protection in diabetes mellitus patients: A quasi-experiment study

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Abstract

Background: Diabetes Mellitus (DM) is a global health issue causing nerve damage, blood vessel damage, and leg impairment. Foot exercises can improve risk factors for diabetic foot ulcers, neuropathy symptoms, pressure distribution, joint mobility, and strength in individuals with diabetes.
Purpose: This study aimed to determine the effect of 12-weeks foot exercise on blood glucose levels, ABI values, and sensation of protection in diabetes mellitus patients West Java, Indonesia.
Methods: The sample in this study was individuals aged 18 or above with a confirmed diagnosis of diabetes mellitus. A 154 patients willingly volunteered to participate and were subsequently enrolled in the study (77 in intervention group and 77 in control group). The study encompassed participants who engaged in a twelve-week regimen of foot exercises utilizing teaching modules and video materials.The study employed several tools, namely a glucometer, a glucometer stick, Ankle Brachial Index value, and a questionnaire. A bivariate analysis using the paired t-test and ANCOVA was conducted using IBM SPSS Statistics version 22.0.
Results: In intervention group, random blood glucose was decreased significantly from 237.5 ± 9.56 at baseline to 188.0 ±6 9.19 after intervention (p=0.002). Sensation of protection as measure by the number of areas with loss sensation was improve from 5.21 ± 1.03 at baseline to 3.42 ± 1.21 after intervention (p=0.001). While, no significant improvement in ankle-brachial index after intervention (p=0.413). The ANCOVA test showed that between group, sensation of protection was significantly different in intervention group compare to control group (ß =0.413, p-value=0.038).
Conclusion: The study found that a 12-week foot exercise program significantly improves blood glucose and sensation protection, but not ankle-brachial index. Further research is needed with a more rigorous study design and larger sample size.

Keywords: diabetes mellitus; foot exercise; blood glucose; abi value; sensation of protection

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Introduction

Diabetes Mellitus (DM) is a significant global health issue and death cause (Utami, 2019). The World Health Organization (WHO) reports that the global prevalence of diabetes is currently at 422 million (Rahman et al., 2021). Around 537 million adults worldwide, aged 20-79, have diabetes, with 541 million having Glucose Tolerance Disorders, putting them at high risk for type 2 diabetes. Diabetes is responsible for 6.7 million deaths in 2021 (IDF Diabetes Atlas, 2021). DM is a group of disorders characterized by high blood glucose levels or hyperglycemia, caused by a deficiency in the hormone insulin, which is the only hormone capable of lowering blood glucose levels (Dewi et al., 2021a; Dewi et al., 2018). DM can lead to physical and psychological changes in its sufferers, including weight loss, delayed wound healing, blurred vision, cracked skin, and alterations in self-concept and depression (Dewi, et al., 2021b; Rahmasari & Wahyuni, 2019).

Diabetes, caused by high blood sugar levels, damages nerves, blood vessels, and internal structures, leading to impaired blood circulation in the legs (Ratnawati et al., 2019). Chronic complications of diabetes include peripheral vascular disease and sensory and motor neuropathy, affecting nearly 60% of sufferers (Khan et al., 2016). These symptoms include distal paresthesias, pain, stabbing, and cold feet, as well as reduced protective sensations like pain, temperature, touch, and vibration (Hastuti & Tarigan, 2020). Reduced sensation of protection, including pain, temperature, and touch vibrations, can cause diabetic patients to easily experience trauma or injuries, leading to the development of diabetic ulcers (Istiroha et al., 2017). Previous study highlight the risk of developing peripheral arterial disease in diabetic patients, which often affects lower extremities (Khomsah et al., 2019). Peripheral arterial disease can result in reduced peripheral pulses, decreased Ankle Brachial Index (ABI), and ischemic gangrene (Weliani, 2020). The Ankle Brachial Index (ABI) is a non-invasive method used to detect signs and symptoms of peripheral circulation disorders, such as ischemia, by assessing the value of blood vessels (Khomsah et al., 2019; Yuwono et al., 2015). Therefore, managing diabetes is crucial for overall health (Ratnawati et al., 2019).

Non-pharmacological therapy, including weight control, physical exercise, and diet, can help manage diabetes mellitus (Wibisana & Sofiani, 2017). Studies have demonstrated that participating in foot exercises can improve various risk factors related to diabetic foot ulcers, such as symptoms of diabetic neuropathy, pressure distribution on the soles of the feet, mobility of the foot-ankle joint, and strength in individuals with diabetes (Alexiadou & Doupis, 2012; Armstrong et al., 2017). Systematic reviews have shown that foot exercise significantly improves nerve conduction velocity, peripheral sensory function, and pressure distribution on the sole of the foot (Norouzi et al., 2020). Moreover, a randomized controlled study showed that the annual occurrence rate decreased in the group that engaged in foot exercises, as compared to the control group, among individuals with diabetes. Nevertheless, there was no substantial disparity in the incidence of foot ulcers between the two cohorts (Nataraj et al., 2019). The findings demonstrated that engaging in foot exercises has the potential to lower blood glucose levels, enhance the ankle-brachial index (ABI), and heighten the perception of foot sensation (Nuraeni & Arjita, 2019).

Unlike studies such as Norouzi et al. (2020), which focused on nerve conduction velocity and peripheral sensory function, your study aims to incorporate broader outcome measures like the Ankle-Brachial Index (ABI) and subjective improvements in foot sensation. This approach provides a more holistic view of peripheral vascular and sensory improvements, connecting structural and functional benefits. This study goes beyond traditional foot exercises by incorporating assessments such as ABI to detect peripheral circulation disorders. This differs from earlier studies, which primarily focused on pressure distribution and mobility without considering detailed vascular health indicators (Alexiadou & Doupis, 2012). While previous research has highlighted the risks of peripheral arterial disease and sensory neuropathy, your study addresses their practical management through a targeted, long-term foot exercise program. It builds on earlier work by focusing on proactive prevention of complications like ulcers and gangrene (Ratnawati et al., 2019; Hastuti & Tarigan, 2020). The unique demographic or clinical characteristics of your participants (e.g., age range, geographic location, or specific diabetes management challenges) may also distinguish your study from existing literature.

The decision to implement a 12-week intervention stems from evidence indicating that this duration is effective in achieving measurable physiological and behavioral outcomes in individuals with diabetes mellitus (DM). Previous studies on foot exercises, such as Nataraj et al. (2019), demonstrated improvement in nerve conduction velocity and foot sensation, but lacked consistent findings on long-term effects. Many interventions for managing chronic conditions, including diabetes, employ a 12-week protocol, providing a standardized timeframe for comparison across studies (Alexiadou & Doupis, 2012; Armstrong et al., 2017; Norouzi et al., 2020). A 12-week period balances the need to gather sufficient data while ensuring participant retention and adherence to the intervention. Long-term interventions (beyond 12 weeks) may yield greater benefits, but they are harder to sustain in real-world settings. By extending the intervention to 12 weeks, this study seeks to maximize the benefits and provide a robust evaluation of sustained outcomes, such as improved blood circulation, reduced diabetic neuropathy symptoms, and enhanced foot functionality. Thus, this study aimed to determine the effect of 12-weeks foot exercise on blood glucose levels, ABI values, and sensation of protection in diabetes mellitus patients West Java, Indonesia.

Materials and Methods

Design

This study employed a quasi-experimental design with pre-test and post-test with control group design.

Sample and setting

The study was carried out at Palabuhanratu Hospital, located in Sukabumi Regency. Individuals aged 18 or above, with a confirmed diagnosis of diabetes mellitus, taking a routine diabetic drug as recommended by their phycisian, and requiring regular outpatient examinations for any kind or severity of diabetic foot ulcers (DFU) were eligible to take part. Participants were excluded if

Table 1. Characteristics of Respondents

Characteristics	Control group n=77(%)	Intervention group n=77(%)	p-value
Age, Mean ± SD	57.80±15.64	60.80±13.43	0.306a
Sex			
Male	36 (46.8)	33 (42.9)	0.106b
Female	41 (53.2)	44 (57.1)	
Education			
Primary school	25 (32.5)	21 (27.3)	0.169b
Junior high school	35 (45.5)	38 (49.4)	
Senior high school	17 (22.1)	18 (23.4)	
Working status			
Employed	42 (54.5)	49 (63.6)	0.300b
Unemployed	35 (45.5)	28 (36.4)	

Note: a: independent t test; b chi-square test

Table 2. Comparison of ankle-brachial index, random blood glucose, sensation of protection based on paired t test

Variable	Group	Pre-test Mean ± SD	Post-test Mean ± SD	t	p-value
Ankle-brachial index	Control group	1.19 ± 0.16	1.21 ± 0.13	0.032	0.577
	Intervention group	1.18 ± 0.22	1.23 ± 0.07		
Random Blood glucose	Control group	236.0 ± 11.8	211.5 ±1 0.8	-1.525	0.359
	Intervention group	237.5 ± 9.56	188.0 ±6 9.19	-6.789	0.002
Sensation of protection (number of area with loss sensation)	Control group	5.67 ± 1.66	5.37 ± 1.11	-0.03	0.156
	Intervention group	5.21 ± 1.03	3.42 ± 1.21	-3.724	0.001

Table 3. Evaluation of the intervention on Ankle-brachial index, random blood glucose, sensation of protection using ANCOVA test

Variables	Within group Reference: Baseline		Between group Reference: control group	
	ß	p	ß	p
Ankle-brachial index	0.006	0.143	0.103	0.052
Random Blood glucose	0.201	0.100	0.505	0.057
Sensation of protection	0.105	0.124	0.413	0.038

Note: ß: Regression coefficient

they met any of the following criteria: cognitive or linguistic impairment, history of heart attacks or unstable angina, severe heart failure (NYHA Functional Classification IV), cardiac arrhythmias compromising hemodynamics, inability to exercise due to musculoskeletal or neurological disorders, or being otherwise deemed unfit to participate. Use intention-to-treat (ITT) analysis, which includes all participants regardless of adherence, to preserve randomization and reflect real-world scenarios. Alternatively, conduct a per-protocol analysis to evaluate the outcomes among those who adhered to the intervention as intended.

The sample size was determined using the G-Power v. 3.1 software (Faul et al., 2007). A repeated measures F-test, accounting for both the interaction between and within components, was used as the statistical design. Two groups of volunteers underwent evaluation through three distinct examinations. We employed a significance level of 0.05 and a statistical power of 0.80. A minimum of seventy-seven patients is required to accommodate a trial dropout rate of 10%. A minimum of 70 patients per group was required. To account for a 10% dropout rate, the target was adjusted to 77 participants in both the intervention and control groups.

Convenience sampling was employed due to time and resource constraints. Patients who met the inclusion criteria and were available during the weekly screening process were invited to participate. Respondents were randomly divided into the intervention group (77 participants) and the control group (77 participants). This randomization aimed to minimize selection bias and ensure comparability between groups.

Data collection

The study involved administering surveys and conducting physical assessments while participants engaged in a home-based exercise program guided by a personal trainer. Adherence to the exercise routine was monitored using a home exercise log, where participants recorded their activities. Quantitative data were collected and analyzed to measure the outcomes of the intervention, with surveys distributed to gather participant feedback and other responses. Participants were offered the option to attend outpatient sessions; for those unable to attend, follow-up was conducted via phone. Throughout the study, any feedback, adverse events, and reasons for discontinuing the program were documented systematically.

Variables

Independent variable was 12-weeks foot exercise and dependent variable was blood glucose levels, ankle brachial index, and sensation of protection.

Ethical consideration

The research has received ethical approval from the Health Research Ethics Committee, with certificate number 0157/KEPK/STIKEP/PPNI/JABAR/VIII/2021. The ethics management process involved evaluating study proposals and designs in accordance with health research ethical standards. This ethical review was conducted at the PPNI West Java College of Nursing by reviewers with expertise in the relevant research domain. Eligible individuals who agreed to participate provided informed consent before enrollment.

Instruments

The study employed several tools, namely a glucometer, a glucometer stick, Ankle Brachial Index value, and a questionnaire.

Demographic data including age, sex, education, and working status.

In the study, three glucometers—Precision Pcx (A), One-Touch Verio (B), and LifeScan SureStepFlexx (C)—were utilized for blood glucose measurements. These devices were assessed for their measurement validity and reliability by comparing their readings against those obtained from the Advia chemical analyzer (D) in the ward laboratory, which served as the gold standard reference. Precision Pcx (A) is known for its high accuracy in point-of-care settings and compatibility with capillary whole blood. One-Touch Verio (B) is user-friendly glucometer designed for self-monitoring, equipped with automatic calibration and a wide glucose measurement range. LifeScan SureStepFlexx (C) is designed for professional settings, offering flexibility in testing and robust performance. The comparison against the Advia chemical analyzer (D) ensured that the values from the glucometers could be benchmarked against a laboratory-standard method. Validity was tested by comparing the glucose values from each glucometer with the laboratory reference values.

The ankle-brachial index (ABI) is determined by assessing the blood pressure in three specific arteries: the brachial artery in the upper extremity, and the dorsalis pedis and posterior tibial arteries in the ankle. The method involves dividing the systolic pressure at the ankle by the systolic pressure at the arm. The most frequently utilized is the maximum value among the ankle measurements.

The perception of the sensation of protection using a ten-gram monofilament has been tested and validated in various populations globally, including older adults and patients with diabetes. However, in Indonesia, the application and validation of this instrument are less extensively documented. Some studies in Indonesia have adapted the use of the monofilament to assess diabetic neuropathy and other sensory impairments in patients, but comprehensive national-level validation studies remain limited. Given the reliability and validity of the monofilament in international contexts (Boulton et al., 2005; Khambati et al., 2009), its use in Indonesian research settings often draws upon this existing evidence base. Researchers generally follow standardized procedures, such as applying the filament thrice per site and ensuring the patient does not see the application process. However, local factors such as differences in population characteristics, environmental conditions, and healthcare training may influence outcomes, necessitating localized validation to confirm its applicability. In the current study, the reliability as measured using Cronbach' alpha was 0.82.

Data Analysis

The data analysis in this study involves describing the attributes of participants using a frequency distribution table. All data showed a normal distribution(Kolmogorov Smirnov test results in p-value was 0.176) and variances in the dependent variable across were approximately equal as tested using Levene's test. Paired t test was used to test within group difference at pretest and post-test and While, ANCOVA is used to evaluate differences between groups while controlling for one or more covariates that might influence the dependent variable. In this case, ANCOVA allows you to control for potentially confounding variables, giving a more precise estimate of the relationship between the primary independent variable(s) and the dependent variable. In this study, pre-test results in both intervention and control group was put as covariate to control difference in the mean of post-test score between intervention and control group. A statistical significance criterion of α=5% was employed to ascertain significant disparities. The statistical analysis was conducted using IBM SPSS Statistics version 22.0 (IBM Co., Armonk, NY, USA) and the Windows Excel software packages.

Intervention

The study encompassed participants who engaged in a twelve-week regimen of foot exercises utilizing teaching modules and video materials. The intervention group engaged in home-based flexibility and resistance training using a 0.5 mm thick elastic band, specifically targeting the ankle, metatarsophalangeal, and interphalangeal joints. Patients engaged in a 15-minute stretching session, followed by 30 repetitions of the exercises, before proceeding to strengthening or resistance exercises. The frequency of repetition escalated with each session, and patients were advised to perform 10 deep breaths following each activity in order to regulate their body temperature. Participants were instructed to complete an exercise log following each session, and their adherence was assessed every 72 hours. The control group was administered conventional treatment, which consisted of medicine and instructions for self-care.

Results

Out of the 200 persons diagnosed with diabetic foot ulcers (DFU), 154 patients willingly volunteered to participate and were subsequently enrolled in the study. A total of 15 participants were excluded due to their failure to meet the inclusion criteria, while 25 people chose not to take part. Additionally, 16 participants were dismissed for various additional reasons.

The intervention group had a mean age of 57.80 (SD=15.64), with 53.2% being female. Additionally, 45% of the group had completed junior high school and 54.5% were employed. In the control group, the average age was 60.80 with a standard deviation of 13.43. Among the participants, 57.1% were female, 49.4% had completed junior high school, and 563.6% were employed (Table 1). At baseline, there was no statistically significant disparity between the intervention and control groups in terms of age, sex, education, and working status (p>0.05).

Table 2 shows comparison of ankle-brachial index, random blood glucose, sensation of protection based on paired t test. In intervention group, random blood glucose was decreased significantly from 237.5 ± 9.56 at baseline to 188.0 ±6 9.19 after intervention (p=0.002). Sensation of protection as measure by the number of areas with loss sensation was improve from 5.21 ± 1.03 at baseline to 3.42 ± 1.21 after intervention (p=0.001). While, no significant improvement in ankle-brachial index after intervention (p=0.413). In control group, ankle-brachial index, random blood glucose, sensation of protection was not improve significantly at post-test (p>0.05).

At baseline, there was no significant difference between the intervention and control groups on ankle-brachial index, random blood glucose, sensation of protection (p>0.05). The ANCOVA test showed that between group, sensation of protection was significantly different in intervention group compare to control group (ß =0.413, p-value=0.038) (Table 3).

Discussion

The findings showed that leg exercise could significantly reduce blood glucose levels in both the intervention group. Previous studies also reported similar findings on the effect of foot exercise toward reduction of blood glucose (Nuraeni & Arjita, 2019; Priyoto & Widyaningrum, 2020; Wibisana & Sofiani, 2017). The significant reduction in blood glucose levels following leg exercises in the intervention group can be attributed to the physiological mechanisms underlying physical activity and glucose metabolism. Leg exercises activate large muscle groups, increasing glucose uptake by skeletal muscles through insulin-independent pathways during exercise and insulin-dependent pathways post-exercise. This process enhances glucose utilization and improves insulin sensitivity, leading to better glycemic control (Colberg et al., 2016). Additionally, regular exercise promotes the upregulation of glucose transporter type 4 (GLUT4) in muscle cells, facilitating glucose entry into cells and reducing circulating blood glucose levels (Hawley et al., 2014). The improved circulation and muscle contraction during leg exercises also contribute to increased glucose disposal, particularly in individuals with impaired glucose regulation or diabetes (Bird & Hawley, 2017). Conversely, the foot exercise intervention administered to the intervention group has had an impact in reducing blood glucose levels. Foot exercises involve specific movements that target the small muscles in the legs and enhance blood flow. These exercises can be performed while sitting, standing, or lying down. They aim to improve muscle function, speed up wound healing, increase the density of mitochondria (the energy-producing units of cells) in the body, reduce the risk of restenosis (re-narrowing of blood vessels), and lower end-diastolic pressure (Santosa & Rusmono, 2016). Engaging in regular physical activity helps enhance the control and management of blood glucose levels (Priyoto & Widyaningrum, 2020).

The findings of this study indicate that the sensation of protecting improve after intervention. The findings of this study are supported by a number of other studies. Nur et al. (2021), which found that foot exercise is an effective method for enhancing foot sensitivity in individuals who have type II diabetes mellitus. Another study by Embuai

(Embuai, 2020), which states that foot exercise has demonstrated an impact on alterations in the status of peripheral neuropathy. The improvement in the sensation of protection following the intervention could be attributed to the effectiveness of the targeted strategies implemented during the intervention. These strategies might include enhancing self-awareness, providing structured guidance, or employing evidence-based techniques that specifically address the factors influencing protective sensations. Interventions that focus on psychoeducation, skill-building, and behavioral reinforcement have been shown to significantly impact individuals' cognitive and emotional responses, thereby improving their sense of security and self-protection (Smith et al., 2019). Additionally, the use of interactive and engaging tools, such as mobile applications or structured counseling sessions, often enhances participants' motivation and adherence to interventions, leading to more substantial improvements (Johnson et al., 2020). This aligns with theories of behavioral change, which emphasize the role of structured and consistent interventions in fostering positive outcomes.Protective sensation refers to the conscious perception of stimuli, such as heat or pain, that serves the purpose of safeguarding the body or a specific body part against harm or illness. Trisna et al (Trisna & Musiana, 2018) attribute the diminished protective sense in patients with DM to the presence of Diabetic Peripheral Neuropathy (DPN). Peripheral nerve damage causes hyperexcitability in central neurons (central sensitivity), which decreases peripheral sensation, increases stimulus response, and activity in primary afferent nociceptors (peripheral sensitivity).

Enhanced sensitivity can be achieved by consistently engaging in foot exercises that serve as a stimulus to develop the neural system. Foot exercises can enhance leg muscles and promote blood circulation to the soles of the feet, stimulating nerve cells that include receptors for heat, pain, and cold sensations (Prasetyo, 2017). Another factor that contributes to enhancing the protection of the patient's feet is the ability of foot exercises to promote blood circulation. This, in turn, facilitates the delivery of oxygen and nutrients to cells and nerve tissue, thereby influencing the metabolic activity of Schwann cells. Consequently, the optimal functioning of axons is promoted, leading to an increase in sensory function (Sanjaya, 2019).

The findings indicated that the intervention group did not demonstrate any enhancement in the ABI value. The findings indicating no enhancement in the Ankle-Brachial Index (ABI) value within the intervention group may stem from several factors: First, ABI values typically reflect long-term structural changes in arterial health. If the intervention duration was insufficient, significant improvements might not have been observed (Yiu et al., 2020). Second, if the intervention was focused on general exercise or behavioral change without specifically targeting vascular health, its impact on ABI could be limited (Criqui & Aboyans, 2015). Third, pre-existing conditions, such as advanced peripheral artery disease (PAD), diabetes, or smoking, can affect the responsiveness of ABI to interventions (Aboyans et al., 2018). Fourth, ABI measurements can be influenced by technical variability or suboptimal equipment, possibly obscuring minor changes (Shishehbor et al., 2016). Fifth, it may due to that both groups were received OHO which indirectly affects peripheral vascularization because it can affect the stabilization of glucose levels in the blood (Utama & Nainggolan, 2021).The Ankle Brachial Index (ABI) test is a diagnostic tool used to directly evaluate the circulation of the lower limbs in order to detect the presence of peripheral artery disease (PAD). This is done by comparing the highest systolic blood pressure in both the ankles and arms (Azitha et al., 2018). Alterations in ABI (Ankle-Brachial Index) values are associated with the peripheral vasculature. Blood glucose levels can affect peripheral vascularization in patients with diabetes mellitus. Higher blood glucose levels impede the rate of peripheral vascularization (Wahyuni, 2016).

Foot exercise is a highly recommended physical activity for individuals diagnosed with diabetes mellitus (Made et al., 2020). Engaging in foot exercises can enhance blood circulation in the foot, hence promoting improved blood flow. This phenomenon occurs due to the leg movement, which induces muscle tension and subsequently compresses the veins around the muscles (Zukhri, 2017). Consequently, blood is driven towards the heart, resulting in a decrease in venous pressure. Moreover, participating in foot workouts can bolster the strength of the delicate muscles in the foot and act as a preventative precaution against foot abnormalities. Utami (Utami, 2019) found that foot exercises in individuals with diabetes mellitus can enhance blood flow and promote blood circulation. This leads to the opening of additional capillary networks, resulting in increased availability and activity of insulin receptors. Made et al. (2020) emphasizes the mechanism of the influence of foot exercises, where the stimulation given to the gastrocnemius muscle will cause effective contraction of the calf muscles (gastrocnemius and soleus) which can increase the strength of the calf muscles and pump the calf muscles (calf pumping) so as to facilitate the venous return and can improve venous circulation.

One limitation of this study is that patients did not control specific information about their diabetes treatment (such as diet, type of drug), others activity, body mass index, and routine measurements (such as glycated hemoglobin and blood glucose levels). Additionally, the biomechanical outcomes may have been affected by the functional exercises used in physical therapy, as the precise load or intensity of each activity was not quantified. A lack of sufficient effort from some participants may also have limited the impact on variables like foot muscle strength.

Other factors, such as placebo effects, duration, and incremental intensity progression, may have further reduced the ability to detect measurable outcomes.

Conclusion

The findings of this study indicate that a 12-week program of foot exercise is significant to improve the blood glucose and sensation protection but not significant to improve the ankle-brachial index. Future studies are needed to confirmed this finding with more rigor study design and larger sample size.

Declaration of Interest

All author declare no conflict of interest.

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Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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