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Improving Peripheral Circulation Through Mindful Movement–Based Diabetic Foot Exercise in Patients with Diabetes Mellitus

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ABSTRAK

Diabetes melitus adalah gangguan metabolisme kronis yang sering menyebabkan gangguan sirkulasi perifer, meningkatkan risiko ulkus kaki diabetik. Latihan kaki diabetik dapat meningkatkan perfusi perifer, namun efektivitasnya terbatas karena kurangnya kesadaran gerak pasien. Pendekatan gerakan sadar (mindful movement) dengan berolahraga dengan kesadaran penuh terhadap pernapasan dan sensasi tubuh diyakini dapat mengoptimalkan manfaatnya. Tujuan penelitian ini adalah untuk mengevaluasi pengaruh latihan kaki diabetik berbasis gerakan sadar terhadap sirkulasi perifer pada pasien diabetes melitus tipe 2. Bahan dan metode. Desain pra-uji dan pasca-uji satu kelompok kuasi-eksperimental dilakukan pada 33 responden di Klinik Hidayatullah Medika, Depok. Intervensi dilakukan sekali seminggu selama empat minggu, 30 menit per sesi. Hasil. Sirkulasi perifer dinilai menggunakan Indeks Brakial Pergelangan Kaki (Ankle Brachial Index/ABI) sebelum dan sesudah intervensi. Hasil uji t berpasangan menunjukkan peningkatan signifikan pada ABI dari 1,03 ± 0,12 menjadi 1,16 ± 0,11 (p = 0,017). Kesimpulan. Latihan kaki diabetik berbasis gerakan sadar efektif meningkatkan sirkulasi perifer dan dapat diterapkan sebagai intervensi sederhana non-farmakologis untuk mencegah komplikasi vaskular pada pasien diabetes.

Kata kunci: Indeks Brakial Pergelangan Kaki; Diabetes Melitus; Latihan Kaki Diabetik; Gerakan Sadar; Sirkulasi Perifer

ABSTRACT

Diabetes mellitus is a chronic metabolic disorder that often causes peripheral circulatory impairment, increasing the risk of diabetic foot ulcers. Diabetic foot exercise can enhance peripheral perfusion, yet its effectiveness is limited by patients' lack of movement awareness. The mindful movement approach exercising with full awareness of breathing and bodily sensations is believed to optimize its benefits. The study purpose was evaluate the effect of mindful movement-based diabetic foot exercise on peripheral circulation in patients with type 2 diabetes mellitus. Materials and methods. A quasi-experimental one-group pre-test and post-test design was conducted on 33 respondents at Hidayatullah Medika Clinic, Depok. The intervention was performed once weekly for four weeks, 30 minutes per session. Results. Peripheral circulation was assessed using the Ankle Brachial Index (ABI) before and after the intervention. Paired t-test results showed a significant increase in ABI from 1.03 ± 0.12 to 1.16 ± 0.11 (p = 0.017). Conclusions. Mindful movement-based diabetic foot exercise effectively improves peripheral circulation and can be applied as a simple, non-pharmacological intervention to prevent vascular complications in diabetic patients.

Keywords: Ankle Brachial Index; Diabetes Mellitus; Diabetic Foot Exercise; Mindful Movement; Peripheral Circulation

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INTRODUCTION

Diabetes mellitus (DM) is a chronic metabolic disease characterized by hyperglycemia resulting from impaired insulin secretion or action (Word Health Organization, 2023). This disease has become one of the major global health challenges, with its incidence continuously increasing. According to data from the International Diabetes Federation (IDF, 2023), the number of people with diabetes worldwide has reached more than 540 million and is projected to increase to 784 million by 2045. Indonesia ranks

fifth, with approximately 19.5 million people living with diabetes, making it one of the countries with the highest burden of non-communicable diseases in the Southeast Asian region.

Chronic complications of diabetes are a major cause of increased morbidity and mortality, particularly those related to peripheral circulatory disorders. Vascular endothelial damage and peripheral neuropathy lead to decreased tissue perfusion in the lower extremities, resulting in diabetic foot ulcers and, in severe cases, amputation. World Health Organization (2023), it has been reported that approximately 15–25% of patients with diabetes will experience a diabetic foot ulcer during their lifetime, and 85% of lower-extremity amputations in diabetic patients are preceded by poorly managed foot ulcers. This condition underscores the importance of preventive interventions to maintain peripheral circulatory function and prevent diabetic foot complications (WHO, 2023).

One of the proven effective non-pharmacological interventions is diabetic foot exercise a simple physical activity that increases blood flow to the lower extremities, strengthens foot muscles, maintains joint flexibility, and reduces the risk of diabetic ulcers. In addition, this exercise helps improve the Ankle-Brachial Index (ABI) as an indicator of peripheral circulatory function. However, the effectiveness of this exercise depends on the patient's level of awareness and focus while performing it. Many patients carry out the exercise mechanically, without full awareness of their body movements, resulting in suboptimal physiological and psychological benefits (Conyers et al., 2025).

To enhance the effectiveness of the intervention, a new approach known as mindful movement has emerged a form of physical exercise performed with full awareness of breathing, sensations, and body movements. This approach integrates physical and psychological dimensions through body awareness, which can reduce stress, improve autonomic nervous regulation, and increase exercise adherence. According to (Qi et al., 2025), mindfulness-based exercises can improve autonomic balance and lower cortisol levels, while (Marôco et al., 2025) found that mindful movement enhances the release of nitric oxide (NO) from vascular endothelium, which plays a crucial role in vasodilation and peripheral tissue perfusion.

The integration of diabetic foot exercise and mindful movement is believed to have a synergistic effect on improving peripheral circulatory function. Physiologically, guided movements combined with mindful breathing can optimize the function of the calf muscle pump, thereby enhancing venous return and tissue perfusion pressure. Psychologically, mindful movement exercises help patients achieve relaxation and emotional balance, which in turn promote adherence and exercise effectiveness. This approach aligns with the principles of holistic nursing, which view humans as an integrated unity of biological, psychological, social, and spiritual dimensions (Blanchette et al., 2025).

Several recent studies support this approach Weng et al. (2021) demonstrated that mindful movement exercises improve tissue oxygenation and peripheral circulation (Weng et al., 2022), while Wu et al. (2024) emphasized their role in enhancing the quality of life among patients with chronic diseases

(Wu et al., 2024). Nevertheless, empirical evidence regarding the effectiveness of mindful movement–based diabetic foot exercises remains limited, particularly within the context of primary healthcare settings in Indonesia.

Hidayatullah Medika Clinic in Depok is one of the primary healthcare facilities with a high population of diabetes patients, where in 2024, 48% of diabetic patients showed an Ankle-Brachial Index (ABI) value of less than 1.0, indicating reduced peripheral blood flow. This condition provides an important basis for developing a mindful movement–based non-pharmacological intervention as a preventive and promotive strategy against diabetic foot complications.

This study aims to evaluate the effectiveness of mindful movement–based diabetic foot exercise in improving peripheral circulatory function among patients with diabetes mellitus. The results of this research are expected to serve as a scientific foundation for implementing a simple, safe, and effective preventive nursing intervention in primary healthcare facilities.

METHOD

This study employed a quasi-experimental design with a one-group pre-test and post-test approach to evaluate the effectiveness of mindful movement–based diabetic foot exercise in improving peripheral circulatory function among patients with diabetes mellitus.

The study was conducted at Hidayatullah Medika Clinic, Depok, West Java, from May to July 2025. Participants consisted of patients with type 2 diabetes mellitus selected through purposive sampling based on the following inclusion criteria: diagnosed with diabetes for at least one year, having no active foot ulcers, being able to perform light physical exercise, and willing to participate by signing informed consent. The exclusion criteria included patients with severe vascular disease, diabetes with complications such as chronic kidney disease (CKD) or congestive heart failure (CHF), advanced neuropathy, or any physical condition preventing participation in the exercise program. A total of 33 respondents met the eligibility criteria.

The independent variable in this study was the mindful movement based diabetic foot exercise, while the dependent variable was peripheral circulatory function, measured using the Ankle-Brachial Index (ABI). ABI measurements were performed using a portable vascular Doppler device before and after the intervention.

The intervention was conducted over four weeks, with exercise sessions held once a week, each lasting 30 minutes. Each session consisted of a 5-minute warm-up, 20 minutes of core exercise, and a 5-minute cool-down. During the core exercise phase, participants were guided to perform diabetic foot exercises while maintaining awareness of their breathing, muscle contractions, and bodily sensations such as warmth or lightness in the feet as a form of body awareness. Throughout the sessions, the researcher provided verbal guidance to help participants maintain focus and breathing rhythm.

Data were collected through ABI measurements taken before and after the intervention. Demographic data (age, gender, duration of diabetes, and type of therapy) were obtained using a questionnaire. Data analysis was performed using SPSS version 26.0. Descriptive analysis was used to describe participant characteristics, while differences in ABI values before and after the intervention were analyzed using a paired t-test with a significance level of $p < 0.05$.

FINDING AND DISCUSSION

Table 1. Characteristics of Research Respondents (n = 33)

Characteristics	Category	Frequency	Percentage
Gender	Male	16	48,5
	Female	17	51,5
Age	18–44 years	1	3,0
	45–59 years	15	45,5
	≥60 years	17	51,5
Education Level	No formal education	0	0
	Elementary School	0	0
	Junior High School	2	6,1
	Senior High School	9	27,3
	Diploma/University	22	66,6
Occupation	Unemployed	19	57,6
	Employed	14	42,4
Duration of Diabetes Diagnosis	< 1 year	4	12,1
	1–10 years	22	66,7
	>10 years	7	21,2
Type of Medication Used	OAD (Oral Antidiabetic Drugs)	15	45,5
	Insulin	4	12,1
	Combination	14	42,4

Table 1 shows that the majority of respondents were female (51.5%) and aged ≥ 60 years (51.5%), indicating that the elderly group is more susceptible to peripheral circulatory disorders caused by chronic diabetes. Most respondents had a higher education level (66.6%), were unemployed (57.6%), and had been diagnosed with diabetes mellitus for 1–10 years (66.7%). The majority used oral antidiabetic drugs (OAD) as therapy (45.5%), followed by a combination of OAD and insulin (42.4%).

Table 2. Differences in the Mean Ankle-Brachial Index (ABI) Values Before and After Foot Exercise (n = 33)

Variable	Pre-Exercise (Mean ± SD)	Post-Exercise (Mean ± SD)	t-value	p-value
ABI	1,03 ± 0,12	1,16 ± 0,11	2,50	0,017

Based on Table 2, the results of the analysis using the paired t-test showed an increase in ABI values from 1.03 ± 0.12 to 1.16 ± 0.11 after the intervention. The p-value of 0.017 ($p < 0.05$) indicates

that the difference was statistically significant, meaning that the mindful movement–based diabetic foot exercise was effective in improving peripheral circulatory function in patients with diabetes mellitus.

The results of this study indicate that the majority of respondents were female (51.5%), while males accounted for 48.5%. This composition aligns with the findings of Aschalew et al. (2020), which reported that the prevalence of peripheral vascular complications in female diabetic patients tends to be higher due to hormonal variations and differences in physical activity. However, the higher female participation in this study also reflects relatively better health awareness compared to males.

In terms of age, the majority of respondents were in the ≥60 years group (51.5%), followed by those aged 45–59 years (45.5%). This indicates that most participants belonged to the elderly group, which is at high risk of reduced vascular elasticity and impaired peripheral microcirculation due to atherosclerosis and chronic diabetic neuropathy (Gálvez Galán et al., 2021). Therefore, selecting this age group is relevant, as the elderly population is the most in need of interventions to improve peripheral circulation.

Based on education level, the majority of respondents had a higher education (66.6%), indicating good health literacy. High literacy plays an important role in understanding exercise instructions and maintaining consistency in following the intervention (Herini et al., 2020). Conversely, participants with lower to moderate education levels require visual and demonstrative approaches to achieve a similar level of understanding.

In terms of occupation, 57.6% of respondents were unemployed, which could positively support adherence to the exercise program due to more flexible time availability. The majority of participants had been living with diabetes for 1–10 years (66.7%), indicating a population in a chronic-stable phase, where vascular complications have begun to emerge but can still be improved through non-pharmacological interventions such as physical exercise.

The most commonly used therapy was oral antidiabetic drugs (OAD), accounting for 45.5%, followed by a combination of OAD and insulin (42.4%). This indicates that the majority of respondents had moderate glycemic control with the potential for a favorable physiological response to regular physical activity. Overall, these characteristics suggest that the respondent group represents an ideal population for evaluating the effectiveness of body-awareness–based physical exercise on peripheral circulation.

Based on ABI values, this study showed an increase in the Ankle-Brachial Index (ABI) from 1.03 ± 0.12 before the intervention to 1.16 ± 0.11 after the implementation of mindful movement–based diabetic foot exercise, with a p-value of 0.017 ($p < 0.05$). This increase is statistically and clinically significant, indicating an improvement in peripheral circulation and vascular function in type 2 diabetes mellitus patients who participated in the intervention.

Discussion

Diabetes mellitus causes impaired peripheral perfusion through mechanisms involving endothelial dysfunction, accelerated atherosclerosis, and microcirculatory disturbances. Chronic hyperglycemia induces the formation of Advanced Glycation End Products (AGEs), which bind to Receptors for Advanced Glycation End Products (RAGE) on endothelial cells, activating the Nuclear Factor Kappa-B (NF-ϰB) pathway and increasing the production of proinflammatory cytokines such as TNF-α, IL-6, and CRP (Iacobini et al., 2021). This process leads to oxidative stress and endothelial dysfunction, characterized by decreased Nitric Oxide (NO) production and increased vasoconstriction due to the dominance of Endothelin-1 (ET-1). As a result, vasodilatory capacity and peripheral tissue perfusion are reduced, which is reflected in decreased ABI values (Takeda et al., 2020).

In addition, chronic glucotoxicity damages arterial walls through increased lipid peroxidation and macrophage infiltration, triggering the formation of early atherosclerotic plaques (Puchałowicz & Rac, 2020). The progressive atherosclerotic process narrows the lumen of peripheral arteries, reduces vascular elasticity, and impedes blood flow to the lower extremities. The combination of these structural and functional changes places diabetic patients at high risk for Peripheral Arterial Disease (PAD), diabetic ulcers, and even amputation (Chala et al., 2025).

The increase in ABI values following the implementation of mindful movement–based diabetic foot exercise in this study indicates a restoration of vascular function through hemodynamic, neuroendocrine, and metabolic mechanisms.

1. Hemodynamic Mechanism: Activation of the Calf Muscle Pump

The rhythmic contraction of the calf muscles during exercise functions as a calf muscle pump, which increases proximal venous pressure and accelerates venous return to the heart. The contraction of the gastrocnemius and soleus muscles generates interstitial pressure that propels blood from the deep veins of the lower limbs toward the central veins, thereby reducing venous pooling and improving capillary perfusion pressure (Priyanto et al., 2025). The enhancement of venous return subsequently increases the arteriovenous pressure gradient in the lower extremities, promotes greater arterial blood flow, and improves the ankle-brachial index (ABI) value (American Diabetes Association, 2023).

2. Endothelial Mechanism: Increased Nitric Oxide (NO) Production

Repeated muscle activity induces shear stress on the endothelial walls, stimulating the expression of endothelial nitric oxide synthase (eNOS). The released nitric oxide (NO) acts as a natural vasodilator, reducing peripheral vascular resistance, widening the vessel lumen, and improving peripheral tissue perfusion (Kucuksayan et al., 2021). NO also exerts anti-platelet aggregation and anti-inflammatory effects, thereby preventing the progression of atherosclerosis and enhancing peripheral vascular function (Arkoudis et al., 2021).

In addition to NO, physical exercise also decreases the level of asymmetric dimethylarginine (ADMA), an endogenous eNOS inhibitor that is often elevated in diabetic patients (Gonzalez et al., 2025). The reduction of ADMA strengthens vasodilatory effects and improves blood flow responsiveness to the metabolic demands of tissues.

3. Metabolic Mechanism: Insulin Sensitivity and Reduction of Oxidative Stress

Regular muscle activity enhances insulin sensitivity by increasing the expression of GLUT-4 on muscle cell membranes, which accelerates the uptake of blood glucose into the cells (Bashandy et al., 2025). The reduction in blood glucose levels directly decreases the formation of advanced glycation end-products (AGEs) and oxidative stress, which are major contributors to arterial stiffness and endothelial dysfunction (Cavestro, 2025).

In addition, exercise increases the levels of vascular endothelial growth factor (VEGF), which plays a crucial role in angiogenesis and the formation of collateral circulation, thereby expanding the perfusion area of peripheral tissues (Dahlan et al., 2019).

4. Neurophysiological Mechanism: Effects of Mindful Movement

The integration of mindful movement in diabetic foot exercise provides a modulatory effect on the autonomic nervous system. Focusing on movement awareness and deep breathing enhances parasympathetic activity and reduces excessive sympathetic activation, which is commonly observed in diabetic patients with autonomic neuropathy (Lin & Zhao, 2025). Parasympathetic activation induces peripheral vasodilation through increased vagal tone, decreased plasma catecholamine levels, and enhanced heart rate variability, all of which contribute to improved blood flow to the lower extremities (Lieberman et al., 2025).

The findings of this study are consistent with those of Hidayatullah (2023), which demonstrated that audiovisual education on tips for living harmoniously with diabetes mellitus can improve patients' quality of life by enhancing their awareness and adherence to self-management. Body-awareness–based education and interactive media have been proven effective in motivating patients to take a more active role in self-care, aligning with the principles of mindful movement, which emphasize full attention to the body and physiological processes during exercise. This approach not only improves peripheral circulatory function but also strengthens self-regulation and enhances the psychological well-being of patients with diabetes (Hidayatullah, 2023).

In addition, the mindfulness component reduces the secretion of cortisol and other stress hormones, which indirectly lowers peripheral vascular pressure and improves tissue perfusion. The combination of mechanical mechanisms (muscle contraction), biochemical mechanisms (NO and VEGF), and neurophysiological mechanisms (relaxation and autonomic modulation) collectively explains the significant improvement in ABI values observed in this study (Budiati et al., 2024).

The statistically and physiologically significant increase in ABI indicates that mindful movement–based foot exercise can serve as an effective non-pharmacological intervention to improve peripheral circulation in patients with type 2 diabetes mellitus. This intervention offers several advantages, including being easy to implement in primary healthcare settings, requiring no special equipment, performable independently by patients, and providing holistic benefits that encompass both physical and psycho-emotional well-being (Auliya et al., 2025). This diabetic foot exercise can be integrated into diabetes education and rehabilitation programs as a promotive and preventive effort against vascular complications, such as diabetic ulcers and amputation (Fan et al., 2025).

This study has a limitation in using a one-group pre–posttest design, which does not eliminate external factors such as variations in daily physical activity, diet, or glycemic control. The ABI measurement should also be complemented with additional parameters such as the toe–brachial index (TBI) or transcutaneous oxygen pressure ($TcPO_2$) to strengthen the evidence of microcirculatory improvement. Further research using a randomized controlled trial (RCT) design and a longer intervention duration is needed to confirm the long-term effects on vascular status and the prevention of diabetic foot ulcers.

CONCLUSIONS

This study demonstrates that mindful movement–based diabetic foot exercise is effective in improving peripheral circulatory function in patients with type 2 diabetes mellitus, as evidenced by the increase in Ankle-Brachial Index (ABI) values after the intervention. The improvement in peripheral circulation is associated with enhanced blood flow to the lower extremities through vascular stimulation, increased vascular elasticity, and reduced peripheral resistance, consistent with the pathophysiological mechanisms of diabetes that often lead to atherosclerosis and endothelial dysfunction.

The implication of this study is that mindful movement–based diabetic foot exercise can serve as a safe and effective non-pharmacological intervention to prevent peripheral vascular complications in patients with diabetes mellitus. Routine implementation in both clinical and community settings can enhance extremity perfusion, reduce the risk of peripheral artery disease, and support the holistic management of diabetic patients. The findings of this study provide a scientific foundation for healthcare professionals to integrate mindful movement–based diabetic foot exercise programs as a primary and secondary prevention strategy against peripheral circulatory disorders.

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