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Foot-Ankle Exercise Effective to Increase Ankle Brachial Index (ABI) and Foot Sensitivity in Type 2 Diabetes Mellitus Patients

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Abstract

Diabetes mellitus is a chronic metabolic disease often associated with complications such as peripheral arterial disease and neuropathy, increasing the risk of diabetic foot ulcers. Foot-ankle exercises are a non-pharmacological intervention believed to improve vascular circulation and nerve sensitivity. However, limited studies have evaluated their combined effects on the Ankle Brachial Index (ABI) and foot sensitivity. This study aimed to determine the effectiveness of foot-ankle exercises on ABI and foot sensitivity in patients with type 2 diabetes mellitus. A quasi-experimental design with a pretest-posttest control group was conducted at a Public Health Center, Bandung. Seventeen participants were selected from the Prolanis program through purposive sampling. The intervention group performed foot-ankle exercises three times per week for two weeks, while the control group received only educational booklets. ABI was measured using a vascular Doppler, and foot sensitivity was assessed with a 10-gram monofilament. The data were analyzed using paired t-tests and Wilcoxon signed-rank tests. The results showed a significant increase in right ABI (from 95.86 to 115.43; $p = 0.018$), while left ABI did not significantly improve ($p = 0.128$). Foot sensitivity increased significantly on both the right (from 4.29 to 6.86; $p = 0.027$) and left feet (from 5.14 to 7.57; $p = 0.043$). Foot-ankle exercises significantly improve peripheral circulation (right ABI) and foot sensitivity in patients with type 2 diabetes. Future research is encouraged to further explore the long-term effects of foot-ankle exercises and to examine the impact of combining these exercises with other management approaches.

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INTRODUCTION

Diabetes mellitus (DM) is a group of metabolic disorders characterized by chronic hyperglycemia resulting from impaired insulin secretion, insulin action, or both (Perkeni, 2021). The increasing prevalence of diabetes has become a global concern, with the number of cases rising steadily each year. The International Diabetes Federation (IDF) projects that by 2030, the global number of people living with diabetes will reach 643 million (11.3%), and this figure is expected to increase to 783 million (12.2%) by 2045. Similar to global trends, Indonesia has also experienced a significant increase in diabetes cases. According to (IDF, 2021), Indonesia is the only Southeast Asian country included in the top 10 countries with the highest number of people with diabetes, ranking seventh globally, with an estimated 10.7 million people affected (Kemenkes, 2020).

One of the main causes of hyperglycemia in diabetic patients is pancreatic beta-cell dysfunction. Persistent hyperglycemia contributes to the development of various complications, both acute and chronic. Chronic complications of diabetes mellitus can be categorized into microvascular and macrovascular complications (Nisar et al., 2015; Schwartz et al., 2016). Microvascular complications include retinopathy, neuropathy, and nephropathy (Khawaja et al., 2018). One of the most common long-term microvascular complications found in diabetic patients is diabetic foot ulcers. These ulcers may result from peripheral neuropathy, peripheral arterial disease (PAD), or a combination of both. Diabetic foot ulcers are defined as wounds that affect all layers of the skin, potentially leading to necrosis or gangrene, and typically appear on one or both soles due to the aforementioned complications (Rosyid, 2017).

Peripheral Arterial Disease (PAD) is a chronic atherosclerotic condition characterized by the narrowing (stenosis) or complete blockage (occlusion) of peripheral arteries, most commonly affecting the arteries of the lower extremities from the abdominal aorta to the pedal arteries. While many individuals with PAD are initially asymptomatic, the disease significantly increases the risk of adverse outcomes such as walking impairment, intermittent claudication, and critical limb ischemia. If left untreated, PAD can progress to limb-threatening complications, including gangrene and amputation. The condition is therefore associated with considerable morbidity and reduced quality of life, warranting early diagnosis and appropriate management strategies (Frank et al., 2019). Peripheral arterial disease is generally diagnosed using Doppler ultrasound. However, clinically, it can be identified through increased ankle-brachial index (ABI) values and reduced foot sensitivity (Ahmad, 2016; Chevtchouk, da Silva, & do Nascimento, 2017; Noor, Zubair, & Ahmad, 2015). To prevent the progression of complications such as diabetic foot ulcers, patients with diabetes are encouraged to perform regular foot care (Timar et al., 2016). One form of foot care includes physical exercises that focus on the foot and ankle areas. These exercises aim to improve microvascular blood flow, enhance neuropathic conditions, and slow the progression of nerve and vascular damage, thereby playing a vital role in preventing diabetic foot ulcers (Monteiro-Soares et al., 2020; Monteiro et al., 2022; Monteiro et al., 2018; Silva et al., 2021).

Several studies have demonstrated that foot exercises have a positive impact on specific aspects of diabetes complications, particularly in improving either foot sensitivity or peripheral perfusion as measured by the Ankle Brachial Index (ABI). Regular foot exercises have been found to significantly improve foot sensitivity in patients with type 2 diabetes mellitus. Similar findings were reported in a study that demonstrated the effectiveness of active range of motion exercises in enhancing foot sensitivity among type 2 DM patients, thereby supporting the potential of simple interventions to improve peripheral neurological function (Asih & Widiastuti, 2024). Additionally, foot exercises have been shown to improve Ankle Brachial Index (ABI) values in individuals with type 2 diabetes, indicating better peripheral blood flow and vascular health (Bakara & Kurniyati, 2021). This result is further supported by a study that found regular physical exercise training could enhance ABI in type 2 diabetes patients, suggesting that exercise has a direct impact on peripheral vascular function (Gibbs, Dobrosielski, Althouse, & Stewart, 2013). However, these studies focused on only one outcome either ABI or foot sensitivity and did not evaluate the combined effect of foot exercises on both aspects simultaneously. This highlights a gap in the current research that needs to be addressed to optimize preventive strategies for diabetic foot complications.

Although several studies have demonstrated the benefits of physical exercise in patients with diabetes, there remains a gap in the literature regarding the quantitative effectiveness of foot-ankle exercises on both vascular indices, such as the Ankle-Brachial Index (ABI), and neurological indicators, such as foot sensitivity. Most previous studies have not directly compared the impact of these exercises on both aspects within a structured experimental framework (Akbari & Naimi, 2022; Budi, 2023).

The main motivation for this study is the increasing prevalence of diabetic foot complications, which require low-cost, simple, and self-manageable preventive approaches. Foot-ankle exercises present a promising solution that can be integrated into nursing practice and routine patient education. The findings of this study are expected to contribute meaningfully to the development of non-pharmacological interventions for diabetes complication prevention and to serve as a foundation for incorporating foot exercises into standard care for diabetic patients, especially in resource-limited healthcare settings.

This study was conducted to address that gap and provide scientific evidence on the effectiveness of foot-ankle exercises as a preventive intervention in patients with type 2 diabetes mellitus. Specifically, the objectives of this research are to determine the effectiveness of foot-ankle exercises in improving ABI and foot sensitivity, as well as to compare these outcomes between the intervention and control groups.

METHODS

The research applied a quasi-experimental design with a pretest and posttest control group format to examine the effectiveness of foot-ankle exercises on the Ankle Brachial Index (ABI) and foot sensitivity in patients with type 2 diabetes mellitus. A total of 32 patients participated in the initial screening, with 17 patients who demonstrated decreased ABI and/or reduced foot sensitivity selected through purposive sampling to participate as study respondents. 9 patients were assigned to the intervention group, while 8 patients were included in the control group. Within the intervention group, several patients received both ABI and sensitivity interventions, while others were allocated specifically to ABI intervention only. Similarly, in the control group, some patients were assessed for both ABI and sensitivity, whereas others were evaluated solely for ABI or sensitivity outcomes. In total, the intervention group consisted of 7 patients who received both ABI and sensitivity interventions, whereas the control group included 5 patients assessed for sensitivity and 6 patients assessed for ABI, with their respective conditions distributed as previously described. Within the intervention group, several patients received both ABI and sensitivity interventions, while others were allocated specifically to ABI intervention only. Similarly, in the control group, some patients were assessed for both ABI and sensitivity, whereas others were evaluated solely for ABI or sensitivity outcomes. It should be emphasized that in both the intervention and control groups, some respondents experienced decreased ABI or reduced sensitivity only in one foot, while others showed impairment in both feet. The data collection instruments included a demographic questionnaire and clinical observation sheets for ABI and foot sensitivity measurement (S. L. Casey, Lanting, & Chuter, 2020). The ABI was assessed using a Vascular Doppler Ultrasound Probe and sphygmomanometer, while foot sensitivity was measured using the 10-gram monofilament test, part of the Michigan Neuropathy Screening Instrument (MNSI) (Abouhamda, Alturkstani, & Jan, 2019; Álvaro-Afonso et al., 2018; S. Casey, Lanting, Oldmeadow, & Chuter, 2019; Potier, Abi Khalil, Mohammedi, & Roussel, 2011; Sutkowska et al., 2023; Tehan, Bray, & Chuter, 2016). The intervention group received foot-ankle exercises, while the control group was only given an educational booklet. Foot-ankle exercises were administered three times per week for two consecutive weeks. Both ABI and foot sensitivity were measured before and after the intervention in both groups. Data were analyzed using SPSS software. Preliminary analyses included normality and homogeneity testing. The normality assessment with the Shapiro–Wilk test indicated that most variables were not normally distributed ($p < 0.05$), except for Post-ABI right, Pre-sensitivity left, and Post-sensitivity right, which followed a normal distribution ($p > 0.05$). Consequently, pre- and post-intervention comparisons were conducted using the non-parametric Wilcoxon Signed Rank Test. Since non-parametric methods do not require the assumption of homogeneity of variances and the sample size was relatively small, homogeneity testing was not performed. A p-value of < 0.05 was considered the threshold for statistical significance. The equipment used met clinical standards: the Vascular Doppler ensured reliable ABI measurements with real-time waveform visualization, while the monofilament kit used nylon filaments calibrated to 10 grams, following international guidelines for diabetic neuropathy screening (Tehan et al., 2016). All procedures were conducted in accordance with established ethical standards for human research. Ethical approval for this study was granted by the Health Research Ethics Committee of Bhakti Kencana University (KEPK UBK) on November 2025, under approval number 306/09.KEPK/UBK/XI/2025. The intervention involved minimal-risk and non-invasive procedures, namely foot-ankle exercise, ABI measurement, and monofilament testing, which are routinely recommended in clinical practice for patients with diabetes mellitus. To ensure participant safety, clear instructions were provided, and all exercise sessions were directly supervised by the research team, with participants allowed to discontinue the activity at any time if discomfort occurred. Informed consent was obtained from all participants, and the principles of voluntary participation, confidentiality, and anonymity were strictly maintained throughout the research process.

RESULTS

This study aimed to evaluate the effectiveness of foot-ankle exercises in improving the Ankle Brachial Index (ABI) and foot sensitivity among patients with type 2 diabetes mellitus. The intervention was conducted over a two-week period, during which the intervention group received foot-ankle exercises three times per week, while the control group received only an educational booklet.

Table 1. Frequency Distribution of Ankle Brachial Index (ABI) and Foot Sensitivity in Intervention and Control Group

Ankle Brachial Index (ABI)	**Intervention Group - Right n (%)**	**Intervention Group - Left n (%)**	**Control Group - Right n (%)**	**Control Group - Left n (%)**
Normal **(≥1)**	4 (57.1)	1 (14.3)	1 (16.7)	4 (66.7)
Mildly abnormal (0.80-0.99)	2 (28.6)	5 (71.4)	5 (83.3)	2 (33.3)
Moderate obstruction (0.40-0.79)	1 (14.3)	1 (14.3)	0 (0)	0 (0)
Foot Sensitivity	**Intervention Group - Right Foot n (%)**	**Intervention Group - Left Foot n (%)**	**Control Group - Right Foot n (%)**	**Control Group - Left Foot n (%)**
Present (≥8)	1 (14.3)	2 (28.6)	2 (40)	0 (0)
Reduced sensitivity (1-7)	2 (28.6)	3 (42.8)	3 (60)	5 (100)
Absent sensitivity (0)	4 (57.1)	2 (28.6)	0 (0)	0 (0)

Source: *Primary Data*

Table 1 presents the frequency distribution of Ankle Brachial Index (ABI) highlights clear differences between the intervention and control groups. On the right side, 57.1% of participants in the intervention group had normal ABI values compared to 16.7% in the control group, while the control group showed a higher proportion of mildly abnormal ABI (83.3%). On the left side, mildly abnormal ABI was more common in the intervention group (71.4%), whereas normal ABI was more frequently observed in the control group (66.7%). Moderate obstruction appeared only in the intervention group (14.3% on both sides), although in small numbers. Overall, the distribution indicates distinct ABI patterns between the two groups on both limbs. The frequency distribution of foot sensitivity among participants in the intervention and control groups. In the intervention group, absent sensitivity was more frequent on both sides (57.1% right; 28.6% left), while a smaller proportion showed normal sensitivity. In the control group, 40% of participants had normal sensitivity on the right side, and none presented absent sensitivity. On the left side, all control participants (100%) demonstrated reduced sensitivity. These results indicate differing baseline levels of foot sensitivity across both groups.

Table 2. The Effectiveness of Foot-Ankle Exercise on the Ankle-Brachial Index

Variable	Mean	SD	P- Value
Pre right ABI	95.86	41.204	0.018
Post right ABI	115.43	19.924	
Pre left ABI	64.71	41.532	0.128
Post left ABI	100.00	48.035	
Variable	**Mean**	**SD**	**P- Value**
Pre right foot sensitivity	4.29	4.071	0.027
Post right foot sensitivity	6.86	2.478	
Pre left foot sensitivity	5.14	3.716	0.043
Post left foot sensitivity	7.57	1.512	

Source: *Primary Data*

Based on the statistical analysis presented in Table 2, there was an increase in the mean ABI values on both the right and left sides following the intervention. On the right side, the mean ABI increased from 95.86 (SD = 41.204) to 115.43 (SD = 19.924), with a p-value of 0.018, indicating a statistically significant improvement ($p < 0.05$). In contrast, the left-side ABI increased from a mean of 64.71 (SD = 41.532) to 100.00 (SD = 48.035); however, the p-value of 0.128 ($p > 0.05$) indicates that this change was not statistically significant. These results suggest that the foot-ankle exercise intervention had a significant effect on improving right-side ABI but did not produce a statistically meaningful improvement on the left side. There was a clear improvement in foot sensitivity following the intervention. Both sides demonstrated statistically significant increases. The right foot sensitivity improved from a mean of 4.29 (SD = 4.071) to 6.86 (SD = 2.478), with a p-value of 0.027. Similarly, the left foot sensitivity increased from 5.14 (SD = 3.716) to 7.57 (SD = 1.512), with a p-value of 0.043. These results indicate that the foot–ankle exercise significantly enhanced peripheral sensory function in both lower limbs.

DISCUSSION

The frequency distribution results provide important insights into the baseline vascular and neurological conditions of the participants. Most respondents demonstrated normal ABI values on the right side, particularly in the intervention group, where 57.1% fell within the normal range. This aligns with previous findings indicating that individuals with early-stage peripheral arterial changes may still present with normal ABI values on at least one limb (Ahmad, 2016; Noor et al., 2015). Conversely, the higher proportion of mildly abnormal ABI in the control group reflects early signs of peripheral arterial disease, which is consistent with the literature suggesting that ABI values between 0.80 and 0.99 represent early vascular impairment often observed in patients with type 2 diabetes (Frank et al., 2019). The small proportion of participants with moderate obstruction in the intervention group also corresponds to epidemiological patterns showing that more advanced arterial impairment is less common but remains clinically important (Noor et al., 2015).

A similar pattern appears in the distribution of foot sensitivity. The intervention group showed a higher number of participants with absent sensitivity, indicating more pronounced neuropathic impairment at baseline. This is consistent with the natural course of diabetic peripheral neuropathy, in which sensory loss is often uneven and may affect one limb more severely (Jin et al., 2012; Lepesis, Marsden, Rickard, Latour, & Paton, 2023). In contrast, the control group had more participants with normal right-foot sensitivity, supporting earlier research that neuropathy severity varies widely among patients and may be influenced by glycemic control and duration of diabetes (Sutkowska et al., 2023). The distribution patterns observed in this study reinforce existing evidence that both peripheral vascular impairment and neuropathy frequently coexist among individuals with diabetes, although their severity may differ across limbs and between patients (Monteiro-Soares et al., 2020; Yang et al., 2025). These baseline differences highlight the importance of tailored interventions, as patients with varying degrees of impairment may respond differently to therapeutic exercises.

The results of this study indicate a significant improvement in the right-side Ankle Brachial Index (ABI) following the intervention. The mean right ABI increased from 95.86 to 115.43 with a lower standard deviation post-intervention (from 41.204 to 19.924), reflecting greater consistency in outcomes. A p-value of 0.018 ($p < 0.05$) confirms that this change was statistically significant. This finding suggests that the foot-ankle exercises implemented in this study effectively enhanced peripheral perfusion in the lower right extremity. These results are consistent with previous studies that report physical activity can improve peripheral vascular function through enhanced endothelial reactivity and improved blood flow dynamics (Gibbs et al., 2013; Kluding et al., 2017; Rickard, 2023; Van Netten et al., 2024).

On the left side, although the mean ABI increased from 64.71 to 100.00 after the intervention, the p-value of 0.128 ($p > 0.05$) indicates that this improvement was not statistically significant. The large standard deviations in both pre- (41.532) and post-intervention (48.035) values suggest considerable variability among respondents. This inconsistency may be influenced by individual factors such as asymmetric vascular pathology, varying levels of arterial stiffness, or underlying severity of peripheral arterial disease (Mandaglio-Collados, Marín, & Rivera-Caravaca, 2023).

Regarding foot sensitivity, a significant improvement was observed on the right side, with the mean score increasing from 4.29 to 6.86 and a p-value of 0.027. This suggests that the intervention was effective in enhancing peripheral nerve function, as regular foot exercises can improve microcirculation and support nerve regeneration (Monteiro-Soares et al., 2020). Furthermore, the reduced post-intervention standard deviation (2.478 compared to 4.071 pre-intervention) indicates more consistent outcomes across participants. Similarly, on the left side, foot sensitivity improved from a mean of 5.14 to 7.57, with a p-value of 0.043 ($p < 0.05$). The reduction in standard deviation from 3.716 to 1.512 also suggests a more uniform response. This supports the hypothesis that foot-ankle exercises are beneficial not only for improving blood circulation but also for enhancing neural responsiveness in the lower limbs. These results align with previous findings indicating that exercise contributes to improved neural conduction and reduced symptoms of diabetic neuropathy (Jin et al., 2012; Lepesis et al., 2023; Pang, Wang, Zhang, Guo, & Liu, 2025; Streckmann et al., 2022).

In contrast, the control group did not demonstrate meaningful changes in ABI or foot sensitivity during the same observation period. For ABI, only 16.7% of patients in the control group had a normal right ABI, while the majority (83.3%) were mildly abnormal, and no cases of moderate obstruction were identified. On the left side, 66.7% of the control group showed normal ABI, whereas 33.3% were mildly abnormal, with no significant shifts observed over time. Similarly, in terms of foot sensitivity, 40% of control patients had normal right foot sensitivity and 60% had reduced sensitivity, while on the left side all patients (100%) fell into the reduced sensitivity category, with no cases of absent sensitivity. When compared to the intervention group, which showed significant improvements in right-side ABI and bilateral foot sensitivity, these findings underscore that the positive outcomes observed were specifically attributable to the foot-ankle exercise intervention rather than natural progression or external factors (Gracia-Sánchez et al., 2025).

Overall, the results of this study demonstrate that foot-ankle exercises significantly improved right-side ABI and bilateral foot sensitivity. The absence of a significant improvement in the left ABI may be attributed to individual physiological differences or a relatively short intervention period. Therefore, future research with a larger sample size and longer intervention duration is recommended. Additionally, combining foot-ankle exercises with glycemic control, pharmacological therapy, or other rehabilitative modalities may offer more comprehensive benefits in managing diabetic neuropathy and preventing foot complications (Gholami, Naderi, Saeidpour, & Lefaucheur, 2024).

CONCLUSION

This study demonstrates that foot-ankle exercise is an effective non-pharmacological intervention for improving peripheral circulation and sensory function in patients with type 2 diabetes mellitus. Significant improvements were observed in the right-side Ankle Brachial Index (ABI) and in bilateral foot sensitivity following a structured two-week intervention. These results indicate that regular foot-ankle exercise can enhance blood perfusion and peripheral nerve response, which are crucial for preventing complications such as diabetic foot ulcers and neuropathy. Although the left-side ABI did not show statistically significant improvement, this may be attributed to individual variability in vascular condition and the relatively short intervention period. Therefore, future studies with larger samples, longer duration, and consideration of additional contributing factors are recommended. Integrating foot-ankle exercise into routine diabetes care programs holds promise for promoting lower-extremity vascular health and preventing progressive neuropathic complications.

SUGGESTION

In light of the findings obtained in this study, it is suggested that foot-ankle exercises be integrated into the routine care and education of patients with type 2 diabetes mellitus, particularly those at risk of peripheral vascular impairment and neuropathy. Given the significant improvements in right-side ABI and bilateral foot sensitivity, healthcare professionals, especially nurses and diabetes educators, should consider incorporating foot-ankle exercise protocols as part of preventive strategies in primary healthcare settings. While the intervention did not yield statistically significant results on the left-side ABI, this highlights the importance of tailoring exercise interventions to individual patient conditions and possibly extending the duration of exercise for more consistent outcomes.

Future research is encouraged to further explore the long-term effects of foot-ankle exercises and to examine the impact of combining these exercises with other management approaches, such as glycemic control or pharmacological treatment. In addition, broader studies with larger sample sizes are recommended to validate the effectiveness of this intervention and to better understand the underlying factors that influence variability in patient response. Ultimately, strengthening the role of non-pharmacological interventions such as foot-ankle exercises could contribute significantly to improving the quality of life and reducing the risk of foot-related complications in individuals living with type 2 diabetes.

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CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest related to the financial, consultative, institutional, or personal aspects of this manuscript that could have influenced the research outcomes or its interpretation.

AUTHOR CONTRIBUTIONS

All authors contributed substantially to the completion of this research and the preparation of the manuscript. A.J. (Anggi Jamiyanti) was responsible for the research design, data collection, and analysis. She also led the manuscript writing. V.V. (Vina Vitniawati) and S.M.R. (Sri Mulyati Rahayu) contributed to literature review, data interpretation, and manuscript editing. All authors read and approved the final version of the manuscript.

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