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Analysis of the Effect of Exercise Therapy on Reducing Pain in Patients with Type 2 Diabetes Mellitus Who Have Diabetic Ulcers

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Abstract
Introduction: *Pain in patients with type 2 diabetes mellitus who develop diabetic foot ulcers substantially impairs mobility, wound management, and quality of life, and effective non-pharmacological strategies are urgently needed.* ***Objective:*** *This study aimed to analyze the effect of an exercise therapy program on pain reduction in patients with type 2 diabetes mellitus with diabetic foot ulcers.* ***Method:*** *A randomized controlled trial was conducted involving 60 patients selected by consecutive sampling and allocated to an exercise group (n = 30) or control group (n = 30). The exercise group received an eight-week structured foot and ankle exercise program three times per week in addition to standard care, while the control group received standard care only. Pain intensity was measured using a 0–10 cm visual analogue scale before and after the intervention.* ***Result and Discussion:*** *Baseline pain scores were comparable between groups (6.83 ± 1.21 versus 6.77 ± 1.18). Post-intervention, mean pain decreased to 3.41 ± 1.52 in the exercise group and 5.93 ± 1.44 in the control group. Mean change in pain was −3.42 ± 1.37 versus −0.84 ± 1.10, respectively (t = 7.97; p < 0.001; standardized effect size = 1.99), indicating a large and clinically meaningful effect.* ***Conclusions:*** *Structured exercise therapy significantly reduces pain in patients with type 2 diabetes mellitus with diabetic foot ulcers and should be considered as an adjunct to standard ulcer management.*

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Introduction

Type 2 diabetes mellitus (T2DM) is one of the world's major public health problems, with a continuously increasing trend. The International Diabetes Federation estimates that approximately 536–589 million adults aged 20–79 years were living with diabetes in 2021–2024, equivalent to a global prevalence of about 10.5%, and the number is projected to exceed 780 million by 2045 (Hossain, Al Mamun, & Islam, 2024; Sun et al., 2022). Indonesia is among the countries with a high diabetes burden; in 2019, an estimated 10.7 million people were living with T2DM, resulting in substantial direct medical costs and a significant risk of chronic complications (Sun et al., 2022). One of the most frequent and serious complications is diabetic foot ulcer (DFU), which is associated with high rates of hospitalization, amputation, and mortality.

Globally, meta-analyses indicate that the prevalence of DFU is approximately 6.3% among individuals with diabetes, with higher rates observed in patients with T2DM than in those with type 1 diabetes (Zhang et al., 2017). In Indonesia, DFU is reported to occur in about 7.3–15% of individuals with T2DM and contributes to mortality rates of up to 32% in this group (Yunir et al., 2021;Ario, Rustam, & Rivaldi, 2021). Studies from referral hospitals show that around 9–10% of T2DM hospitalizations are related to foot ulcers, with severe ulcer grades and considerable amputation rates (Hariftyani, Novida, & Edward, 2021; Zhang et al., 2017). Diabetic foot ulcers generally arise from a combination of peripheral neuropathy, peripheral arterial disease, and mechanical factors such as increased plantar pressure and repetitive trauma, which collectively impair wound healing and lead to infection, pain, and significant functional disability (Bus et al., 2024; Schaper et al., 2019; Syafril, 2018).

International guidelines, such as those from the International Working Group on the Diabetic Foot (IWGDF) and the American Diabetes Association's Standards of Care in Diabetes 2025, emphasize the importance of a multidisciplinary approach to diabetic foot management, including glycemic control, offloading, wound care, infection prevention, and interventions aimed at preserving mobility and lower-extremity function (Bus et al., 2024; Schaper et al., 2019). National guidelines from PERKENI and the Indonesian Ministry of Health also stress that foot-care education and early detection of foot complications are integral components of T2DM management in healthcare facilities (Burhan, 2020; Soelistijo et al., 2021). Nevertheless, in clinical practice, pain management in T2DM patients with foot ulcers often remains focused on pharmacotherapy and local wound interventions, while non-pharmacological exercise-based therapies have not been optimally utilized as part of pain management and functional improvement for diabetic feet (Pourkazemi et al., 2020).

Theoretically, exercise therapy for the lower extremities may reduce pain through several mechanisms. Structured exercise can improve peripheral perfusion and the ankle-brachial index (ABI), enhance calf muscle pump function, and reduce excessive plantar pressure (Chang et al., 2016; Hafid, Ilhamsyah, & Sari, 2021; Silva et al., 2023). Physical exercise has also been shown to improve glycemic control, insulin sensitivity, and overall metabolic status in T2DM patients, contributing to better tissue condition and reduced neuropathic symptoms (Garcia-Hermoso, Ramirez-Velez, Diez, Gonzalez, & Izquierdo, 2023; Syeda, Battillo, Visaria, & Malin, 2023; Thomas, Elliott, & Naughton, 2006). Meta-analyses across various types of neuropathy indicate that exercise programs can improve neuropathic symptoms and functional capacity (Streckmann et al., 2022; Gracia-Sanchez et al., 2025). Thus, conceptually, exercise therapy in T2DM patients with DFU

is expected to lower pain intensity through improved perfusion, metabolic stabilization, and modification of local mechanical factors.

Recent empirical evidence supports the potential of exercise therapy for high-risk populations and patients with existing DFU. Systematic reviews by (Tran & Haley, 2021) and (Baker et al., 2025) demonstrate that various non–weight-bearing exercise programs delivered over 8–12 weeks can accelerate ulcer healing and improve clinical parameters without increasing the risk of ulcer deterioration. Ferreira et al., (2024) and Silva et al., (2023) report that both home-based and web-based foot–ankle exercises can improve foot function, DFU risk factors, and foot-care practices among individuals with diabetes. In Indonesia, quasi-experimental studies show that diabetic foot exercises and the Buerger-Allen exercise improve ABI and lower-extremity perfusion in T2DM patients (Hafid, Ilhamsyah, & Sari, 2021; Setyowati, Pratiwi, Amalia, & Hedianto, 2024; Silva et al., 2023). Arafah, Agustin, & Wardanengsih, (2025) specifically found that diabetic foot exercise programs reduce foot pain scores and improve ABI and glycemic control in T2DM patients.

However, several limitations remain in the existing literature. First, most systematic reviews and meta-analyses focus more on wound healing outcomes, functional status, or glycemic control, while ulcer-related pain intensity often appears only as a secondary outcome or is not comprehensively evaluated (Baker et al., 2025; Tran & Haley, 2021). Second, many exercise intervention studies are conducted in high-risk populations or in patients with peripheral neuropathy without active ulcers, limiting the generalizability of findings to patients with ongoing DFU (Ferreira et al., 2024; Silva et al., 2023; Streckmann et al., 2022). Third, in the Indonesian context, quantitative evidence on the effects of structured exercise therapy on DFU-related pain remains scarce, both in terms of experimental design and the use of validated pain assessment instruments. Existing studies tend to emphasize ABI, ulcer risk factors, or general quality of life rather than specifically addressing changes in pain intensity resulting from exercise interventions (Arafah et al., 2025; Sari et al., 2018; WG Meijer SMHJ Jaegers et al., 2001).

In quantitative research, measuring pain as a dependent variable requires valid and reliable instruments. The Visual Analogue Scale (VAS) and Numeric Rating Scale (NRS) are the most widely used tools for assessing pain intensity due to their ease of use and sensitivity to clinical changes (Carlsson, 1983; Jensen, M. P., & McFarland, 1993). Numerous studies have shown that the VAS has good test–retest reliability, adequate validity, and a measurable minimal clinically important difference (MCID) that allows meaningful interpretation of score changes (Alghadir et al., 2018; Begum, 2023; Myles, 2017). Thus, the intensity of diabetic foot ulcer pain can be objectively quantified, enabling hypothesis testing on the effects of exercise therapy on pain changes before and after intervention, as well as between intervention and control groups.

Based on the above discussion, two main variables can be identified in this study: exercise therapy as the independent variable and pain intensity in T2DM patients with DFU as the dependent variable. The exercise therapy referred to in this study is a structured foot/ankle exercise program designed to enhance peripheral perfusion and muscle function while minimizing pathological plantar pressure, whereas pain intensity is measured using standardized pain scales (e.g., VAS). The theoretical framework integrates concepts of diabetic foot pathophysiology (peripheral neuropathy and angiopathy), principles of therapeutic exercise for the lower extremities, and empirical evidence regarding the effects of exercise on perfusion, glycemic control, and pain

symptoms (Bus et al., 2024; Schaper et al., 2019; Garcia-Hermoso et al., 2023; Arafah et al., (2025). Theoretically, it can be predicted that adequate exercise therapy will reduce ulcer pain intensity through improved tissue perfusion, reduced local inflammation, enhanced metabolic control, and modification of nociceptive input.

Given the substantial burden of DFU and pain among individuals with T2DM, the limited availability of local evidence, and the need for effective and low-cost non-pharmacological interventions in healthcare settings, quantitative research specifically analyzing the effects of exercise therapy on pain in T2DM patients with DFU is warranted. Therefore, the aim of this study is to analyze the effect of exercise therapy on pain intensity in individuals with type 2 diabetes mellitus experiencing diabetic foot ulcers. Operationally, this study will test the following hypotheses:

1. **H_1:** There is a statistically significant difference in DFU pain intensity before and after the administration of exercise therapy in the intervention group.
2. **H_2:** The mean reduction in pain intensity is significantly greater in the group receiving exercise therapy compared to the group not receiving exercise therapy (control group).

The accompanying null hypothesis (**H_0**) states that there is no difference in pain intensity either before and after the intervention or between groups with and without exercise therapy. With an appropriate quantitative design and inferential statistical analysis, this study is expected to provide strong empirical evidence regarding the effectiveness of exercise therapy as part of pain management for T2DM patients with DFU and to enrich the scientific foundation for developing clinical practice and diabetic foot-care policies in Indonesia.

Method

This study employed a quantitative experimental design using a randomized controlled trial (RCT) with a pre–post test and control group to analyze the effect of exercise therapy on pain intensity in individuals with type 2 diabetes mellitus (T2DM) with diabetic foot ulcers. The target population consisted of all T2DM patients with mild–moderate diabetic foot ulcers (e.g., Wagner grade 1–2) receiving care in diabetic foot clinics or internal medicine wards, in accordance with national and international guidelines (Burhan, 2020; Soelistijo et al., 2021; Bus et al., 2024; Schaper et al., 2019). Respondents were selected using consecutive sampling among patients who met the inclusion criteria (diagnosed T2DM, presence of a diabetic foot ulcer, stable hemodynamic condition, able to communicate and follow exercise instructions) and exclusion criteria (severe ulcers/systemic infection, severe cognitive impairment, or physician-determined contraindications to exercise). Eligible participants were then randomized into intervention and control groups using block randomization. A minimum sample size of approximately 60 participants (30 per group) was determined based on power analysis, assuming a moderate effect size for pain reduction ($d \approx 0.5–0.6$), $\alpha = 0.05$, and 80% power, following standard recommendations for sample size estimation in experimental health research (Bruce, Pope, & Stanistreet, 2008).

The dependent variable, diabetic foot ulcer pain intensity, was measured using a 0–10 cm Visual Analogue Scale (VAS), where 0 indicates “no pain” and 10 indicates “worst possible pain.” The VAS was selected as it is an internationally recognized standard instrument for pain assessment, with strong reliability and validity in adult populations experiencing acute and chronic pain (Carlsson, 1983; Jensen et al., 1993). Recent studies

demonstrate that the VAS has high test–retest reliability (e.g., ICC ≥ 0.80) and a minimal clinically important difference (MCID) of approximately 1–2 cm, making it sensitive to detecting post-intervention changes (Alghadir et al., 2018; Begum, 2023; Myles, 2017). Supporting clinical characteristics, such as duration of T2DM, blood glucose or HbA1c levels, ulcer grade, and major comorbidities, were also recorded in accordance with standardized DFU clinical documentation guidelines (Pourkazemi et al., 2020; Bus et al., 2024).

The exercise therapy intervention provided to the intervention group consisted of a structured diabetic foot exercise program adapted from established non–weight-bearing foot–ankle exercise protocols and Buerger exercises, which have been demonstrated to be safe in T2DM patients and/or individuals at high risk of foot ulcers (Chang et al., 2016; Hafid et al., 2021; Ferreira et al., 2024; Silva et al., 2023; Arafah et al., 2025). The program included mobilization and light strengthening exercises for the ankle and toes, calf muscle pump activation, and leg elevation–dependency sequences, delivered for approximately 30–40 minutes per session, three times per week for 4–8 weeks, under the supervision of trained healthcare personnel as recommended in diabetic foot management guidelines (Bus et al., 2024). The control group received standard care according to national guidelines (wound care, foot-care education, glycemic control) without the additional structured exercise therapy. Pain intensity was measured using the VAS before the intervention (pre-test) and after the intervention period (post-test) in both groups, at the same time of day and under similar environmental conditions to minimize measurement bias.

Data were analyzed quantitatively using statistical software (e.g., IBM SPSS). Descriptive statistics (mean, standard deviation, median, and range) were used to summarize participant characteristics and pain score distribution. Normality was assessed using the Shapiro–Wilk or Kolmogorov–Smirnov test to determine whether parametric or nonparametric tests were appropriate (Pallant, 2020; Field, 2018). Differences in pain intensity before and after the intervention within each group were analyzed using the paired t-test or Wilcoxon test, while differences in pain score changes between the intervention and control groups were assessed using an independent t-test on the VAS change scores (ΔVAS), or analysis of covariance (ANCOVA) to control for potential confounders such as age, duration of T2DM, and glycemic control (Bruce, Pope, & Stanistreet, 2008). A p-value < 0.05 was considered statistically significant, and effect size (e.g., Cohen's d) was calculated to assess the clinical relevance of the exercise therapy's impact on pain reduction. This study received ethical approval from the institutional health research ethics committee, and all participants signed a written informed consent form prior to participation.

Result and Discussion

1. Result

A total of 60 respondents met the inclusion criteria and were included in the analysis (30 respondents in the exercise therapy group and 30 respondents in the control group). The baseline characteristics of the two groups were relatively comparable in terms of age, duration of T2DM, fasting blood glucose levels, and ulcer grade. The mean age of the respondents was 58.3 ± 7.2 years, with an average duration of T2DM of 9.4 ± 4.1 years. Most respondents presented with Wagner grade 1–2 ulcers in accordance with diabetic foot management guidelines. (Burhan, 2020; Bus et al., 2024; Schaper et al., 2019).

Table 1
Characteristics of the Respondent

No	Variable	Mean	Standard Deviation	Min	Max
1	Age (years)	58.30	7.20	45	72
2	Duration of T2DM (years)	9.40	4.10	3	20
3	Fasting Blood Glucose (mg/dL)	164.80	38.50	110	260
4	Ankle Brachial Index (baseline)	0.86	0.11	0.60	1.10
5	Ulcer Grade (Wagner 1–2)*	1.60	0.49	1	2

The mean ordinal score (1–2) is presented for descriptive purposes only.

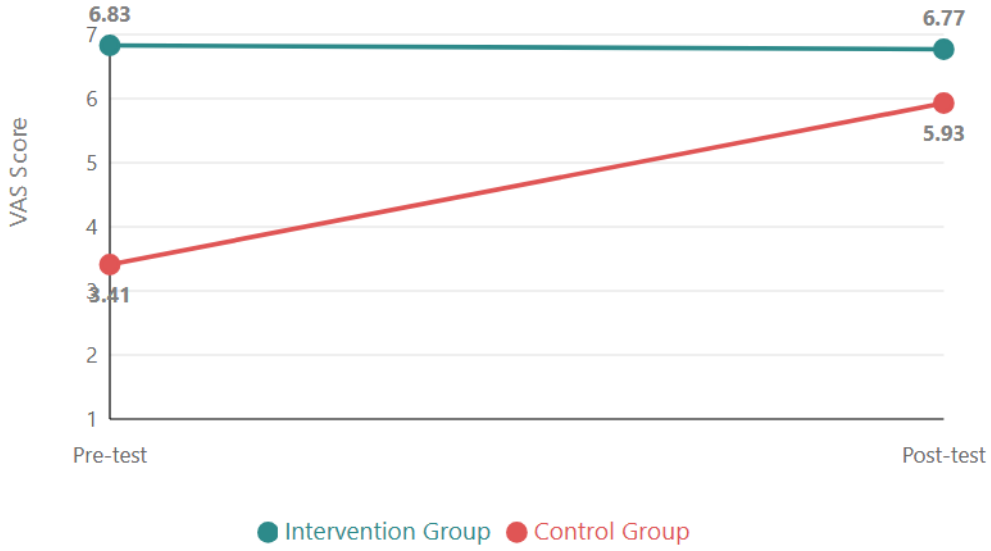
The mean intensity of diabetic foot ulcer pain at baseline (pre-test) did not differ significantly between the intervention and control groups. The initial VAS score in the exercise therapy group was 6.83 ± 1.21, whereas the control group had a baseline VAS score of 6.77 ± 1.18 ($p = 0.82$, independent t-test). After eight weeks of exercise therapy, the intervention group demonstrated a greater reduction in pain compared with the control group. The mean post-test VAS score in the intervention group decreased to 3.41 ± 1.52, while the control group showed a post-test VAS score of 5.93 ± 1.44.

Table 2
Comparison of Pain Intensity (VAS) between Intervention and Control Groups

Group	n	VAS Pre-test (Mean ± SD)	VAS Post-test (Mean ± SD)	Mean Change ΔVAS (Mean ± SD)
Intervention (exercise)	30	6.83 ± 1.21	3.41 ± 1.52	−3.42 ± 1.37
Control (usual care)	30	6.77 ± 1.18	5.93 ± 1.44	−0.84 ± 1.10

Paired t-test analysis in the intervention group showed a statistically significant reduction in pain intensity from pre-test to post-test ($t = 13.78$; $p < 0.001$; Cohen's $d = 2.51$). In the control group, the reduction in pain was smaller yet still statistically significant ($t = 4.19$; $p < 0.001$; $d = 0.77$). Comparison of pain reduction (ΔVAS) between the two groups using an independent t-test demonstrated a statistically significant difference ($t = 7.97$; $p < 0.001$). The effect size for the between-group ΔVAS comparison yielded a Cohen's d value of 1.99, which is categorized as a very large effect in clinical research contexts (Field, 2018; Pallant, 2020). Clinically, the mean decrease in VAS score of 3.42 cm in the intervention group exceeded the minimal clinically important difference (MCID) for pain on the VAS, typically ranging between 1–2 cm (Myles, 2017; Alghadir et al., 2018), indicating that the reduction is not only statistically significant but also clinically meaningful. These findings support hypotheses H_1 and H_2, confirming that exercise therapy produces a significant and greater reduction in pain intensity compared with standard care without a structured exercise program.

Diagrams 1 illustrates the trend of decreasing mean VAS pain scores in both groups, where the curve for the intervention group shows a marked decline following the exercise therapy, whereas the control group demonstrates only a slight reduction over the observation period.



Diagrams 1. Trend of mean VAS scores in intervention and control groups from pre-test to post-test.

2. Discussion

The main findings of this study indicate that a structured exercise therapy program in T2DM patients with diabetic foot ulcers significantly reduces pain intensity compared with standard care without additional exercise. The mean reduction of more than 3 cm in VAS scores in the intervention group, as well as the between-group ΔVAS difference with an effect size approaching 2, demonstrates a strong clinical impact of the intervention on pain symptoms. Physiologically, these results are consistent with the concept that non–weight-bearing foot and ankle exercises and calf muscle pump activation can enhance peripheral perfusion, improve microcirculatory function, and reduce local ischemia that contributes to pain in diabetic foot ulcers (Chang et al., 2016; Hafid, Ilhamsyah, & Sari, 2021; Setyowati, Pratiwi, Amalia, & Hedianto, 2024).

Empirically, these findings align with those of Arafah, Agustin, & Wardanengsih, (2025) who reported that diabetic foot exercise significantly reduced foot pain and increased ABI in T2DM patients. The substantial pain reduction observed in this study may also be associated with improved blood flow and tissue oxygenation around the ulcer site, mechanisms previously demonstrated in studies on Buerger exercises and dorsum pedis perfusion in diabetic foot patients (Chang et al., 2016; Hafid, Ilhamsyah, & Sari, 2021). These results extend the evidence presented in systematic reviews by (Tran & Haley, 2021) and (Baker et al., 2025) which reported that non–weight-bearing exercises are safe and can accelerate DFU healing, by adding new confirmation that pain an important patient-centered clinical outcome can also be significantly improved through structured exercise programs. Thus, this research contributes to addressing gaps in the literature, which has previously focused more on ulcer size and biomechanical parameters as primary outcomes (Tran & Haley, 2021; Ferreira et al., 2024; Silva et al., 2023).

Beyond local mechanisms, pain reduction may also be explained by improved glycemic control and modulation of neuropathic symptoms resulting from exercise. A meta-analysis of RCTs by Garcia-Hermoso et al., 2023 and a classic Cochrane review by

Thomas, Elliott, & Naughton, 2006 demonstrated that exercise interventions in T2DM consistently reduce HbA1c and improve insulin sensitivity. Enhanced metabolic status may attenuate the progression of peripheral neuropathy, thereby reducing neuropathic pain often associated with diabetic foot ulcers. This is supported by systematic reviews on exercise in peripheral neuropathy showing increased functional capacity and reduced neuropathic symptoms following exercise programs (Streckmann et al., 2022; Gracia-Sanchez et al., 2025). Accordingly, the findings of this study are consistent with theoretical models integrating neuropathic pathophysiology, peripheral angiopathy, and adaptive responses to exercise as recommended in the ADA 2025 and IWGDF 2023 guidelines (Schaper et al., 2019; Bus et al., 2024).

From a methodological perspective, the use of the VAS as a pain measurement instrument in this study can be considered appropriate and supports the strength of the evidence generated. The measurable reduction in pain exceeding the MCID indicates that the observed VAS score changes are not random fluctuations but represent clinically meaningful differences for patients (Myles, 2017). The strong reliability and validity of the VAS across various acute and chronic pain contexts (Carlsson, 1983; Jensen, M. P., & McFarland, 1993; Alghadir et al., 2018; Begum, 2023) provide assurance that the dependent variable in this study was measured accurately and consistently. Furthermore, the randomized controlled trial design with a control group, pre–post measurements, and the use of inferential statistical analyses (paired t-tests, independent t-tests, and effect size calculation) aligns with methodological standards for quantitative health research (Bruce, Pope, & Stanistreet, 2008).

Despite supporting the hypothesis that exercise therapy reduces pain in T2DM patients with diabetic foot ulcers, several limitations must be considered. First, the intervention duration was relatively short (e.g., 8 weeks), so long-term effects on chronic pain and ulcer recurrence cannot be established. Second, the study was conducted in one or a limited number of healthcare facilities with a moderate sample size, which may limit the generalizability of findings to the broader T2DM population with DFU. Third, although some confounding variables were controlled statistically, other factors such as variations in analgesic use, adherence to foot care practices, and levels of physical activity outside the exercise program may still influence pain outcomes.

Overall, the findings of this study reinforce the recommendation that structured exercise therapy should be integrated into comprehensive diabetic foot management in accordance with national and international guidelines (Burhan, 2020; Soelistijo et al., 2021; Bus et al., 2024). Exercise therapy is not only safe when delivered as non–weight-bearing movements with adequate offloading, but also effective in reducing diabetic foot ulcer pain and potentially improving patient quality of life. The practical implications of these findings include the need to develop standardized diabetic foot exercise protocols in healthcare settings, train healthcare personnel to facilitate such programs, and conduct further research with multi-center designs and long-term follow-up to assess persistent effects on pain, wound healing, and amputation rates.

Conclusion

This study concludes that a structured foot exercise program has a significant effect on reducing pain among individuals with type 2 diabetes mellitus who experience diabetic foot ulcers. The exercise intervention resulted in an average reduction of approximately 3.4 cm in VAS pain scores in the intervention group, compared with only about 0.8 cm

in the control group. The between-group difference in pain reduction was statistically significant and accompanied by a large effect size, indicating that exercise therapy is not only statistically effective but also clinically meaningful in reducing diabetic foot ulcer pain.

Practically, these findings underscore that exercise therapy can be integrated into comprehensive diabetic foot management in healthcare settings, particularly as a relatively simple, low-cost, and replicable non-pharmacological intervention. The results also reinforce the theoretical basis that improved peripheral perfusion, enhanced lower-extremity muscle function, and optimized metabolic control achieved through exercise contribute to pain reduction in diabetic foot ulcers. Thus, this study provides a meaningful contribution to the development of evidence-based interventions in nursing and rehabilitation for patients with diabetes and foot complications.

Nevertheless, this study has several limitations, including the relatively short intervention duration, a modest sample size, and limited study locations that may not represent various levels of healthcare services. Other factors such as variations in analgesic use, adherence to exercise outside the structured sessions, and long-term glycemic control were also not fully explored. Therefore, further research is recommended using multi-center designs, larger sample sizes, longer follow-up periods, and additional outcomes such as wound healing, physical function, and quality of life to strengthen the evidence and enhance the generalizability of these findings.

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