Jurnal
Berita Ilmu Keperawatan

Jurnal Berita Ilmu Keperawatan
Vol. 19 (1), 2026
p-ISSN: 1979-2697
e-ISSN: 2721-1797
https://doi.org/10.23917/bik.v19i1.12891

Heel Raise Exercise: Effects on ABI and Peripheral Neuropathy

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Abstract:
Vascular complications, particularly impaired peripheral perfusion as reflected by reduced Ankle Brachial Index (ABI) values and the occurrence of peripheral neuropathy, are frequently observed in individuals with type 2 diabetes mellitus (T2DM). These conditions significantly contribute to an increased risk of diabetic foot ulceration and lower limb amputation. Therapeutic exercise targeting the lower extremities represents a non-pharmacological preventive strategy, among which Heel Raise Exercise (HRE) is considered practical and feasible for routine implementation. This study aimed to evaluate the effect of HRE on ABI values and peripheral neuropathy scores in patients with T2DM. This study employed a quasi-experimental design with a nonequivalent control group approach. A total of 62 participants were recruited using purposive sampling from the service area of Buleleng I Primary Health Care Center. Group allocation into intervention and control groups was conducted through non-random assignment based on participant enrollment order and operational considerations at the study site. ABI measurements were performed using an 8 MHz Doppler ultrasound device in conjunction with a sphygmomanometer, while peripheral neuropathy was assessed using the Michigan Neuropathy Screening Instrument (MNSI). Statistical analysis involved paired t-tests to examine within-group differences before and after the intervention and independent t-tests to compare mean differences between groups. The results demonstrated that the intervention group exhibited an increase in mean post-intervention ABI values to 0.93, accompanied by a reduction in peripheral neuropathy scores to 2.89. In contrast, no statistically significant changes were identified in the control group. The mean differences in ABI (0.07 ± 0.04) and peripheral neuropathy scores (0.40 ± 0.61) in the intervention group were statistically significant. In conclusion, Heel Raise Exercise was shown to be effective in improving peripheral vascular status and reducing peripheral neuropathy severity in patients with type 2 diabetes mellitus.

Keywords: Type 2 Diabetes Mellitus; Heel Raise Exercise; Ankle Brachial Index; Peripheral Neuropathy

Submitted: 15 September 2025, reviewed: 20 October 2025, revised: 06 January 2026, accepted: 06 January 2026, published: 31 January 2026

INTRODUCTION

One of the most common chronic metabolic disorders is Diabetes Mellitus (DM), which is characterized by chronic hyperglycemia due to insulin deficiency, insulin resistance, or a combination of the two (Webber, 2021). This disease is predicted to continue to increase in prevalence in the future and become one of the causes of serious death in the world. According to a 2021 report by the International Diabetes Federation (IDF), the prevalence of diabetes in the age group of 20–79 years is

recorded at 10.5% or around 536.6 million people, and is estimated to increase to 783.2 million people in 2045 with a prevalence of 12.2%. Indonesia itself ranks fifth in the world in the number of diabetes cases, with a total of 19.5 million patients in 2021, so it is included in the top ten countries with the highest cases (Webber, 2021). The trend of increasing DM cases has also been identified in various regions in Indonesia, including in Bali Province. Based on a report by the Health Office, the number of DM cases in this province increased from 37,736 cases in 2020 to 52,282 cases in 2022. Buleleng Regency is the area with the second highest number of cases after Denpasar City, with 12,464 cases in 2022. Of the nine districts/cities in Bali Province, Buleleng recorded a percentage of DM case services of 83.1%, a figure that is still lower than the provincial average of 97.3% (Kemenkes, 2021).This fact indicates that DM needs to be the focus of health service priorities, especially in terms of providing nursing care in Buleleng Regency. These data highlight the urgent need for prioritizing diabetes management, particularly nursing-based preventive care, in Buleleng Regency.

The increasing prevalence of DM significantly contributes to the development of vascular complications, including microvascular complications (neuropathy, nephropathy, and retinopathy) and macrovascular complications such as cardiovascular disease, stroke, and peripheral artery disease (PAD) (Farmaki et al., 2020). widely used non-invasive method to detect vascular impairment is the measurement of the Ankle Brachial Index (ABI), which assesses the integrity of large and peripheral blood vessels.The reduced ABI values indicate impaired peripheral perfusion, which may lead to tissue ischemia, particularly in distal areas such as the toes, thereby increasing the risk of diabetic foot ulcers. This vascular impairment is primarily driven by chronic hyperglycemia that induces vascular inflammation, endothelial dysfunction, and atherosclerosis, ultimately disrupting peripheral blood circulation (Beckman & Creager, 2016)

Low ABI value (<0.9) indicates peripheral circulation disorders and an increased risk of diabetic ulcers (Danieluk & Chlabicz, 2021). Suboptimal peripheral circulation acts as a predisposing factor for infection and gangrene, which may worsen diabetic ulcers and lead to lower-limb amputation (Jiménez et al., 2017). Research by Yang et al., (2021) proved a significant relationship between low ABI and the incidence of diabetic foot ulcers in patients with type 2 DM. These findings are strengthened by the research of Syauta et al., (2021), which showed a correlation between ABI values and the incidence of diabetic foot ulcers.

In addition to vascular impairment, peripheral neuropathy represents one of the most prevalent chronic complications in patients with DM, affecting more than 50% of individuals (Selvarajah et al., 2019). Peripheral neuropathy occurs due to nerve damage that causes loss of sensation, numbness, pain, and impaired sensory function of the extremities. The development of this condition can interfere with the integrity of nerves, small joints, and intrinsic muscles in the ankle (Sacco et al., 2015). Chronic hyperglycemia has been shown to increase oxidative stress which directly damages peripheral nerve cells (Rachmantoko et al., 2021). In addition, insulin resistance that occurs in type 2 diabetes inhibits the entry of glucose into nerve cells, thereby disrupting metabolism, lowering neurotrophic signals, and eventually causing symptoms of peripheral neuropathy (Feldman et al., 2019).

Peripheral neuropathy typically develops after approximately 10 years of diabetes, with a prevalence of up to 50%. This condition has a serious impact because it increases the risk of falls, infections, amputations, and decreases the quality of life of DM sufferers (Bondar et al., 2021). Neuropathy-related muscle weakness, limited joint mobility, and reduced walking speed have been identified as major risk factors for diabetic foot ulcers, diabetic foot syndrome, and ulcer recurrence (Wang et al., 2019). Furthermore, research by Ede et al., (2018) even found symptoms of diabetic neuropathy in 93.33% of patients with diabetic foot ulcers, and 73.33% in patients without foot ulcers, u nderscoring its critical role in diabetic foot pathology.

Various previous studies have recommended foot exercises as one of the interventions to prevent foot complications in people with type 2 DM. Radhika et al., (2020) reported that Buerger-Allen exercises performed 5–6 times a day for four consecutive days can significantly increase ABI values. A similar study by Faizah et al., (2021) showed that diabetic foot exercises performed 3–4 times a week for four weeks were able to increase ABI values in DM patients. Meanwhile, Suryani et al., (2021)

proved that resistance exercises involving the leg muscles provide a significant improvement in the sensory and motor function of patients with peripheral neuropathy. However, the intervention is considered less flexible because it requires special equipment and varied movements, so its application is limited. Therefore, it takes a simple, practical, and easy form of exercise for DM patients to maintain foot health while reducing the risk of complications.

Therefore, a simple, practical, and easily performed exercise is needed to support foot health and reduce the risk of complications among patients with DM. One exercise that can be an alternative is the Heel Raise Exercise (HRE). This exercise aims to strengthen the plantar flexor muscles of the ankle through heel lifting movements involving the calf and heel muscles (Mori, 2015). The activity of calf and ankle muscle contractions during this exercise has been shown to increase blood flow to the lower extremities. This increase in perfusion has the potential to correct the low ABI value due to DM(Dewi et al., 2024). In addition, optimal blood circulation can support the supply of oxygen and nutrients to peripheral nerves thereby helping to improve nerve function (Holmes & Hastings, 2021)

Several previous studies on the effectiveness of HRE have yielded promising results. Lee et al., (2017) found that HRE is able to improve muscle strength, walking speed, and static and dynamic balance in stroke patients. Another study by Seo & Lee, (2022) also concluded that HRE plays a positive role in improving muscle strength and body balance. However, there have been no studies that have specifically evaluated the effect of HRE on ABI values and peripheral neuropathy in patients with type 2 DM. In addition, most previous studies involved only a limited sample, which was about 20 people per group. Based on this, this study was designed to determine the effect of Heel Raise Exercise on ABI values and peripheral neuropathy in patients with type 2 diabetes mellitus.

METHODS

Research design

This study was a quantitative study with a quasi-experimental approach using a Nonequivalent Control Group Design, involving an intervention group and a control group.

Location setting

The research was conducted in the Working Area of the Buleleng I Health Center, Buleleng Regency, Bali Province, from January 29 to March 26, 2024. The study population consisted of patients with type 2 diabetes mellitus (DM).

Sample

Total of 62 respondents were included in this study, with 31 participants assigned to the intervention group and 31 to the control group. The study population consisted of 797 patients with type 2 diabetes mellitus registered for routine follow-up at the Buleleng I Health Center**.** During the recruitment period, 180 patients were screened, of whom 79 met the inclusion and exclusion criteria. Sixty-two eligible patients agreed to participate, resulting in a response rate of 78.48%.

The sample size was determined using the paired numerical comparative hypothesis formula Dahlan (2016), resulting in a minimum requirement of 17 participants. To anticipate a potential dropout rate of 45% the sample was adjusted to 31 respondents per group. Participants were selected using purposive sampling based on predefined eligibility criteria.No interim analyses or stopping rules were applied due to the short duration and low-risk nature of the intervention. Inclusion criteria: adults with type 2 DM up to 70 years old, MNSI-B score ≥ 2.5, ABI value ≤ 1.0, no movement disorders or physical disabilities affecting HRE performance, and willingness to sign informed consent. Exclusion criteria: diabetic ulcers, gangrene, neurological complications (e.g., stroke), uncontrolled hypertension, osteoarthritis, retinopathy, nephropathy, recent lower-limb surgery (within 1 year), and participation in lower-extremity exercise programs within the past 3 months.

Intervention

The intervention provided is Heel Raise Exercise (HRE), which is a simple exercise aimed at strengthening the plantar flexor muscles in the lower legs, especially the gastrocnemius and soleus muscles. The procedure is carried out in this way: the respondent stands upright while holding the crutch to maintain balance, then slowly raises both heels as high as possible so that they rest on the toes, then slowly lowers them back for ±2 seconds. In the initial stage, the exercise is carried out with the help of a handrest, which is then reduced according to the respondent's ability. The intervention group first received HRE training at the Health Center by a certified physiotherapist with at least 2 years of clinical experience. Each exercise session consisted of 3 sets of 10 repetitions, with each set lasting approximately 30–40 seconds and the entire session lasting about 3–5 minutes including short rest intervals. Participants performed the exercise 5 times per week for 6 consecutive weeks, resulting in a total of 30 intended sessions throughout the intervention period. Thus, the total intended exposure duration for each participant was approximately 90–120 minutes over 6 weeks. After that, the respondents carried out the exercises independently at home with the assistance of a research assistant through home visits 5 times per week for 6 weeks. In addition to exercise, blood sugar levels are checked every 2 days. The control group only received a home visit for blood sugar checks once every 2 days, without being given an HRE intervention. After a 6-week intervention period, both groups underwent a post-test to measure ABI scores and peripheral neuropathy scores.

Data collection and measurement

This study used several instruments to collect relevant data from patients with type 2 diabetes, including a demographic questionnaire that recorded the respondent's identity (name, address, phone number), age, sex, duration of diabetes, Body Mass Index (BMI), and cardiovascular history; Ankle Brachial Index (ABI) measurement using a sphygmomanometer and an 8 MHz Doppler probe following the Standard Operating Procedure recommended by the American Heart Association as a globally recognized method; and the Indonesian version of the Michigan Neuropathy Screening Instrument (MNSI), which consists of part A for subjective assessment using yes/no questions and part B for objective foot examination including inspection, ankle reflex testing, vibration sensation, and monofilament testing. The Indonesian version of the MNSI had been previously validated, showing significant validity parameters ($p < 0.05$) with r-values ranging from 0.261 to 0.764, exceeding the r-table value of 0.195, and demonstrated good reliability with a Cronbach's Alpha value of 0.678; furthermore, the section B cut-off score of ≥ 2.5 indicated a sensitivity of 95.0% and a specificity of 90.5%, confirming its suitability for diagnosing peripheral neuropathy.

Data analysis

Data analysis included univariate analysis to describe respondent characteristics, ABI values, and peripheral neuropathy scores. Data normality was assessed using the Shapiro–Wilk test. Paired t-tests were used to analyze pre–post differences within each group, while independent t-tests were applied to compare changes between the intervention and control groups. To control potential confounding factors, bivariate analyses were performed to examine the associations between external variables (age, sex, duration of diabetes, BMI, physical activity, cardiovascular history, and blood glucose levels) and changes in ABI values and peripheral neuropathy scores. Variables with p-values > 0.05 were considered not to significantly influence the outcomes, indicating that the observed effects were primarily attributable to the intervention.

Ethical Consideration

Ethical clearance was obtained from the Medical Research Ethics Commission of FKKMK Universitas Gadjah Mada (Ref. No. KE/FK/0150/2024). All participants received detailed information about the study and signed informed consent prior to involvement.

RESULTS

Respondent Characteristics

The characteristics of the study respondents included age, gender, length of diabetes, body mass index (BMI), history of cardiovascular disease, blood glucose levels at the time, and physical activity. An overview of the characteristics of the respondents can be seen in table 1.

Table 1. Characteristics of Treatment and Control Group Respondents in Type 2 Diabetes Patients (n=62).

		Group				p
		Treatment (n=31)		Control (n=31)		
		f	%	f	%	
Age (years)	Mean ± SD	59,42 ± 8,80		57,13 ± 7,08		0.263
Gender	Man	9	29.0%	11	35.5%	0.587
	Woman	22	71.0%	20	64.5%	
Long Suffering from Diabetes		0	0.0%	0	0.0%	0.896
		1	3.2%	3	9.7%	
		21	67.7%	17	54.8%	
		9	29.0%	11	35.5%	
Body Mass Index	Median (min-max)	23 (18-26)		24 (18.7-31)		0.151
Physical Activity	Median (min-max)	500 (240-820)		500 (300-1150)		0.944
History of Cardiovascular Disease	Ada	10	32.3%	12	38.7%	0.596
	No	21	67.7%	19	61.3%	
Type	Hypertension	10	100.0%	12	100.0%	-
Early GDS	Mean ± SD	209.48 ± 81.42		205.97 ± 76.58		0.862
GDS rerata	Mean ± SD	194.11 ± 72.85		187.47 ± 64.76		0.706
Final GDS	Mean ± SD	188.13 ± 63.09		201.03 ± 60.94		0.745
GDS minimal	Mean ± SD	156.13 ± 59.76		158.74 ± 59.77		0.864
Maximum GDS	Mean ± SD	226.55 ± 77.71		222.32 ± 68.54		0.821

From table 1, it can be seen that the study used 62 respondents, divided into a treatment group (31 respondents) and a control group (31 respondents). The average age of the respondents was 59.42 years for the treatment group and 57.13 years for the control group. The majority of respondents were female, with 71% in the treatment group and 64.5% in the control group. Most of the respondents had had diabetes for 5-10 years (67% in the treatment group and 54.8% in the control group), while the rest had suffered for more than 10 years. The majority of respondents had a body mass index (BMI) in the range of 23 which was included in the overweight category. The physical activity of participants in both groups was in the range of 500 which was included in the light category. Some respondents had a history of cardiovascular disease, especially hypertension which was 32.2% in the treatment group and 38.7% in the control group. Data on blood sugar levels at the beginning, average, end, minimum and maximum showed similar average values between the two groups. There were no significant differences in respondent characteristics between the treatment and control groups, including ABI values and neuropathy scores before the intervention, suggesting both groups were homogeneous ($p>0.05$).

Differences in ABI Values Before and After Intervention in the Intervention and Control Groups

A paired differential test was used in this study to determine the difference in the mean value of ABI values and peripheral neuropathy scores before and after intervention in the treatment and control groups using a parametric statistical test dependent test because the data was normally distributed. The results of the analysis can be seen in table 2.

Table 2. Differences in Brachial Ankle Index (ABI) Values and Peripheral Neuropathy Scores Before and After Intervention in the Treatment and Control Groups

Group	ABI Value			Peripheral Neuropathy Score		
	Before	After	*p* value	Before	After	*p* value
	Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD	
Control	0.86 ± 0.06	0.93 ± 0.07	<0.001*	3.29 ± 0.66	2.89 ± 0.78	0.001*
Treatment	0.87 ± 0.05	0.87 ± 0.06	0.682	3.26 ± 0.59	3.19 ± 0.67	0.572

Table 2 shows that in the treatment group there was a significant increase in the ABI value from before the intervention (mean 0.86) to (mean 0.93) after the intervention. In addition, there was a significant decrease in neuropathy scores from before the intervention (mean 3.29) to (mean 2.89) after the intervention. In the control group, there was no significant difference in either ABI (0.87 before and after the intervention) and neuropathy score (3.26 before and 3.19 after the intervention).

Differences in Mean Values of ABI and Peripheral Neuropathy Scores in the Intervention and Control Groups

The statistical test used to determine the effect of heel raise exercise on ABI values and peripheral neuropathy scores is an independent parametric test because the data is normally distributed. This test was used to see the difference between the average ABI score and peripheral neuropathy score in the two groups as seen in table 3.

Table 3. Comparison of the Difference in Average Brachial Index Ankle Score (ABI) and Peripheral Neuropathy Score Between the Treatment Group and the Control Group

Variabel	ABI Value	Peripheral Neuropathy Score	D	p	CI 95%	d'Cohen
	Mean ± SD	Mean ± SD				
Control Treatment	0.07 ± 0.04	0.009 ± 0.01	0,07	<0.001*	0.06 – 0.09	2.05
	0.40 ± 0.61	0.06 ± 0.63	0,34	0.036*	0.02 – 0.65	0.55

Table 3 shows that in the treatment group there was an increase in the ABI value with an average change of (0.07 ± 0.04) higher than the control group (0.009 ± 0.013) with a difference of 0.07 and a significant difference (p<0.001). This shows that the intervention has a positive and significant impact on the improvement of ABI values. In addition, in the intervention group, there was a decrease in neuropathy scores with an average change of (0.40 ± 0.61) greater than that of the control group (0.06 ± 0.63) with a difference of -034 and a p= value of 0.036*. In addition, d'Cohen scores on both variables showed that the effects of the intervention on improvement in ABI values were in the strong category (d'Cohen >0.8) and the decrease in neuropathy scores were included in the moderate category (d'Cohen >0.5).

Test Candidate Between External Variables with ABI Values and Peripheral Neuropathy Scores.

Bivariate tests are performed to select external variables (age, sex, length of diabetes, body mass index (BMI), physical activity, history of cardiovascular disease and current blood glucose levels) to be included in the regression test. The results of bivariate analysis can be seen in table 4.

Table 4. External Variable Candidate Test with ABI Value and Peripheral Neuropathy Score in Type 2 Diabetes Patients

Variabel	ABI Value Difference		Peripheral Neuropathy Score Difference	
	r	p	r	p
Age	0.031	0.814	-0.018	0.892
Gender	0.147	0.194	0.109	0.398
Long Suffering from Diabetes	-0.042	0.744	-0.026	0.840
IMT	-0.031	0.813	-0.245	0.055
Physical Activity	-0.085	0.512	0.180	0.162
History of Cardiovascular Disease	-0.002	0,988	0.154	0.231
Early GDS	0.099	0.443	0.029	0.821
GDS rerata	0.139	0.280	-0.002	0.985
Maximum GDS	0.076	0.556	-0.004	0.976
GDS minimal	0.120	0.352	0.078	0.545
Final GDS	0.128	0.320	0.056	0.663

Table 4 shows the results of the test of the relationship between external variables and ABI values and peripheral neuropathy scores. The results showed that there was no association between age, sex, length of diabetes, history of cardiovascular disease, blood sugar levels, and physical activity with ABI values and peripheral neuropathy scores due to p>0.05 values.

DISCUSSION

This study was designed to assess the effectiveness of heel raise exercise (HRE) in improving vascular and neurological parameters, specifically Ankle Brachial Index (ABI) values and peripheral neuropathy scores in patients with type 2 diabetes mellitus. The findings of the study show that a simple intervention in the form of HRE is able to have a positive and significant impact on both variables. The average post-test ABI value in the intervention group increased to 0.93, while the control group only reached 0.87. A greater improvement in the treatment group suggests that leg muscle contractions through HRE exercises contribute to improved vascular health of the lower extremities.

From a physiological perspective, the contraction of the gastrocnemius and soleus muscles during HRE acts like a "calf muscle pump" that helps to facilitate venous backflow while increasing peripheral tissue perfusion. This mechanism is particularly relevant for diabetic patients who generally experience endothelial dysfunction as well as decreased elasticity of blood vessels. Research by Fujiwara et al., (2010) corroborates these results by showing that HRE over six weeks significantly increases the strength of the plantar flexors as well as the thickness of the gastrocnemius and soleus muscles. Meanwhile, Lee et al., (2017)study proved that this exercise not only improves leg muscle strength, but also improves walking speed and dynamic balance in stroke patients, thus showing broader benefits in the musculoskeletal and vascular contexts.

Additional scientific evidence was presented in a systematic review by Suryawan et al., (2022) which stated that leg muscle resistance exercises, especially those that are dynamic in large muscle groups, have been shown to improve peripheral circulation in diabetic patients. The review emphasized that training of at least 24 sessions in 12 weeks was able to significantly improve vascular parameters. Although the intervention in this study lasted a shorter period (6 weeks), the number of sessions was

30 times, so the positive effects were still significant. This fact reinforces the notion that consistency and frequency of exercise play a more important role than just the length of the intervention period.

When viewed from a molecular perspective, the improvement in ABI in the intervention group may be attributed to increased production of Nitric Oxide (NO) during muscle contraction activity. NO functions to widen blood vessels, increase arterial elasticity, and prevent endothelial damage (Suryawan et al., 2022). In line with that, a meta-analysis by (Montero et al., 2013) found that exercise on the lower extremities significantly improved the arterial endothelial function of patients with type 2 diabetes. Given that endothelial dysfunction is one of the early markers of atherosclerosis (Sandoo et al., 2015) is often found in people with type 2 diabetes mellitus (Zhou et al (2018), these findings confirm the importance of HRE as a preventive strategy for cardiovascular complications.

In addition to affecting vascular aspects, HRE has also been shown to have an impact on the improvement of peripheral neuropathy. The study data showed that the average post-test neuropathy score of the intervention group decreased to 2.89 ($p<0.001$), while the control group remained at 3.19 ($p=0.572$) so that there was no significant change. This improvement is most likely related to increased peripheral blood flow that improves the supply of oxygen and nutrients to the nerves. The improvement of microcirculation supports nerve regeneration and optimizes sensory responses, so that neuropathy symptoms such as numbness, tingling, and burning can be reduced. These findings are in line with research by (Barone Gibbs et al., 2013)which showed that increased peripheral perfusion has a direct impact on nerve function.

Previous studies have demonstrated that various forms of lower-extremity exercises, such as Buerger-Allen exercise and resistance training, are effective in improving peripheral circulation and ABI values in patients with diabetes mellitus (Faizah et al., 2021; Radhika et al., 2020; Suryani et al., 2021). However, most of these studies primarily focused on vascular outcomes alone. The present study extends existing evidence by simultaneously evaluating both ABI values and peripheral neuropathy scores, providing a more comprehensive assessment of vascular and neurological benefits. In addition, this study was conducted in a primary healthcare setting, highlighting the feasibility of implementing Heel Raise Exercise as a routine nursing intervention in community-based diabetes management.

Furthermore, the compliance and consistency aspects of the exercise are important factors that support the success of the intervention. Based on diary book records, participants in the intervention group routinely performed HRE five times per week for six weeks, with the number of repetitions gradually increased according to the protocol. This consistency has been proven to increase insulin sensitivity, so that glucose utilization becomes more efficient. This mechanism reduces the accumulation of sorbitol and oxidative stress in neuronal cells, improves the activity of Na^+/K^+-ATPase, as well as improves neural signal transduction(Montero et al., 2013). This is consistent with the report of Suryawan et al., (2022) which states that regular leg exercises at least three times per week can significantly reduce the severity of peripheral neuropathy.

From comparative perspective, several other forms of intervention such as regular walking or diabetic foot exercises have also been shown to be able to increase ABI, improve endothelial function, and reduce symptoms of neuropathy. However, the advantage of HRE lies in its simplicity: it does not require special tools, can be done independently at home, and is easy to monitor by primary health workers. This practicality makes HRE a more feasible alternative to be applied in preventive and rehabilitative programs for diabetic patients at the Puskesmas level.

Additional analysis showed that demographic and clinical factors such as age, sex, length of diabetes, body mass index, blood sugar levels at a time, physical activity, and cardiovascular history were not significantly associated with changes in ABI and neuropathy scores in this study. The inconsistency with some previous studies is most likely due to sample heterogeneity, study design variations, or other unmeasured confounding factors. However, the length of time you have diabetes is still considered an important variable in predicting the risk of peripheral neuropathy and vascular disorders.

From a nursing practice perspective, these findings indicate that Heel Raise Exercise can be integrated into routine diabetes care programs at the primary healthcare level. Nurses play a critical

role as educators and facilitators by teaching proper exercise techniques, monitoring patient adherence, and incorporating HRE into chronic disease management and community-based health promotion programs. The low cost and practicality of this intervention support its sustainability and suitability for independent home practice.

Despite these findings, several limitations should be acknowledged in the interpretation of this study's results. First, the use of a quasi-experimental design without random allocation may have introduced selection bias. Second, as the research was carried out in a single primary healthcare facility, the external validity and applicability of the findings to broader populations may be limited. Third, although a number of potential confounding variables were considered, other unassessed factors, including dietary habits and adherence to prescribed medications, may have affected the study outcomes. Lastly, the relatively brief duration of the intervention restricts the assessment of the long-term effectiveness and sustainability of the Heel Raise Exercise intervention.

CONCLUSION

This study proves that heel raise exercise interventions have a significant effect on increasing the value of Ankle Brachial Index (ABI) and decreasing peripheral neuropathy scores in patients with type 2 diabetes mellitus in the work area of the Buleleng I Health Center. These findings indicate that simple exercises that focus on strengthening calf muscles and stimulating peripheral circulation can be an effective nonpharmacological strategy to improve vascular health and peripheral nerve function in people with diabetes. The results of this study also confirm that demographic and clinical factors such as age, gender, length of diabetes, body mass index, current blood glucose levels, history of cardiovascular disease, and physical activity do not have a meaningful relationship with changes in ABI values or peripheral neuropathy scores, so this intervention can be applied widely to different groups of diabetic patients regardless of their basic characteristics.

Based on the results of this study, it is recommended that the general public, especially people with type 2 diabetes mellitus, start implementing structured physical exercise such as heel raise exercise as part of a healthy lifestyle to maintain peripheral vascular health and reduce the risk of neuropathy. For health workers and program managers in health care facilities, the results of this research can be used as a basis for developing an educational program that emphasizes the importance of simple, cheap, and easy physical exercise, as one of the non-pharmacological interventions in the prevention of diabetes complications. As for scientific development, follow-up research with a wider sample coverage, longer duration of intervention, and measurement of additional variables such as quality of life or patient independence level is strongly encouraged to strengthen the scientific evidence and broaden understanding of the effectiveness of these exercises in the context of comprehensive diabetes management.

ACKNOWLEDGMENT

Thanks to all patients as respondents at Buleleng I Health Center, Buleleng Regency, Bali Province.
Thanks to all the staff of Buleleng I Health Center, Buleleng Regency, Bali Province.

AUTHOR CONTRIBUTION

KNA: Conceptualization, Methodology, Software, Formal analysis, Investigation, Resources, Data Curation, Writing - Original Draft, and Writing - Review & Editing
WAN: Conceptualization, Methodology, Supervision, Writing - Original Draft, and Writing - Review & Editing
HNP: Conceptualization, Methodology, Supervision, Writing - Original Draft, and Writing - Review & Editing

ETHICAL APPROVAL AND CONSENT

Ethical clearance was obtained from the Medical Research Ethics Commission of FKKMK Universitas Gadjah Mada (Ref. No. KE/FK/0150/2024). All participants received detailed information about the study and signed informed consent prior to involvement.

DATA AVAILABILITY STATEMENT

The data supporting the findings of this study are not publicly available due to privacy or ethical constraints. The data available by contacting the corresponding author, by writing data requests with a reasonable reason.

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