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Effectiveness of Foot Exercise and Kersen Leaf Infusion on Blood Glucose in Type 2 Diabetes Mellitus

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Abstract

Type 2 diabetes mellitus (T2DM) requires accessible complementary strategies to support glycemic control. This study aimed to evaluate the effects of foot exercise, kersen (Muntingia calabura L.) leaf infusion, and their combination on random blood glucose levels. A quasi-experimental pretest-posttest study with four parallel groups involved 60 adults with T2DM, allocated equally to diabetic foot exercise, kersen leaf infusion, combined intervention, or control groups (n = 15 each). Interventions were delivered for two weeks. Foot exercise consisted of seven movements for approximately 30 minutes, three times weekly, while the infusion group received 100 mL of warm kersen leaf infusion once daily before bedtime. Random blood glucose was measured before and after the intervention using a glucometer. Within-group changes were examined using paired t-tests, and post-intervention differences among the four groups were evaluated using one-way analysis of variance followed by Bonferroni-adjusted post hoc comparisons. The results of this study showed that blood glucose decreased significantly in the diabetic foot exercise group (mean change 16.67 mg/dL; 95% CI 3.08-30.26; p=0.020), kersen infusion group (12.53 mg/dL; 95% CI 6.24-18.83; p=0.001), and combination group (39.07 mg/dL; 95% CI 19.48-58.65; p=0.001), but not in the control group (9.87 mg/dL; 95% CI -5.50 to 25.23; p=0.190). Bonferroni analysis showed lower posttest glucose in the combination group than in the foot-exercise group (mean difference -64.80 mg/dL; 95% CI -119.94 to -9.66; p=0.013). In conclusion, the combined intervention produced the largest reduction and significantly lower posttest glucose than foot exercise alone and control.

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1. INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a major non-communicable disease associated with persistent hyperglycemia, vascular complications, neuropathy, and reduced quality of life. Indonesia continues to experience an increasing diabetes burden, and local health-service data indicate that diabetes is among the leading conditions managed in primary care. Effective management therefore requires pharmacological treatment together with sustainable lifestyle and self-care strategies (Kementerian Kesehatan Republik Indonesia, 2020; Soelistijo et al., 2024).

Countries in the Arab-North African and Western Pacific regions are ranked first and second, respectively, with the highest prevalence of diabetes in people aged 20-79 years in seven regions worldwide at 12.2% and 11.4%, respectively. Southeast Asia is ranked 3rd with an incidence rate of 11.3%. Indonesia ranks 7th out of 10 countries with the largest number of affected people, namely 10.7 million people (Kementerian Kesehatan Republik Indonesia, 2020). In Indonesia, based on Riskesdas data for 2013 and 2018, the prevalence of blood glucose test results has increased from 6.9% to 8.5%, and the rate of diabetes discovered by doctors has increased from 1.5% to 2%. Based on all prevalence data in East Kalimantan Province, Samarinda City ranks first among all cities in East Kalimantan with a figure of 3.04%, whereas Paser ranks lowest with a figure of 1.15% (Badan Penelitian dan Pengembangan Kesehatan, 2019). Based on a preliminary study conducted by researchers on October 12, 2022, data showed that diabetes mellitus was the fourth disease out of the top 10 diseases at Bukuan Samarinda Community Health Center, and data on the number of diabetes mellitus cases in January-September 2022 was 80 cases.

Diabetes has both pharmacological and nonpharmacological effects. Pharmacological treatments include insulin injections or oral forms such as glibenclamide and metformin (Muawana & Rustanti, 2020). Meanwhile, for nonpharmacological treatment, the World Health Organization (WHO) recommends treatment with traditional medicine (herbal) to prevent and treat disease, especially chronic disease. Kersen (*Muntigia calabura L.*) is a plant that has antioxidant capacity. To lower blood glucose, this mixture of kersen leaf can be combined with other herbal medicines or used alone with 10 fresh kersen leaf. The management of DM also begins with a healthy lifestyle, including medical nutrition therapy, physical activity, and exercise. Foot exercises are one of the sports performed by patients with diabetes. This is intended to increase blood circulation so that nutrients reach functioning tissues; strengthen small muscles, thighs, and calves; and overcome the limited joint movement seen in patients with diabetes. Diabetic foot exercises can also be performed by anyone with type 1 or type 2 diabetes. As the patient is diagnosed with diabetes, this therapy must be used to prevent diabetes complications as early as possible (Ruben, Rottie, & Karundeng, 2016).

Diabetic foot exercises prevent injury and improve blood circulation in individuals with T2DM and those without diabetes. Nurses help patients with diabetes by providing foot exercises and allowing them to perform foot exercises independently. This foot exercise improves blood circulation, strengthens leg muscles, and moves joints. Therefore, foot care for diabetes patients can improve their quality of life (Basuni, 2022). During leg exercise, energy requirements increase owing to increased glucose utilization. Glucose is converted into energy, which increases muscle activity and reduces Blood glucose levels (Ariyanti, 2019). Based on research by Asniati & Hasanah (2021) regarding diabetic foot exercises, research shows that diabetic foot exercises have a significant influence on blood glucose levels, value = 0.000 < (0.05) (Asniati & Hasanah, 2021).

Several studies have shown a decrease in blood glucose levels after consuming kersen leaf decoctions. The decrease in blood glucose levels was caused by kersen leaf

content. Kersen leaf contains saponins and flavonoids that inhibit the absorption of Blood glucose from the intestine, thereby inhibiting the absorption of carbohydrates from the intestine. Flavonoids are classified into several groups, including flavones, flavonols, flavonones, catechins, and isofurasone. Quercetin is a flavonol compound that is thought to lower blood glucose levels. The mechanism of action of Quercetin in reducing glucose levels is by allowing pancreatic cells to function normally. Flavonoids also stimulate glucose production in peripheral tissues and regulate the activity of enzymes involved in carbohydrate metabolism (Norma, 2019). Kersen leaf (100 g) contained water (77.8 g), protein (0.384 g), fat (1.56 g), carbohydrates (17.9 g), dietary fiber (4.6 g), and ash (1.14 g)., calcium (1.24 mg), phosphorus (84 mg), iron (1.18 mg), carotene (0.019 g), thianin (0.065 g), riboflavin (0.037 g), niacin (0.55 g), vitamin C 80.5 mg) (Widiantara et al., 2021)). Based on research by Reski et all (2020), the results showed that boiling kersen leaf reduced blood glucose levels (p= 0.009). The decoction of kersen leaf has been proven to lower blood glucose levels and can be used as an herbal medicine for patients with T2DM (Reski et al., 2020). Previous studies have generally evaluated exercise and kersen leaf preparations separately. Evidence is therefore insufficient regarding whether combining a muscle-mediated intervention with a phytochemical intervention may produce a larger glycemic response than either approach alone. This study addressed that gap by examining changes in random blood glucose across diabetic foot exercise, kersen leaf infusion, combined-intervention, and control groups. The study aimed to determine within-group changes and to describe which intervention produced the largest mean reduction over two weeks.

2. METHODS

This study used a quasi-experimental pretest-posttest design with four parallel groups: diabetic foot exercise, the kersen leaf infusion, combined diabetic foot exercise and kersen leaf infusion and control. The sample size used in this study was calculated using Roscoe's formula. A total of 60 adults with T2DM were included, with 15 participants in each group. The intervention period was two weeks.

Participants were recruited purposively from eligible adults receiving diabetes care at the study site. Inclusion criteria were a diagnosis of T2DM, absence of an active diabetic foot ulcer, ability to follow the intervention instructions, and willingness to participate. Participants with cognitive impairment, acute illness, or severe comorbid conditions that prevented safe participation were excluded. After recruitment, eligible participants were assigned to the four study groups of equal size using a lottery procedure.

The diabetic foot exercise group performed seven standardized movements for approximately 30 minutes, three times per week. The kersen leaf infusion group received 100 mL of warm infusion once daily before bedtime. The combined group received both interventions according to the same schedules, duration and dose, whereas the control group continued routine care without either study intervention. Intervention instructions followed written standard operating procedures. Attendance and daily intake were recorded on monitoring sheets, and the research team provided repeated instructions to support intervention fidelity.

Random blood glucose was measured before the first intervention and after the two-week intervention period using the same glucometer procedure. The instruments included the diabetic foot exercise standard operating procedure, the kersen leaf infusion preparation procedure, monitoring sheets, alcohol swabs, and a glucometer. Data analysis was conducted in stages. The Shapiro-Wilk test was used because each group contained 15 participants; all pretest and posttest distributions were approximately normal ($p>0.05$). Homogeneity was assessed using Levene's test. Within-group pretest-posttest changes

were evaluated using paired-samples t-tests and are reported as mean differences with 95% confidence intervals. To address the reviewer's recommendation for a direct comparison among the four groups, post-intervention random blood glucose was analyzed using one-way analysis of variance (ANOVA). The magnitude of the overall group effect was estimated using eta-squared (eta-squared = SSbetween/SStotal), interpreted as small (0.01), medium (0.06), or large (0.14). When the omnibus ANOVA was significant, Bonferroni-adjusted post hoc tests were applied to identify pairwise group differences while controlling the family-wise type I error rate. Statistical significance was set at $p<0.05$. Ethical approval for this study was obtained from the Ethics Committee of Semarang Health Polytechnic (No. 0988/EA/KEPK/2023). Written informed consent was obtained from all participants after explanation of the study objectives, procedures, potential benefits, and voluntary nature of participation.

3. RESULTS AND DISCUSSION

Table 1. Participant allocation and study flow.

Stage	Participants
Screened and enrolled	60 adults with T2DM
Allocated by lottery	60
Diabetic foot exercise	15
Kersen leaf infusion	15
Combined intervention	15
Control	15
Included in pretest-posttest analysis	15 in each group; 60 total

Table 1 shows that there were sixty participants in this study. The participants were split up into four groups, each with fifteen members.

Table 2. Frequency distribution of respondents by age, gender, other diseases suffered and long suffering from diabetes.

Characteristics	Diabetic Foot Exercises		Kersen Leaf Infusion		Combination		Control		N	
	f	%	f	%	f	%	f	%	f	%
Age										
36-45 years	6	40.0	3	20.0	3	20.0	3	20.0	15	25.0
46-55 years	4	26.7	6	40.0	4	26.7	4	26.7	18	30.0
56-65 years	5	33.3	4	26.7	6	40.0	6	40.0	21	35.0
>65 years	-	-	2	13.3	2	13.3	2	13.3	6	10.0
Gander										
Male	6	30.0	5	33.3	3	20.0	4	26.7	18	30.0
Female	9	70.0	10	66.7	12	80.0	11	73.3	42	70.0
Other Diseases Suffered										
Blood Pressure	9	60.0	11	73.3	15	100.0	8	53.3	43	71.7
Kidney Failure	1	6.7	-	-	-	-	1	6.7	2	3.3
Heart Disease	3	20.0	1	6.7	-	-	3	20.0	7	11.7
Other	2	13.3	3	20.0	-	-	3	20.0	8	13.3
Long Suffering from Diabetes										
< 5 years	7	46.7	5	33.3	4	26.7	6	40..0	22	36.7
> 5 years	8	53.3	10	66.7	11	7.3	9	60.0	38	63.3

Based on Table 2, the results of the research showed that of the 60 respondents who experienced T2DM 21 (35%) were aged 56–65 years. These risk factors increase after the age of 45 years and drastically after the age of 65 years. This happens because, at this age, a person's activity decreases, body weight increases, muscle mass shrinks, and causes pancreatic damage. Damage to the pancreas can increase blood glucose levels because it cannot produce insulin (Ramadhan, 2020). The results of this research are in line with research conducted by (Komariah & Rahayu, 2020) entitled the relationship between age, sex, and body mass index and fasting blood glucose levels in patients with T2DM at the Pratama Outpatient Clinic Proklik, Depok, West Java in 2020 that the majority of type 2 diabetes patients are aged between 46 and 65 years, with a total of 93 patients (69.4).

Recent evidence supports this finding because diabetes is increasingly concentrated in older adults. Sinclair et al. (2020) estimated that 19.3% of adults aged 65–99 years were living with diabetes in 2019, showing that older age is an important demographic factor in diabetes burden (Sinclair et al., 2020). In addition, a systematic review and meta-analysis by Nanayakkara et al. (2021) found that age at diagnosis and duration of diabetes are closely related to mortality and vascular complications. Therefore, the dominance of respondents aged 56–65 years in this study is consistent with current evidence that aging is associated with reduced metabolic reserve, higher insulin resistance, and greater vulnerability to diabetes-related complications (Nanayakkara et al., 2021).

The majority of respondents with type 2 Diabetes Mellitus were women, with a total of 42 respondents (70%), while men with a total of 18 respondents (30%), which was based on the fact that when it was carried out, there were more women than men. Women are more at risk of developing T2DM because, physiologically, they are more likely to experience an increase in BMI. Women also suffer from monthly cycle syndrome after menopause, which can cause body fat to accumulate easily due to this hormonal process, so that women are at a higher risk of developing T2DM (Chairunnisa, 2020). The results of this study are in line with research conducted (Damayanti et al., 2021) entitled The Relationship between Age, Gender, and Temporary Blood Glucose Levels with Serum Creatinine Levels in Diabetes Mellitus Patients at Prambanan Regional Hospital, Sleman Yogyakarta, where 46 people (56.8%) were female than men 35 people.

The gender distribution in this study is also supported by recent literature showing that sex-related biological and behavioral factors influence the risk and clinical course of type 2 diabetes. Kautzky-Willer et al. (2023) explained that changes in body-fat distribution, menopause-related hormonal changes, cardiometabolic risk factors, and health-seeking behavior can affect diabetes risk and outcomes in women. These findings strengthen the interpretation that the high proportion of female respondents may be related not only to the number of women available during data collection, but also to sex-specific metabolic and hormonal factors that influence T2DM risk (Kautzky-Willer et al., 2023).

The majority of type 2 Diabetes Mellitus respondents experienced blood pressure (43 respondents, 71.7%), and a small percentage experienced kidney failure (two respondents, 3.3%). Excessive insulin levels that are too high can increase sodium retention in the kidney tubules, which can lead to hypertension. Many factors influence an increase in blood pressure, including insulin retention, plasma glucose levels, obesity, and other factors in the autoregulatory system that regulates blood pressure. The results of this research are in line with the research conducted by (Basuni, 2022) which stated that the majority of respondents had a history of high blood pressure (19 people, 63.3%).

The finding that hypertension was the most common comorbid disease among respondents is consistent with recent population-based evidence. Pearson-Stuttard et al. (2022) reported that multimorbidity is common among people with type 2 diabetes and that hypertension was one of the most frequent comorbidities at diagnosis. Similarly, Yao et al. (2023) found that hypertension was independently associated with cardiovascular disease risk among patients with diabetes. These findings indicate that blood pressure monitoring and integrated management of cardiovascular risk factors are essential components of diabetes care (Pearson-Stuttard et al., 2022; Yao et al., 2023).

The majority of type 2 Diabetes Mellitus respondents had experience of > 5 years (38 respondents, 63.3%) and < 5 years (22 respondents, 36.7%). The duration of time that diabetes has been experienced will prove how long the patient has suffered from diabetes since the initial diagnosis of the disease. This can also be associated with a risk of complications that will be experienced. The results of this research are in line with research conducted by Setianingsih entitled The Relationship between Long-Term Diabetes Mellitus and Blood Glucose Levels with Foot Sensitivity, which showed that 19 people (63.3%) had diabetes mellitus for a long time (> 5 years). It is usually caused by heredity and an unhealthy lifestyle (Setianingsih, 2023).

The predominance of respondents with diabetes duration of more than five years is clinically important because longer disease duration increases cumulative exposure to hyperglycemia and the risk of complications. Nanayakkara et al. (2021) showed that age at diagnosis and diabetes duration are associated with mortality and vascular complications, while Yao et al. (2023) reported that longer diabetes duration was associated with higher risks of ischemic stroke, coronary artery disease, and predicted ten-year ASCVD risk. Thus, respondents who have lived with diabetes for more than five years require continuous monitoring, lifestyle support, and complication screening (Nanayakkara et al., 2021; Yao et al., 2023).

Table 3. Pretest-posttest random blood glucose and within-group changes.

Groups	N	Pre-test, Mean ±SD	Post-test, Mean ±SD	Mean change (mg/Dl)	d-av	p-value
Diabetic foot exercises	15	302.93±90.949	286.27±71.831	-16.66	0.20	0.020
Kersen leaf infusion	15	248.20±41.454	235.67±39.142	-12.53	0.31	0.001
Combination (Diabetic foot exercises and kersen leaf infusion)	15	260.53±58.374	221.47±41.867	-39.06	0.77	0.001
Control	15	294.13±57.071	284.27±61.214	-9.86	0.17	0.190

Based on Table 3, random blood glucose decreased significantly within all three intervention groups. The combined group showed the largest mean reduction (-39.06 mg/dL) and the largest descriptive standardized mean change (d_av = 0.77). The control group showed a smaller, non-significant reduction.

Table 4. Between-group analysis of post-intervention random blood glucose (One-way ANOVA).

Source	Sum of squares	df	Mean square	F	p-value
Between groups	49.765.650	3	16.588.550	5.443	0.002
Within groups	170.684.933	56	3.047.945		

Table 4. One-way ANOVA of post-intervention random blood glucose levels among the four study groups. The overall effect size was large (eta-squared=0.226), indicating that approximately 22.6% of the variability in posttest glucose was associated with group membership. The one-way ANOVA demonstrated a statistically significant difference in post-intervention random blood glucose among the four groups, F(3,56)=5.443, p=0.002. The calculated eta-squared of 0.226 indicated a large between-group effect. Therefore, Bonferroni-adjusted pairwise comparisons were conducted.

Table 5. Bonferroni post hoc comparisons.

Comparison (I-J)	Mean difference (mg/dL)	SE	p-value	95% CI lower	95% CI upper
Foot exercise - Kersen infusion	50.60	20.159	0.090	-4.54	105.74
Foot exercise - Combination	64.80	20.159	0.013	9.66	119.94
Foot exercise - Control	2.00	20.159	1.000	-53.14	57.14
Kersen infusion - Combination	14.20	20.159	1.000	-40.94	69.34
Kersen infusion - Control	-48.60	20.159	0.115	-103.74	6.54
Combination - Control	-62.80	20.159	0.017	-117.94	-7.66

Table 5. Bonferroni-adjusted pairwise comparisons of post-intervention random blood glucose. Positive mean differences indicate that the first-listed group had a higher posttest value. Bonferroni comparisons showed that the combination group had significantly lower posttest glucose than the diabetic foot exercise group (221.47 vs 286.27 mg/dL; mean difference -64.80 mg/dL; 95% CI -119.94 to -9.66; p=0.013) and the control group (221.47 vs 284.27 mg/dL; mean difference -62.80 mg/dL; 95% CI -117.94 to -7.66; p=0.017). The combination group did not differ significantly from the kersen infusion group (mean difference -14.20 mg/dL; p=1.000). The other pairwise differences were not statistically significant after Bonferroni adjustment.

Comparison of the average decrease in current blood glucose levels pre-test and post-test in the diabetic foot exercise group, the kersen leaf infusion group, combination groups and control group.

The foot-exercise group experienced a mean reduction of 16.66 mg/dL. Repeated contraction of lower-extremity muscles increases energy demand, facilitates insulin-independent glucose transport during activity, and may improve insulin sensitivity after exercise. Foot exercise may also improve circulation and functional capacity, supporting its feasibility as a low-cost nursing intervention. The finding is consistent with previous reports of improved glucose levels and peripheral outcomes following diabetic foot exercise (Asniati & Hasanah, 2021; Dewi et al., 2024). The small standardized change

observed over two weeks may reflect the brief intervention period and high baseline variability. Based on these values, it can be concluded that diabetic foot exercises performed 3 times a week for 2 weeks have an effect. The results of this research are in line with research conducted by (Asniati & Hasanah, 2021); the results of the Paired T-test statistical test showed results with a p-value of 0.000 < 0.05, indicating that there is an influence of diabetic foot exercises on blood glucose levels in people with diabetes mellitus type 2 in the working area of the Payung Sekaki Pekanbaru Community Health Center.

Recent studies support this result. A 12-week foot exercise study in patients with diabetes found a significant decrease in random blood glucose from baseline to post-intervention and improvement in protective sensation (Dewi et al., 2024). Broader exercise evidence also shows that structured physical activity improves fasting blood glucose, postprandial blood glucose, HbA1c, insulin resistance, and functional capacity in people with type 2 diabetes (Amaravadi et al., 2024; Gallardo-Gómez et al., 2024; Parada Flores et al., 2023). These findings strengthen the interpretation that diabetic foot exercises may reduce blood glucose by increasing muscle contraction, peripheral glucose uptake, circulation, and insulin sensitivity.

Analysis of blood glucose levels before kersen leaf infusion showed 248.20 mg/dl and after kersen leaf infusion 235.67 mg/dl, there was a decrease in blood glucose levels of 12.53 mg/dl. Based on these values, it can be concluded that there was an influence on the kersen leaf infusion group. The results of this study are in accordance with the research conducted by (Siringoringo et al., 2021) entitled The Effect of Boiled Kersen Leaf on Blood glucose Levels of Type 2 Diabetes Mellitus Sufferers in the Working Area of the Bontobahari Community Health Center, that there is a significant difference in mean blood glucose levels before and after administration. Intervention of kersen leaf decoction in patients with type 2 diabetes mellitus in the Bontobahari Community Health Center Working Area. The decrease in blood glucose levels was caused by the kersen leaf content. Its ingredients include flavonoids, chalcones, and tannins.

The decrease in blood glucose in the kersen leaf infusion group is consistent with recent evidence on Muntingia calabura. Melina and Wagustina (2022) reported that Muntingia calabura leaf decoction significantly reduced blood glucose levels in type 2 diabetes patients, while Gunny et al. (2024) found that Muntingia calabura leaf extract showed in vitro antidiabetic activity through amylase inhibition and strong interaction of quercetin with the target enzyme. In an animal study, Putra et al. (2024) also found that Muntingia calabura leaf extract reduced fasting blood glucose and showed potential as complementary therapy. These findings support the proposed role of flavonoids, saponins, and related phytochemicals in slowing carbohydrate digestion and supporting glycemic control (Gunny et al., 2024; Melina & Wagustina, 2022; Putra et all, 2024)

The average blood glucose level measured by the researchers before administering a combination of diabetic foot exercises and kersen leaf infusion was 260.53 mg/dL. After a combined intervention of 221.47 mg/dl, blood glucose levels decreased by 39.06 mg/dl. Based on these values, it can be concluded that there was an influence in the intervention group that performed diabetic foot exercises and kersen leaf injections. This was proven by the decrease in the mean value before and after surgery, and it can be concluded that diabetic foot exercises and kersen leaf infusion can reduce blood glucose levels in patients with type 2 diabetes. The results of this study are in line with research conducted by (Ruben, Rottie, & Karundeng, 2016) with the title The Effect of Diabetes Mellitus Foot Exercises on Blood glucose Levels of Type 2 DM Sufferers in the Ciemas Community Health Center Working Area with a p-value of 0.000 < 0.05, which means that H0 is rejected, so it can be stated that there is an effect of diabetic foot exercises on blood

glucose levels in patients with type 2 diabetes mellitus in the working area of the Ciemas Health Center.

The combination group showed the largest mean decrease compared with the single intervention groups. This result is biologically plausible because diabetic foot exercise and kersen leaf infusion may work through different but complementary pathways. Exercise improves glucose uptake and insulin sensitivity through muscle activity, whereas Muntingia calabura leaf may contribute through antioxidant activity and inhibition of carbohydrate-digesting enzymes (Amaravadi et al., 2024; Gallardo-Gómez et al., 2024; Gunny et al., 2024; Putra et all, 2024). Therefore, combining physical activity with herbal infusion may provide a stronger non-pharmacological effect than either intervention alone, although larger randomized studies are still needed to confirm this combined effect.

The results of the research were that the average blood glucose level before the examination was 294.13 mg/dl, after the examination it was 284.27 mg/dl, and there was a decrease in blood glucose levels of 9.86 mg/dl. In the control group using the Paired T-test, the p-value was 0.190 > 0.05, indicating that the control group had no effect on blood glucose levels in patients with T2DM. The result of this study are in line with research conducted by (Sanjaya et al., 2019). In the control group, there was an increase in average, but the difference was not significant with a p value = 0.564 > 0.05. This was because there was no leg movement in the control group, as in the intervention group.

The absence of a significant change in the control group is consistent with studies showing that meaningful glycemic improvement usually requires structured intervention, education, or sustained lifestyle change. In a randomized controlled trial, structured exercise produced significant improvements in glycemic variables compared with standard care (Amaravadi et al., 2024). A systematic review also reported that diabetes self-management education reduced HbA1c compared with standard care in adults with type 2 diabetes in low- and middle-income countries (Chowdhury et al., 2024). Similarly, (Melina & Wagustina, 2022) reported a smaller blood glucose decrease in the control group than in the Muntingia calabura intervention group. These findings support the interpretation that routine care without an active complementary intervention may be insufficient to produce clinically meaningful short-term blood glucose reduction.

Comparison of the average values of blood glucose levels during the pre-test and post-test in intervention group and control group.

The between-group analysis strengthens the within-group findings by demonstrating that the observed posttest differences were unlikely to be explained solely by temporal variation. The large eta-squared value suggests a substantial overall group effect. In particular, the combination group achieved significantly lower post-intervention glucose than foot exercise alone and routine care. This pattern is physiologically plausible because skeletal-muscle contraction increases glucose uptake through insulin-independent GLUT4 translocation and improves subsequent insulin action, whereas bioactive constituents of Muntingia calabura L., including flavonoids and quercetin, may inhibit carbohydrate-digesting enzymes and reduce oxidative stress (Colberg et al., 2016; Gunny et al., 2024; Widodo et al., 2024). These complementary pathways may produce an additive response: exercise increases peripheral glucose disposal, while the leaf infusion may reduce the rate of intestinal glucose appearance and support antioxidant defenses. Recent evidence also indicates that structured physical activity improves glycemic control in type 2 diabetes, although the magnitude depends on exercise dose, mode, and supervision (Gallardo-Gómez et al., 2024).

Nevertheless, the post hoc results do not establish that the combination was superior to kersen infusion alone, because that pairwise comparison was not significant.

In addition, the analysis used posttest ANOVA rather than ANCOVA adjusted for baseline glucose. Baseline means differed descriptively across groups, and the foot-exercise group began with the highest mean glucose. Consequently, the significant posttest differences should be interpreted as evidence of an association between intervention group and post-intervention glucose, not as definitive causal proof of synergism. A randomized trial with allocation concealment, a larger sample, standardized medication and dietary monitoring, and ANCOVA or a repeated-measures group-by-time model would provide a stronger estimate of comparative effectiveness.

This study had several limitations. The quasi-experimental allocation process may have introduced selection bias, and the small sample of 15 participants per group limited statistical power and precision. The intervention lasted only two weeks and used random blood glucose, which is sensitive to recent meals, medication timing, stress, and daily activity. Medication adherence, dietary intake, and additional physical activity were not fully controlled. Although one-way ANOVA and Bonferroni testing enabled direct between-group comparisons, the analysis did not adjust for baseline glucose or other prognostic characteristics. Therefore, residual confounding and regression to the mean cannot be excluded. Future studies should use concealed random allocation, larger samples, standardized co-interventions, fasting glucose and HbA1c outcomes, longer follow-up, and ANCOVA or mixed-effects models to evaluate group-by-time effects.

4. CONCLUSION

Over two weeks, diabetic foot exercise, kersen (Muntingia calabura L.) leaf infusion, and their combination were each associated with significant within-group reductions in random blood glucose, whereas the control group showed no significant change. The combination group had the largest mean reduction and significantly lower posttest glucose than the foot-exercise and control groups; however, it was not significantly different from kersen infusion alone. Thus, the findings support the combination as a potentially useful complementary nursing intervention but do not establish definitive superiority or synergism. Clinical application should complement, rather than replace, standard diabetes treatment and should include monitoring for individual responses. Larger randomized controlled trials using baseline-adjusted analyses and longer-term glycemic outcomes are required.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

HPW carried out the conception, design, statistical analysis of this article, EP and RF conducted the analysis and interpretation of the data. Data collection and assembly were completed by RF and IS. The article was drafted by HPW and EP. Final approval of the article was confirmed by HPW and RF.

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DECLARATION OF ARTIFICIAL INTELLIGENCE USE

This manuscript's inception, literature search, study selection, data extraction, data analysis, interpretation of findings, and scientific decision-making were all done without the assistance of artificial intelligence (AI)-assisted technology. AI was only employed to make the manuscript's language, grammar, readability, and general clarity better. The content of this manuscript is entirely the authors' responsibility.

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