Journal of Health and Nutrition Research
Vol. 5, No. 1, 2026, pg. 426-433, https://doi.org/10.56303/jhnresearch.v5i1.826
Journal homepage: https://journalmpci.com/index.php/jhnr/index

e-ISSN: **2829-9760**

Effect of Foot Exercise and Sago-Based Dietary Education on Fasting Blood Glucose Among Patients with Diabetes: A Quasi-Experimental Study in Ambon, Indonesia

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ORIGINAL ARTICLES

Submitted: 9 September 2025

Accepted: 28 October 2025

Keywords:
Blood Glucose Control; Diabetes Mellitus; Education; Foot Exercise; Sago

ABSTRACT

Diabetes Mellitus (DM) is a chronic metabolic disorder and a major global health challenge, with its prevalence continuing to rise in both developed and developing countries. This increase contributes to high morbidity and mortality rates, underscoring the importance of effective and sustainable management strategies. Conventional DM management typically includes health education, regular physical activity, dietary modification, pharmacological therapy, and routine blood glucose monitoring. In addition, non-pharmacological interventions that utilize local resources and cultural practices are gaining attention for their role in supporting glycemic control and improving patients' quality of life. This study aimed to analyze the effectiveness of foot exercise and sago-based dietary education on blood glucose levels among diabetic patients at Belakang Soya and Waai Health Centers, Ambon. A quasi-experimental design was employed involving 152 respondents (93 intervention, 59 control) selected through purposive sampling. The intervention was conducted over seven days, and blood glucose levels were measured using a GlucoDr glucometer. The Wilcoxon test showed a significant difference in fasting blood glucose levels ($p<0.001$) before and after the intervention, while the Mann-Whitney test indicated a significant difference in fasting blood glucose levels ($p<0.001$) between the intervention and control groups. These findings suggest that integrating foot exercise with sago-based dietary education may serve as an effective complementary strategy in DM management. By combining simple physical activity with culturally relevant dietary practices, this approach has the potential for broader application in community health programs. Further research is needed to assess its long-term effects, scalability, and cultural adaptability in community-based diabetes care.

Key Messages:

Diabetes Mellitus can lead to diabetic foot ulcer complications, which may ultimately result in amputation.

Glycemic control can be achieved through lifestyle modification. Education is a fundamental pillar in the management of diabetes mellitus. Foot exercise is a simple and effective physical activity to help regulate patients' blood glucose levels.

Sago, the staple food of the Maluku people, has a favorable glycemic index and is recommended for patients with diabetes mellitus..

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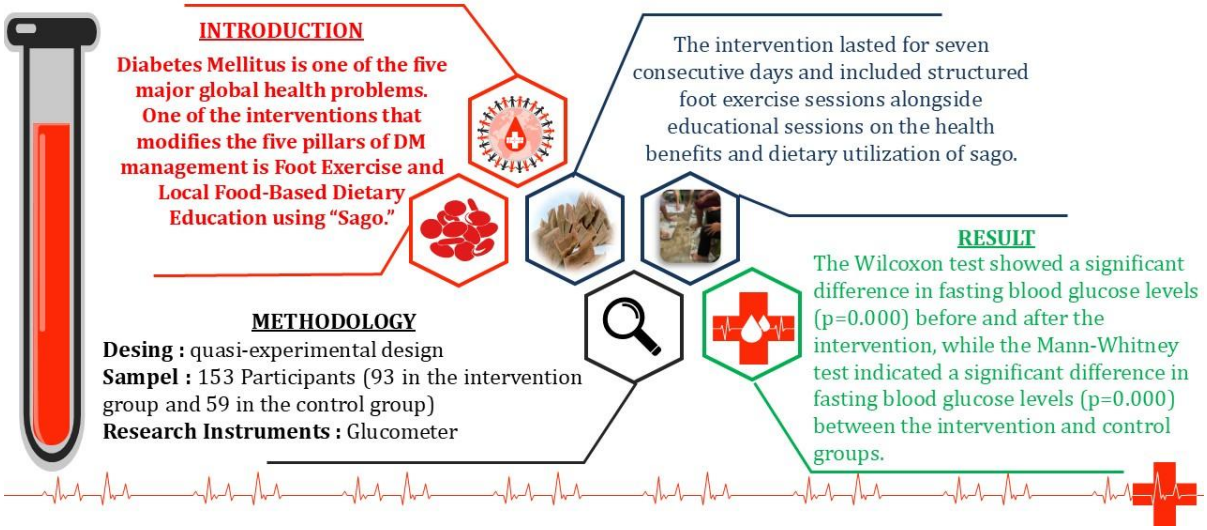
GRAPHICAL ABSTRACT

FOOT EXERCISE AND SAGO EDUCATION REDUCE BLOOD GLUCOSE LEVELS IN DIABETES MELLITUS PATIENTS



INTRODUCTION

The modern era has led to lifestyle changes, such as the high consumption of fast food and lack of physical activity, which contribute to the rise of chronic diseases, one of which is Diabetes Mellitus (DM) (1). DM is a condition characterized by elevated blood glucose levels caused by impaired insulin secretion, insulin resistance, or both (2). The latest report from the International Diabetes Federation (IDF) stated that 11.1% or 1 in 9 adults (aged 20–79 years) worldwide are living with diabetes, and more than 4 in 10 individuals are unaware that they have DM (3). Indonesia ranks seventh in the world for DM prevalence (4). The Basic Health Research (Riskesdas) in 2018 revealed an increase in DM prevalence from 6.9% in 2013 to 8.5% in 2018 (5). A preliminary study at Belakang Soya Health Center in 2023 recorded 89 DM patients, which increased to 93 in 2024 (6).

Non-pharmacological therapies are strongly recommended in the management of Diabetes Mellitus (DM), including education, physical activity, and dietary regulation (7). Physical activity plays an important role in lowering blood glucose levels and reducing cardiovascular risk. A therapeutic approach that combines the three management strategies recommended by Perkumpulan Endokrinologi Indonesia (PERKENI) is foot exercise and sago-based dietary education (8). Foot exercise is one form of physical training for DM patients that can lower blood pressure, thereby preventing complications such as diabetic foot ulcers that may ultimately lead to amputation. Moreover, foot exercise is simple to perform independently in a short period of time and is highly economical since it does not require additional costs (1). In addition, sago is a local food that can be utilized by the people of Maluku as a complementary therapy for DM, as it has a low glycemic index. However, interviews with DM patients at the Belakang Soya Community Health Center and Waai Primary Health Care revealed that they were not yet aware of or utilizing foot exercise and sago-based dietary education as strategies to reduce blood glucose levels. Foot exercise can improve blood circulation, stimulate nerves, promote relaxation through endorphin reduction, and enhance pancreatic hormone secretion, which functions as a natural stress reliever. Since stress can interfere with enzymatic processes and hinder glucose elimination, foot exercise is expected to contribute to lowering blood glucose levels (9).

Previous studies by Yulianti & Januari, 2021 and Nurlinawati *et al,* 2018 confirmed that foot exercise significantly lowers blood glucose levels in DM patients (9;10) . In addition, education is considered a key pillar in DM management, as it improves patients' knowledge, behavior, and motivation (11). Dietary education should be culturally relevant and utilize local food sources (12). In Maluku, sago is

https://doi.org/10.56303/jhnresearch.v5i1.826

a staple local food that offers nutritional advantages compared to rice due to its low glycemic index (GI). For example, sago noodles and macaroni have a GI of 28, sago lempeng 48, and sago porridge 53 (13; 14). Other studies reported sago rice with a GI of 50.9%, papeda 59.6%, and roasted sago (Sanoli) 64.2% (15). Combining foot exercise with sago-based dietary education offers a promising strategy for reducing blood glucose levels and lowering the risk of DM complications, which can ultimately prevent mortality. Based on this background, the present study aims to examine the effectiveness of foot exercise and sago-based dietary education in reducing blood glucose levels among DM patients at Belakang Soya Health Center, Ambon.

METHODS

The research design used in this study was quasi-experimental with two groups, consisting of an intervention group and a control group. Both groups were assessed at baseline (pretest) to evaluate initial equivalence, and again at the end of the study (posttest) after the intervention was administered to the intervention group. The intervention group received a combined program of foot exercise and sago-based dietary education, while the control group received standard care without additional intervention. This approach allows for comparison of the intervention's effects on blood glucose levels between the two groups, thereby enhancing the internal validity of the study findings. In this study, respondents were given an educational intervention on the utilization of Maluku's local food, sago, during the initial session, followed by foot exercise for seven consecutive days. The intervention was designed to evaluate changes in respondents' fasting blood glucose levels.

This study was conducted in the working area of Belakang Soya Health Center during the period of July–August 2025. The study population consisted of 245 patients with DM. After calculating the sample size using the Slovin formula with a margin of error of 0.05, a total of 152 patients with DM were included in this study, drawn from the working areas of Belakang Soya Community Health Center and Waai Primary Health Care. The samples were then divided into two groups: 93 patients in the intervention group and 59 patients in the control group. The sampling technique used was purposive sampling, and the samples were selected based on predetermined inclusion and exclusion criteria. Criteria included: patients willing to participate with documented informed consent, patients able to read, write, and communicate effectively, patients diagnosed with DM by a healthcare professional, patients aged 18–65 years, and patients capable of performing daily activities independently. Exclusion criteria included: patients with impaired vision or hearing, patients who did not complete all stages of the intervention for any reason, patients recently discharged from illness or hospitalization within one week prior to the study, and patients with non-severe DM complications such as diabetic ulcersor retinopathy.

Data collection was carried out in several stages: obtaining ethical clearance and research permission, screening respondents according to inclusion and exclusion criteria, obtaining respondents' consent as evidenced by signed informed consent, explaining the intervention procedures, providing sago dietary education along with a booklet on the first day, and administering foot exercise for seven consecutive days. The foot exercise, performed for 10–15 minutes, consisted of 10 movements, including ankle movements, toe movements, and heel movements as the main exercises, followed by cooling-down exercises such as calf muscle stretching. In this study, respondents were instructed to fast for 6–8 hours to allow measurement of fasting blood glucose levels using the GlucoDr AGM 2100 glucometer. Fasting blood glucose levels were measured on the first and last day of the intervention. After data collection was completed, statistical analysis was conducted using frequency tests for patients' demographic data, the Wilcoxon test to assess pre–post differences within the intervention group, and the Mann–Whitney test to compare differences between the intervention and control groups.

CODE OF HEALTH ETHICS

This study received ethical approval from the Health Research Ethics Committee, Faculty of Public Health, Universitas Airlangga, with ethical clearance number: 74/EA/KEPK/2025. Before the study began, the researcher obtained permission from the respondents as evidenced by their signed informed consent.

https://doi.org/10.56303/jhnresearch.v5i1.826

RESULTS

This study was conducted in the working area of the Belakang Soya Community Health Center, Ambon, and involved an intervention administered to 93 respondents. The intervention and data collection were conducted over 7 days. The frequency distribution of the respondents' characteristics is presented in Table 1.

Table 1. Frequency Distribution of Respondents by Age, Sex, Duration of Illness, and Fasting Blood Sugar

Respondent Characteristics	n	%
Age		
Young Adult: 20–34 Years	23	15.1
Middle Adult: 35–44 Years	35	23
Late Adult: 45–54 Years	66	43.4
Early Elderly: 55–64 Years	28	18.4
Sex		
Male	53	34.9
Female	99	65.1
Duration of Illness		
>5 Years	49	32.2
≤ 5 Years	103	67.8
Fasting Blood Sugar		
Normal	4	2.6
Prediabetes	19	12.5
Diabetes Melitus	129	84.9

The age characteristics of the respondents presented in Table 1 indicate that the majority were in the late adulthood category, totaling 66 respondents (43.4%). This finding is consistent with the theory stating that individuals over 45 years of age have a higher risk of developing DM compared to other age groups.

According to data from the National Health and Nutrition Examination Surveys, the prevalence of DM increases with age. Most cases of DM begin to appear from the age of 30 years and rise sharply as age advances (16). At the age of 40 years and above, the human body often begins to experience a rapid decline in function. Human physiology and metabolism, particularly pancreatic metabolic function, gradually slow down with age. The pancreas is responsible for regulating blood glucose levels. Thus, the risk of insulin resistance and type 2 diabetes mellitus increases as pancreatic metabolism decreases, which consequently affects blood glucose regulation (17).

This is also in line with the study conducted by Rahayu *et al*, 2022, which showed that the risk of developing DM increases with age, as there is a positive correlation between age and the incidence of diabetes mellitus. Individuals who adopt unhealthy lifestyles at a young age may experience accelerated aging, which in turn elevates the risk of developing type 2 diabetes mellitus later in life (18).

The gender characteristics of respondents presented in Table 1 indicate that the majority were female, with a total of 99 respondents (65.1%). The higher prevalence of diabetes mellitus among women may be attributed to differences in body composition and sex hormone levels between adult men and women. Women generally have a higher proportion of body fat compared to men. This is reflected in the differences in normal body fat percentages, which range from 15–20% in men and 20–25% in women. Furthermore, the decline in estrogen levels among postmenopausal women leads to increased body fat storage, particularly in the abdominal region, which results in elevated free fatty acid release. Both of these conditions contribute to insulin resistance (19). A study conducted by Arania, 2021 also reported that the majority of respondents diagnosed with DM were women, with a weak but positive correlation (r = 0.195) between gender and the incidence of diabetes mellitus. This suggests that gender may play a role in increasing the likelihood of developing diabetes (20).

The duration of illness characteristics in Table 1 show that most respondents had been living with DM for ≤5 years, totaling 103 respondents (67.8 %). The duration of type 2 DM is considered a risk factor for the development of sensory neuropathy, a chronic complication in which nerve damage results in

https://doi.org/10.56303/jhnresearch.v5i1.826

numbness of the feet, reducing sensitivity to pressure, injury, trauma, or infection. Prolonged type 2 DM leading to diabetic sensory neuropathy involves activation of the polyol pathway, oxidative stress, vascular abnormalities, and the synthesis of advanced glycosylation end products (AGEs). These mechanisms result in reduced vasodilation, decreased blood flow to nerves, and diminished intracellular myo-inositol levels, ultimately causing diabetic sensory neuropathy (21). Mutmainah, 2013 found that the highest proportion of DM duration was in the 1–5 year group (60.7%). The longer the duration of DM, the greater the risk of persistent hyperglycemia and the accumulation of AGEs, which ultimately contribute to the development of complications (22). Table 1 shows that the majority of respondents had high blood glucose levels or fell into the DM category, totaling 129 respondents (84.9%).

Table 2. Differences in Fasting Blood Glucose Pre-Test and Post-Test Foot Exercise and Sago Diet Education Intervention

Fasting Blood Glucose	Pre-Test		Post-Test		p - value
	n	Precentage (%)	n	Precentage (%)	
Normal	3	3.2	11	11.8	
Prediabetes	12	12.9	76	81.7	0.000
Diabetes Mellitus	78	83.9	6	6.5	

Table 3 shows the results of the fasting blood glucose (FBG) difference test in DM patients before and after the foot exercise intervention and sago-based dietary education, yielding a p-value = 0.000 (p<0.001). This indicates a statistically significant reduction in fasting blood glucose levels among DM patients after 7 days of performing foot exercises and learning to use sago as a local food source in diabetes diet management.

Table 4. Differences in Fasting Blood Glucose Between the Intervention Group and the Control Group

Fasting Blood Glucose	Intervention group		Control group		p - value
	n	%	n	%	
Normal	11	11.8	0	0	
Prediabetes	76	81.7	5	8.5	0.000
Diabetes Mellitus	6	6.5	54	91.5	

Table 4 shows the differences in fasting blood glucose between the intervention and control groups, with p-values of 0.000 or <0.001. Statistically, there is a significant difference in fasting blood glucose between the intervention and control groups.

DISCUSSION

Foot exercise is a physical activity routinely performed by individuals with diabetes mellitus to prevent foot ulcers and improve lower-extremity blood circulation. Its primary purpose is to enhance blood flow, ensure better nutrient delivery to tissues, strengthen intrinsic foot muscles, calf, and thigh muscles, and address joint mobility limitations frequently experienced by DM patients (23).

The present study demonstrated that foot exercise significantly reduced FBG levels among respondents with type 2 DM. This aligns with prior studies showing that light physical activities, such as foot exercise, can improve insulin sensitivity, facilitate peripheral glucose uptake, and enhance blood circulation. Ritonga *et al*, 2023 reported a mean reduction in FBG from 182.80 mg/dl to 143.13 mg/dl (a decrease of 39.67 mg/dl) after a foot exercise intervention (24), while Nalurita & Resiani, 2023 observed a decrease from 124.3 mg/dl to 98.1 mg/dl among DM patients in West Bandung. Physiologically, repetitive contractions of the lower limb muscles increase energy demand, thereby promoting glucose utilization as the primary energy source. Signals from insulin or muscle contractions trigger GLUT4 (glucose transporter type 4) vesicles, which are initially located in the cytoplasm, to translocate to the cell membrane. Once embedded in the membrane, GLUT4 forms a “gateway” for glucose entry. This mechanism enhances glucose transport into muscle cells through GLUT-4 translocation, thus reducing blood glucose levels without excessive insulin secretion (25).

https://doi.org/10.56303/jhnresearch.v5i1.826

Regular low-intensity exercise has been shown to improve glycemic control by increasing glucose uptake and optimizing insulin receptor activity through improved blood flow and capillary recruitment (26). Thus, foot exercise is a simple, cost-effective, and non-pharmacological intervention to support glycemic management in DM patients. In addition to foot exercise, participants also received structured education through lectures and booklets on sago-based dietary management. The findings revealed that sago dietary education contributed positively to FBG reduction. This is consistent with the principle that health education aims to improve knowledge and foster behavioral changes (27). Sago contains polysaccharides, complex carbohydrates, resistant starch, and soluble fiber that slow digestion and glucose absorption in the intestine, contributing to better glycemic stability (28). Consequently, sago is recommended as a local staple food for individuals following a low-glycemic diet or those with DM (29).

Preclinical studies also support these findings; administration of sago flour to diabetic mice for 30 days significantly lowered blood glucose levels compared to rice flour controls (30). Nutritional education on local food sources such as sago not only increases patient compliance but also ensures sustainable, culturally appropriate dietary practices. Prior studies confirm that consumption of low-glycemic local foods, including sago, is effective in lowering FBG. Therefore, integrating sago dietary education with diabetes management programs offers a sustainable and culturally relevant strategy, particularly in sago-rich regions such as Maluku.

The management of Diabetes Mellitus (DM) begins with the implementation of a healthy lifestyle (including nutritional therapy and physical activity) in conjunction with pharmacological interventions using oral and/or injectable antihyperglycemic agents. This management can be initiated with education to build a basic understanding that facilitates behavioral change in patients. Education aimed at promoting a healthy lifestyle should always be carried out as part of preventive efforts and is an essential component of holistic DM management (31).

One of the non-pharmacological therapies is education. Considering the chronic nature of DM, it is undeniable that continuous education becomes crucial (32). According to Orem's Supportive Education System concept, the education and explanations provided to patients will motivate them to perform self-care independently (33). This study demonstrates that routine education increases respondents' knowledge and leads to positive behavioral changes, such as improved dietary patterns, higher levels of physical activity, and stronger family support. As a result, fasting blood glucose levels were better controlled in the intervention group compared to the control group, which only received pharmacological therapy without education. Accurate education and information can improve treatment adherence among DM patients in undergoing comprehensive therapy programs, thereby achieving optimal blood glucose control. Greater adherence also facilitates better absorption of disease-related information, allowing DM patients to live relatively normal lives when they understand their condition and the management strategies required (34).

The findings of Nuradhayani, 2017 showed a reduction in respondents' blood glucose levels in the intervention group that received Diabetes Self-Management Education (DSME) and DM leaflets once a week for approximately seven weeks. The results indicated an average difference in blood glucose levels before and after the intervention of 27.30 mg/dl, with $p=0.013$ ($p<0.05$), suggesting a statistically significant difference. In contrast, in the control group, the mean difference between pre- and post-intervention blood glucose levels was only 4.150 mg/dl, with $p=0.601$ ($p>0.05$), indicating no significant difference (35). Furthermore, Putri & Isfandiari, 2013 explained in their study that there is an association between the absorption of educational interventions and blood glucose levels in DM patients. Their findings revealed that the majority of DM patients with good knowledge had normal blood glucose levels. This indicates that adequate knowledge can positively influence DM self-management skills (34).

This study has several limitations that should be considered when interpreting the results. First, the follow-up period was limited to seven days, which does not allow the assessment of the long-term effects of the intervention. Second, respondents were not randomly allocated, leaving the possibility of selection bias. Third, there was a potential for contamination among respondents, particularly because most participants came from the same community and may have shared information related to the intervention. Fourth, limitations of the measuring devices and the accuracy of blood glucose assessments

https://doi.org/10.56303/jhnresearch.v5i1.826

may have influenced data precision. Nevertheless, the researchers made every effort to minimize bias in order to ensure the validity of the findings.

CONCLUSION

Foot exercises and local sago-based dietary education have been proven effective in reducing fasting blood glucose levels in patients with diabetes mellitus by increasing insulin sensitivity, improving blood circulation, and enhancing glucose utilization by muscles. Therefore, foot exercises and sago diet education can serve as inexpensive, simple, and culturally based non-pharmacological interventions in the management of diabetes mellitus. Future studies should examine the long-term sustainability of these effects and integrate the five components of DM management into a single program for DM patients to help reduce their blood glucose levels.

FUNDING

This research is a 2025 the Ministry of Education, Culture, Research, and Technology (KEMEDIKTISAINTEK)

ACKNOWLEDGMENTS

The authors would like to express their gratitude to the Ministry of Education, Culture, Research, and Technology (KEMEDIKTISAINTEK) for funding this study, as well as to the Moluccas Christian University of Indonesiaand the Belakang Soya Community Health Center, Ambon, for their invaluable support in facilitating the implementation of this research from its initial stages through to the preparation of this article for publication.

CONFLICTS OF INTEREST

All authors declare that there is no potential conflict of interest in the implementation or preparation of this research article.

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