



Effects of 60-minute brisk walking on metabolic and psychosocial health in patients with type 2 diabetes

Efectos del caminar enérgico de 60 minutos sobre salud metabólica y mental en diabetes tipo 2

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Abstract

Introduction and Objective: type 2 diabetes mellitus is a major global public health issue, particularly in low- and middle-income countries such as Indonesia. Although physical activity is widely promoted, there is limited evidence on the immediate effects of a single session of brisk walking. The objective of this study was to evaluate the effectiveness of a 60-minute brisk walking intervention on nitric oxide levels, blood glucose, body mass index, quality of life, and mental health in individuals with type 2 diabetes.

Methodology: a randomized controlled trial with a parallel-group design was conducted involving seventy-two participants with type 2 diabetes, divided into brisk walking and regular walking groups. The intervention lasted twelve weeks, with participants walking five days per week. Standardized biochemical, anthropometric, and psychometric tools were used to assess outcomes before and after the intervention.

Results: the results revealed significant increases in nitric oxide levels and reductions in blood glucose, body mass index, quality of life scores, and diabetes-related emotional distress in the brisk walking group. The most notable improvements were observed in obese participants. These findings align with previous studies showing that moderate-intensity exercise improves endothelial function and glycemic control. They also offer new insights into the role of nitric oxide as a physiological mediator in physical activity interventions.

Conclusions: it is concluded that brisk walking is an effective, accessible, and low-risk strategy to enhance metabolic and psychosocial health in individuals with type 2 diabetes.

Keywords

Body mass index; brisk walking; mental health; nitric oxide; type 2 diabetes mellitus

Resumen

Introducción y Objetivo: la diabetes mellitus tipo 2 representa un desafío de salud pública global, especialmente en países de ingresos bajos y medios como Indonesia. Las intervenciones no farmacológicas, como el ejercicio físico, han sido ampliamente promovidas, aunque existe escasa evidencia sobre los efectos agudos de una sola sesión de caminata vigorosa. El objetivo de este estudio fue evaluar la eficacia de una caminata enérgica de 60 minutos sobre los niveles de óxido nítrico, glucosa en sangre, índice de masa corporal, calidad de vida y salud mental en personas con diabetes tipo 2.

Metodología: se utilizó un diseño experimental de grupos paralelos con asignación aleatoria. Participaron setenta y dos personas con diabetes tipo 2, distribuidas en dos grupos: caminata enérgica y caminata regular. La intervención duró doce semanas, con cinco sesiones semanales. Se emplearon herramientas validadas para medir los parámetros bioquímicos, antropométricos y psicológicos antes y después del protocolo.

Resultados: los resultados mostraron incrementos significativos en los niveles de óxido nítrico, así como disminuciones en glucosa en sangre, índice de masa corporal, puntajes de calidad de vida y síntomas emocionales relacionados con la diabetes en el grupo de caminata enérgica. Los cambios fueron más notorios en personas con obesidad. Los hallazgos concuerdan con estudios previos sobre el efecto del ejercicio moderado en la función endotelial y el control glucémico, y aportan evidencia nueva sobre el papel del óxido nítrico como mediador fisiológico clave.

Conclusiones: se concluye que la caminata enérgica es una intervención accesible, eficaz y segura para mejorar múltiples dimensiones de la salud en personas con diabetes tipo 2.

Palabras clave

Caminar enérgico; diabetes mellitus tipo 2; índice de masa corporal; salud mental; óxido nítrico.

Introduction

Type 2 Diabetes Mellitus (T2DM) continues to represent one of the most significant global health challenges of the 21st century. As of 2021, approximately 537 million adults worldwide are affected by diabetes, with projections indicating an increase to 783 million by 2045 (International Diabetes Federation (Alshowair et al., 2024; H et al., 2022; Shokr et al., 2025)). The current global prevalence stands at 6.1% and is anticipated to more than double by 2050, potentially affecting an estimated 1.3 billion individuals (World Health Organization, 2024). This alarming rise in diabetes cases imposes a substantial burden on healthcare systems and significantly impairs patients' quality of life and mental well-being. In Indonesia, this global trend is reflected, with over 19.47 million cases reported in 2021, positioning it as the country with the fifth-highest diabetes burden globally. Without significant intervention, the prevalence in Indonesia is projected to reach 16.09% by 2045, impacting over 40.7 million individuals (Kementerian Kesehatan Indonesia, 2024). Physical inactivity is a major modifiable risk factor contributing to the incidence and poor management of T2DM. Despite well-established guidelines from the American Diabetes Association (ADA) recommending at least 150 min of moderate-to-vigorous aerobic exercise per week, less than half of individuals with diabetes meet this target (American Diabetes Association, 2022; Kanaley et al., 2022; Syeda et al., 2023a). Walking, as the most accessible and low-impact form of aerobic activity, is increasingly recommended to support glucose regulation, cardiovascular health, and psychological outcomes. However, key questions remain regarding the optimal intensity and duration of walking required to produce significant metabolic and psychosocial benefits in patients with T2DM.

Brisk walking, defined as a moderate-to-vigorous pace ranging from approximately 4.8 to 6.4 km/h, has been identified as a potentially more efficacious modality than casual walking in influencing physiological and psychological outcomes. Recent research has indicated that moderate-intensity brisk walking can significantly reduce blood glucose levels, body mass index (BMI), and glycated haemoglobin (HbA1c), while also enhancing endothelial function through increased nitric oxide (NO) bioavailability (K B et al., 2024; Shannon et al., 2022; Son et al., 2023). Additionally, structured walking interventions have been linked to improved mental health and enhanced quality of life related to diabetes (Kanaley et al., 2022). Nevertheless, there remains a lack of clarity regarding the isolated effect of a single-session brisk walking protocol on multiple integrated outcomes, such as NO levels, glucose concentration, BMI, quality of life, and mental health among individuals with type 2 diabetes mellitus (T2DM). The existing literature has predominantly concentrated on long-term exercise interventions, with relatively few studies examining acute or short-term physiological and psychological responses to a standardised, one-time brisk walking session. Furthermore, many previous studies have either excluded NO biomarkers or inadequately connected physical activity with validated psychosocial outcomes. This highlights a significant gap in understanding the multidimensional effects of brisk walking, particularly in populations with low diabetes awareness and adherence to behavioural changes, such as in Indonesia.

The present study sought to assess the efficacy of a 60-minute brisk walking intervention on serum nitric oxide levels, blood glucose levels, body mass index, quality of life, and mental health in patients with type 2 Diabetes Mellitus (T2DM). Utilising a multidimensional framework that integrates metabolic, anthropometric, and psychosocial outcomes, this study provides a comprehensive understanding of the acute benefits of brisk walking. It also addresses significant gaps in the literature regarding the immediate effectiveness of structured physical activity. Theoretically, this study contributes by elucidating the physiological pathways, particularly the role of nitric oxide modulation, that underlie the benefits of moderate-intensity aerobic exercise in diabetic populations. Practically, the findings may inform more nuanced and culturally appropriate physical activity recommendations in primary healthcare, especially in resource-limited settings. The study employed a quasi-experimental design with a pretest-posttest control group structure. Key variables included serum nitric oxide (measured via the Griess method using the QuantiChrom Nitric Oxide Assay Kit), blood glucose (via Accu-Chek glucometer), BMI (measured using ultrasonic sensor-based devices), and validated psychometric tools, including the Indonesian version of the Diabetes Quality of Life (DQOL) questionnaire and the Problem Areas in Diabetes (PAID) scale. By synthesising current evidence and incorporating biomarkers along with psychosocial indicators, this study addresses an important empirical gap. These findings have the potential to influence diabetes management strategies at both the clinical and community levels. The structure of this paper includes a literature review, a methods section detailing participant selection and measurement tools,



results highlighting pre-post intervention differences, and a discussion of the implications and limitations of the findings.

Method

Study Design

This study utilised a two-arm parallel-group randomised controlled trial (RCT) design to assess the efficacy of brisk walking in comparison with regular walking on serum nitric oxide (NO) levels, blood glucose levels, body mass index (BMI), quality of life, and mental health among individuals with type 2 diabetes mellitus (T2DM). The intervention spanned a 12-week period.

Participants and Setting

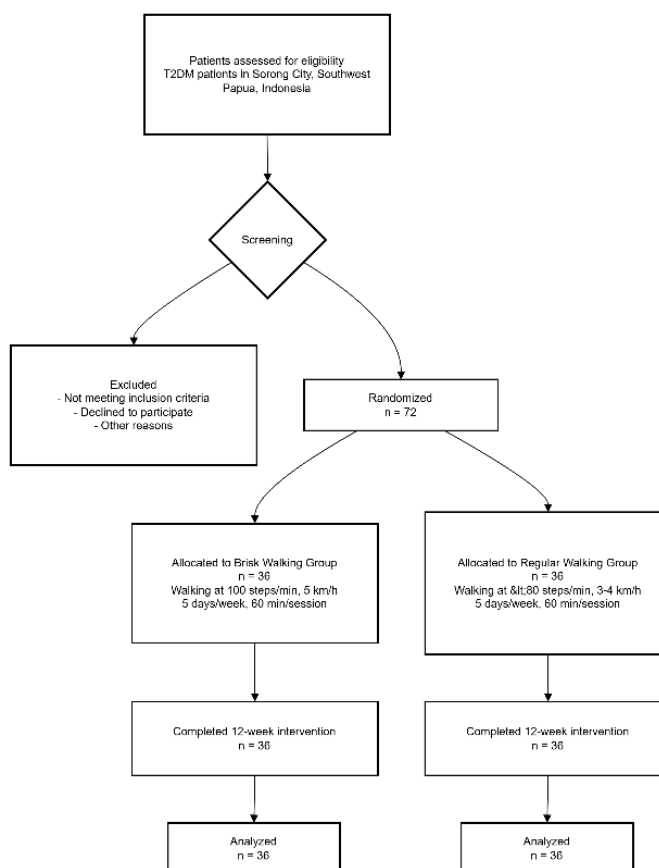
The study population consisted of patients diagnosed with type 2 Diabetes Mellitus (T2DM) who were receiving care at primary health centres and internal medicine outpatient clinics in Sorong City, Southwest Papua, Indonesia. The inclusion criteria were as follows: (1) age range of 35 to 65 years, (2) a confirmed diagnosis of T2DM for a minimum duration of one year, (3) the ability to ambulate independently without the use of assistive devices, and (4) a willingness to fully participate in the study. The exclusion criteria were (1) severe cardiovascular complications, (2) musculoskeletal disorders that limit mobility, (3) current use of corticosteroids, and (4) participation in other structured physical activity programs during the study period. To minimise selection bias, participants were randomly assigned using computer-generated block randomisation (block size = 4) with stratification by sex and age. To reduce information bias, outcome assessors were blinded to the group allocation (single-blind design), and all outcome measurements were conducted using standardised and validated instruments. Potential confounding variables were controlled through multivariate analysis and covariate adjustment for factors such as diabetes duration, baseline BMI, and habitual physical activity. Sample size estimation was based on power analysis for the comparison of two means (paired t-test), assuming an alpha level of 0.05, a statistical power of 80%, and a minimum effect size of 0.5. The minimum required sample size was 64 (32 per group). Allowing for a 10% attrition rate, 72 participants were recruited. A consecutive sampling technique was employed, and recruitment was conducted through community education sessions at local health facilities. Initial screening involved inclusion/exclusion checklists and basic health examinations by medical professionals. The study was conducted at a single centre: the University of Muhammadiyah Sorong and the Malawili Community Health Centre, Sorong Regency, between January and March 2025. The site was selected based on access to the target population, availability of standardised laboratory facilities, and adequate infrastructure and personnel.

Intervention

The intervention spanned 12 weeks, during which each group participated in walking activities five days per week, with each session lasting 60 minutes. The Brisk Walking Group maintained a pace of 100 steps per minute (approximately 5 km/h), while the Regular Walking Group walked at a leisure pace of fewer than 80 steps per minute (approximately 3–4 km/h). Sessions were conducted in designated urban parks and stadium areas prepared by the research team, and all sessions were supervised by trained fitness instructors. The participants received initial training on the intervention protocol and use of pedometers. Adherence was monitored through daily logbooks and in-person supervision three times per week. Intervention fidelity was ensured through structured instructor training and field supervision. In accordance with the TIDieR checklist, each walking session comprised (1) a 10-minute warm-up, (2) 40 min of brisk walking, and (3) a 10-minute cool-down phase. The protocol was registered and validated by a certified physiotherapist. All sessions were overseen by trained instructors and healthcare professionals who had completed a two-day standardisation training program. Participant compliance was monitored using attendance records and daily activity logs. Fidelity monitoring was conducted through weekly field supervision and progress reporting. No protocol modifications were planned, and no washout period was required owing to the parallel design. The control group received standard health education and was instructed to maintain their usual daily activities without any additional intervention. A flowchart and intervention timeline are presented in Figure 1.



Figure 1. Flowchart and intervention timeline



Data Collection

Serum nitric oxide (NO) levels were quantified using the Griess reaction with the QuantiChrom Nitric Oxide Assay Kit (BioAssay Systems, California, USA) at the University of Muhammadiyah Sorong Laboratory. Optical density measurements were performed using an ELISA reader (ELx800; BioTek Instruments, USA) (MARshal Scientific, 2024). Blood glucose levels were determined via the Accu-Chek glucometer using a glucose oxidase enzymatic reaction. Body mass index (BMI) was assessed using an automated device equipped with an ultrasonic sensor and a microcontroller system. Quality of life was evaluated using the Bahasa Indonesia version of the Diabetes Quality of Life (DQOL) questionnaire, which has a validated Cronbach's alpha of 0.735. This 46-item instrument addresses dimensions such as treatment satisfaction, the impact of therapy, future concerns, and social issues (Irianti et al., 2021). Mental health was assessed using the Problem Areas in Diabetes (PAID) scale, comprising 20 items with internal consistency ranging from $\alpha = 0.90$ -0.95 (Gw et al., 1997). Data collection was executed by enumerators who underwent a two-day training on standardised procedures. Quality control measures included double data entry, cross-validation, and field supervision. All data were securely stored on a cloud-based encrypted platform with dual-layer security and weekly backup. Missing data were addressed using multiple imputation techniques. Data collection was conducted in two phases: pre- and post-intervention (12 weeks).

Data Analysis

Data were analysed using the most recent version of the Jamovi statistical software. The primary analysis involved assessing within-group differences using paired t-tests and conducting between-group comparisons using independent t-tests or ANCOVA, incorporating relevant covariates. Secondary analyses included subgroup evaluations based on sex and duration of diabetes. Missing data were addressed through multiple imputations. The effect sizes for each variable were calculated using Cohen's d. All analyses are reported as 95% confidence intervals (CIs). Adjustments for multiple comparisons

were made using Bonferroni correction. Analyses adhered to an intention-to-treat (ITT) approach, with a per-protocol analysis conducted for comparison.

Ethical Considerations

Ethical approval for this study was granted by the Health Research Ethics Committee of the Health Polytechnic of the Ministry of Health in Sorong (Approval No 003/KEPK-Polkesor/II/2025). The study was registered with ClinicalTrials.gov (ID: NCT05888977). Prior to enrolment, written informed consent was obtained from all participants. Data were handled with strict confidentiality and were accessible solely to the principal investigator. While no financial compensation was provided, the participants received complimentary health consultations and diabetes education.

Results

Demographic and Clinical Characteristics of Respondents

A total of 72 respondents were successfully recruited and completed the entire 12-week intervention program. The participants were evenly distributed between two groups: brisk walking ($n = 36$) and regular walking ($n = 36$). Table 1 presents the baseline demographic, clinical, and lifestyle characteristics of the participants before the intervention.

Table 1. Baseline Demographic, Clinical, and Lifestyle Characteristics of Respondents ($n = 72$)

Characteristic	Brisk Walking ($n = 36$)	Regular Walking ($n = 36$)
Age (years, mean $\pm$ SD)	54.6 $\pm$ 6.3	55.1 $\pm$ 6.7
Sex		
- Male	18 (50.0%)	17 (47.2%)
- Female	18 (50.0%)	19 (52.8%)
Marital Status		
- Married	30 (83.3%)	29 (80.6%)
- Unmarried	2 (5.6%)	3 (8.3%)
- Widowed/Divorced	4 (11.1%)	4 (11.1%)
Highest Educational Attainment		
- Primary School	6 (16.7%)	7 (19.4%)
- Junior Secondary	8 (22.2%)	9 (25.0%)
- Senior Secondary	15 (41.7%)	14 (38.9%)
- Tertiary Education	7 (19.4%)	6 (16.7%)
Occupation		
- Permanent Employee	10 (27.8%)	9 (25.0%)
- Self-employed	9 (25.0%)	8 (22.2%)
- Unemployed	14 (38.9%)	15 (41.7%)
- Retired	3 (8.3%)	4 (11.1%)
Monthly Income		
- Below Minimum Wage	22 (61.1%)	23 (63.9%)
- Equal to or Above Minimum Wage	14 (38.9%)	13 (36.1%)
Duration of Diabetes (years)	6.4 $\pm$ 2.8	6.2 $\pm$ 3.1
Family History of Diabetes		
- Yes	25 (69.4%)	26 (72.2%)
- No	11 (30.6%)	10 (27.8%)
History of Diabetes Complications		
- Hypertension	21 (58.3%)	20 (55.6%)
- Nephropathy	5 (13.9%)	6 (16.7%)
- Retinopathy	3 (8.3%)	2 (5.6%)
Current Diabetes Therapy		
- Oral Hypoglycaemic Agents (OHA)	20 (55.6%)	22 (61.1%)
- Insulin	7 (19.4%)	6 (16.7%)
- Combination Therapy	9 (25.0%)	8 (22.2%)
BMI Category (WHO Asia Criteria)		
- Normal	7 (19.4%)	8 (22.2%)
- Overweight	13 (36.1%)	14 (38.9%)
- Obese	16 (44.4%)	14 (38.9%)
Blood Pressure (mmHg)		
- Systolic (mean $\pm$ SD)	138.6 $\pm$ 14.2	137.2 $\pm$ 13.9
- Diastolic (mean $\pm$ SD)	84.1 $\pm$ 9.5	83.4 $\pm$ 9.2
HbA1c (%) ($n = 45$)	8.1 $\pm$ 1.3	8.0 $\pm$ 1.4
Previous Physical Activity		
- Physically active	10 (27.8%)	9 (25.0%)
- Physically inactive	26 (72.2%)	27 (75.0%)



Smoking Status		
- Non-smoker	20 (55.6%)	21 (58.3%)
- Active smoker	8 (22.2%)	7 (19.4%)
- Passive smoker	8 (22.2%)	8 (22.2%)

The demographic and clinical characteristics of the two cohorts were largely comparable. The mean age of participants was approximately 55 years, with a nearly equal distribution of male and female individuals. The majority were married, had completed secondary education, and were either unemployed or retired. Both groups exhibited a high prevalence of obesity, approximately 40%, and most participants had a family history of diabetes as well as elevated blood pressure. Baseline levels of physical activity were generally low, and over half of the participants were non-smokers.

Effect of Brisk Walking on Nitric Oxide Levels, Blood Glucose, BMI, Quality of Life, and Mental Health
This study sought to assess the efficacy of brisk walking, defined as 60 minutes per day, five days per week over a 12-week period, on both clinical and psychosocial parameters in individuals with type 2 diabetes mellitus. The analysis involved a comparative evaluation of two groups—those engaging in brisk walking and those participating in regular walking—to determine changes in nitric oxide (NO) levels, blood glucose, body mass index (BMI), quality of life (DQOL), and mental health, as measured by the PAID score.

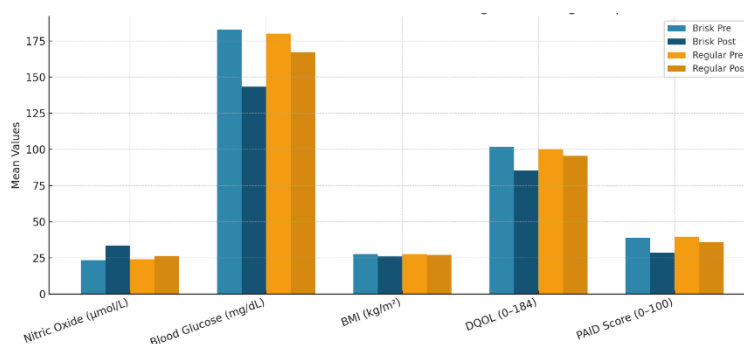
Table 2. Comparison of Mean Values Pre- and Post-Intervention in Brisk Walking and Regular Walking Groups

Variable	Brisk Walking (n = 36)	Regular Walking (n = 36)	p-value (interaction)
Nitric Oxide ($\mu\text{mol/L}$)	Pre: 23.5 ± 5.4 Post: 33.7 ± 6.2	Pre: 24.1 ± 6.0 Post: 26.3 ± 5.8	<0.001
Blood Glucose (mg/dL)	Pre: 182.7 ± 28.1 Post: 143.4 ± 24.6	Pre: 180.1 ± 26.7 Post: 167.2 ± 25.3	<0.001
BMI (kg/m^2)	Pre: 27.8 ± 3.5 Post: 26.1 ± 3.2	Pre: 27.6 ± 3.6 Post: 27.0 ± 3.3	0.002
DQOL (0–184)	Pre: 101.6 ± 17.4 Post: 85.3 ± 15.2	Pre: 100.2 ± 16.7 Post: 95.5 ± 16.1	<0.001
PAID Score (0–100)	Pre: 38.9 ± 10.2 Post: 28.5 ± 9.3	Pre: 39.7 ± 11.4 Post: 35.8 ± 10.1	0.004

Note: This table presents the mean values before and after the intervention in both groups for each parameter: nitric oxide, blood glucose, BMI, diabetes-related quality of life (DQOL), and psychological distress (PAID score).

A significant elevation in nitric oxide levels was observed in the brisk walking group compared to that in the regular walking group ($p < 0.001$). Blood glucose levels exhibited a more pronounced decrease in the brisk walking group (Δ : -39.3 mg/dL) than in the regular walking group (Δ : -12.9 mg/dL). Body Mass Index (BMI) also demonstrated a statistically significant reduction in the brisk walking group ($p = 0.002$). Quality of life markedly improved in the brisk walking group, as indicated by a reduction in Diabetes Quality of Life (DQOL) scores (lower scores denote an enhanced quality of life), whereas the regular walking group exhibited minimal improvement. Additionally, Problem Areas in Diabetes (PAID) scores significantly decreased in the brisk walking group, reflecting reduced diabetes-related emotional distress ($p = 0.004$).

Figure 2 Changes in nitric oxide, blood glucose, BMI, diabetes-related quality of life (DQOL), and psychological distress (PAID score) Levels Before and After Intervention



The graph illustrates a more pronounced increase in nitric oxide, blood glucose, BMI, diabetes-related quality of life (DQOL), and psychological distress (PAID score) levels in the brisk walking group following the 12-week intervention compared to the regular walking group.

Subsections of the General Research Objective

Subgroup Analysis Based on Body Mass Index (BMI)

To explore the differential effects of the intervention across various nutritional statuses, a subgroup analysis was performed based on BMI categories according to the WHO Asia classification: normal ($<23 \text{ kg/m}^2$), overweight ($23\text{--}24.9 \text{ kg/m}^2$), and obese ($\geq 25 \text{ kg/m}^2$).

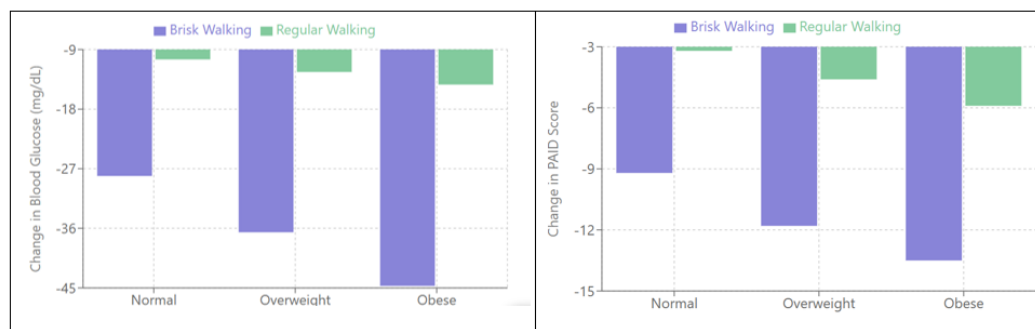
Table 3. Changes in Blood Glucose and PAID Scores According to BMI Category

BMI Category	Δ Blood Glucose Brisk Walking (mg/dL)	Δ PAID Score Brisk Walking	Δ Blood Glucose Regular Walking (mg/dL)	Δ PAID Score Regular Walking
Normal (n = 15)	-28.1 ± 10.3	-9.2 ± 5.6	-10.5 ± 8.7	-3.2 ± 4.1
Overweight (n = 27)	-36.6 ± 12.1	-11.8 ± 6.1	-12.4 ± 9.3	-4.6 ± 4.8
Obese (n = 30)	-44.7 ± 14.5	-13.5 ± 7.2	-14.3 ± 10.5	-5.9 ± 5.3

Note: This table presents the mean changes (pre-post intervention) in blood glucose levels and PAID scores stratified by BMI category.

The effects of brisk walking on glycaemic control and diabetes-related distress (as measured by PAID score) were most pronounced in participants classified as obese. These findings suggest that individuals with a higher BMI derive greater therapeutic benefit from brisk walking in this study.

Figure 3. Comparison of Blood Glucose Reduction & PAID Score Across BMI Categories



The chart demonstrates that the most significant reduction in blood glucose levels and PAID Score was observed in the brisk walking group among obese participants, followed by those classified as overweight, and finally, those with a normal BMI. This pattern underscores the enhanced metabolic and psychological responsiveness to brisk walking in individuals with a higher BMI.

Discussion

This study demonstrated that a 60-minute brisk walking intervention significantly increased nitric oxide (NO) levels, reduced blood glucose concentrations, lowered body mass index (BMI), and improved both quality of life and mental health among patients with type 2 diabetes mellitus (T2DM). These findings underscore the superiority of brisk walking over regular walking, particularly in enhancing endothelial function through greater NO bioavailability and improving metabolic control. Statistically significant elevations in NO serve as robust indicators of endothelial repair, while reductions in blood glucose levels reflect improved insulin sensitivity. The observed BMI reduction within a relatively short intervention period suggests a favorable anthropometric impact. Improvements in Diabetes Quality of Life (DQOL) scores and reductions in Problem Areas in Diabetes (PAID) scores indicate psychosocial benefits, including enhanced treatment satisfaction and a reduced emotional burden associated with T2DM (Amerkamp et al., 2024).



From a physiological standpoint, these findings align with established exercise physiology theories, whereby aerobic exercise stimulates endogenous NO production via endothelial nitric oxide synthase (eNOS) activation (Allen, 2023; Mueller et al., 2024; Tran et al., 2022). NO is a potent vasodilator, enhancing tissue perfusion and facilitating glucose uptake into skeletal muscle. Evidence indicates that aerobic exercise in patients with diabetes increases NO production and facilitates glucose transport through GLUT-4 translocation to the skeletal muscle cell membrane (Singh et al., 2023) (Bassi-Dibai et al., 2022; Soo et al., 2023). Furthermore, moderate-to-high-intensity physical activity can enhance skeletal muscle glucose uptake by up to 40% independently of insulin (Silva et al., 2024).

The glycemic improvements observed here likely reflect synergistic mechanisms: increased insulin sensitivity and insulin-independent glucose transport. These results are consistent with prior reports that regular physical activity improves glycemic control, particularly in individuals with obesity and T2DM (Astbury, 2024; Boye et al., 2021). The optimal intensity of exercise remains debated, with evidence suggesting that higher-intensity interventions promote greater weight loss, whereas moderate-intensity activity more effectively enhances insulin sensitivity (Collins et al., 2022; Gaesser & Angadi, 2021).

The present findings also highlight the relevance of NO to mental health outcomes. Recent studies report that brisk walking can reduce oxidative stress and inflammation—pathways implicated in depression and anxiety among patients with T2DM—through improvements in cerebral vascular function and cerebral blood flow (Vandersmissen et al., 2025). Research in Southeast Asia, including Indonesia, supports these results, showing that 8–12 week brisk walking programs improve glycemic control, aerobic capacity, and subjective well-being in patients with T2DM (Eslami et al., 2025; Harun et al., 2022; Syeda et al., 2023b).

Additionally, recent Retos publications have emphasized the broader role of structured aerobic-based interventions in improving cardiometabolic health and physical function in populations with chronic conditions. Zalillah et al., (2025) demonstrated that a 45-minute session of total-body aerobic gymnastics performed at 88 beats per minute was significantly more effective than low-intensity steady-state walking in improving body composition among sedentary adult women, as evidenced by reductions in BMI and fat mass, and increases in muscle mass. In a different clinical population, Kristiani et al., (2025) reported that uphill treadmill walking, when added to standard therapy, significantly improved hamstring flexibility in patients with grade II–III knee osteoarthritis, with moderate-to-large effect sizes. These findings collectively reinforce the efficacy of targeted, structured walking and aerobic programs in producing meaningful physiological adaptations, supporting the relevance of brisk walking interventions for enhancing functional capacity, metabolic health, and overall quality of life in individuals with T2DM.

From a clinical perspective, brisk walking may promote stable glycemic control without the elevated risk of hypoglycemia commonly associated with pharmacological therapies. The short-term BMI reduction suggests a shift in energy balance, potentially mediated by increased post-exercise basal metabolic rate. The use of ultrasonic sensor-based microcontroller devices for BMI measurement in this study enhances the accuracy and reproducibility of anthropometric data. The improvement in quality of life underscores the necessity for an expanded diabetes management paradigm that incorporates both metabolic and psychosocial domains.

The relatively modest difference in PAID scores between the brisk walking and regular walking groups—while still statistically significant—suggests that the emotional burden of diabetes may be more strongly influenced by interpersonal and environmental factors, such as family support or occupational circumstances, which are less directly modifiable through short-term physical activity. Moreover, psychological improvements may require a longer duration of intervention compared with physiological changes. Longitudinal research is warranted to examine these effects over extended periods.

this study makes a novel contribution by explicitly linking brisk walking-induced NO elevation to improved glycemic outcomes—a mechanism rarely delineated in the literature—and by demonstrating its applicability in an Indonesian diabetic population. From a practical standpoint, these findings advocate for the integration of brisk walking into standard T2DM care, particularly within primary healthcare and community-based lifestyle modification programs. As a low-cost, accessible, and low-risk intervention, brisk walking offers a viable strategy for improving both the metabolic and psychosocial dimensions of diabetes management.



Study Limitations and Future Directions

This study had several limitations. First, the quasi-experimental design employing non-randomized control groups introduces potential selection bias, thereby limiting the generalizability of the findings. Second, the relatively short duration of the intervention may not sufficiently capture long-term effects on psychological and anthropometric parameters. Third, the assessment of NO levels was conducted using pre- and post-intervention measurements without serial monitoring, leaving the dynamic pattern of NO production throughout the intervention period unknown. Fourth, the self-reported nature of the PAID and DQOL instruments introduces the possibility of response bias. Future studies should incorporate additional biochemical markers, such as HbA1c and high-sensitivity C-reactive protein (hs-CRP), to provide a more comprehensive assessment of the inflammatory status and long-term glycemic control. Exploration of other psychosocial outcomes, including sleep quality, self-motivation, and perceived self-efficacy, could further elucidate the broader impact of brisk walking in diabetes management. New research questions, such as whether combining brisk walking with mindfulness interventions produces synergistic effects on patients' mental health, also warrant further investigation.

Conclusions

This study aimed to assess the efficacy of a 60-minute brisk walking intervention on nitric oxide (NO) levels, blood glucose concentrations, body mass index (BMI), quality of life, and mental health in patients with type 2 diabetes mellitus. The principal findings indicated that brisk walking significantly increased NO levels, reduced blood glucose levels, improved BMI, and enhanced both quality of life and mental health compared with regular walking. These outcomes provide valuable support for the integrative theory emphasising the interconnected roles of vascular, metabolic, and psychosocial systems in diabetes management, while underscoring the pivotal role of NO as a central mediator linking physical activity with glycaemic regulation. The significance of these findings lies in their potential to address a critical gap in the literature concerning the specific physiological mechanisms through which simple exercise interventions elicit multidimensional improvements in patients with type 2 diabetes. Despite limitations, including the relatively short duration of the intervention and modest sample size, the results offer robust and meaningful contributions to the current evidence. Future research should consider longitudinal study designs with larger sample sizes, incorporate additional vascular biomarkers, and explore optimised frequencies and intensities of physical activity to maximise therapeutic responses. Furthermore, these findings may serve as a practical basis for healthcare providers and policymakers to advocate brisk walking as an accessible, safe, and cost-effective nonpharmacological strategy for comprehensive type 2 diabetes care.

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