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Long-term high-intensity interval training reduces blood glucose in type 2 diabetes mellitus patients
El entrenamiento en intervalos de alta intensidad a largo plazo reduce la glucosa en sangre en pacientes con diabetes mellitus tipo 2

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Abstract. This study aimed to demonstrate the long-term effects of high-intensity interval training (HIIT) on reducing blood glucose levels in patients with type 2 diabetes mellitus. The research employs a preexperimental design with a one-group pretest–posttest design. A total of 20 patients with type 2 diabetes mellitus, aged 40–60 years, participated in the study and received the HIIT intervention three times per week for eight weeks. Data collection involved measuring fasting blood glucose levels before and after the HIIT intervention via the ONE TOUCH™ BASIC™ Plus Meter. Data analysis was conducted via paired sample t tests with a significance level of 5%, and the effect size was evaluated via Cohen's d. Paired sample t test analysis between pre-HIIT and post-HIIT blood glucose levels (181.50±17.85 mg/dL to 99.50±8.26 mg/dL, $p \leq 0.001$) revealed a significant reduction, with a large effect size (Cohen's d = 5.896). This study confirms that long-term high-intensity interval training is effective in lowering fasting blood glucose levels to normal ranges in patients with type 2 diabetes mellitus.
Keywords: Blood glucose, HIIT, insulin sensitivity, insulin resistance, type 2 diabetes patients

Resumen. Este estudio tuvo como objetivo demostrar los efectos a largo plazo del entrenamiento en intervalos de alta intensidad (HIIT) en la reducción de los niveles de glucosa en sangre en pacientes con diabetes mellitus tipo 2. La investigación emplea un diseño preexperimental con un diseño de prueba previa y posterior a la prueba de un solo grupo. Un total de 20 pacientes con diabetes mellitus tipo 2, de entre 40 y 60 años, participaron en el estudio y recibieron la intervención HIIT tres veces por semana durante ocho semanas. La recopilación de datos implicó medir los niveles de glucosa en sangre en ayunas antes y después de la intervención HIIT mediante el medidor ONE TOUCH™ BASIC™ Plus. El análisis de los datos se realizó mediante pruebas t de muestras pareadas con un nivel de significancia del 5%, y el tamaño del efecto se evaluó mediante la d de Cohen. El análisis de la prueba t de muestras pareadas entre los niveles de glucosa en sangre pre-HIIT y post-HIIT (181,50 ± 17,85 mg/dL a 99,50 ± 8,26 mg/dL, $p \leq 0,001$) reveló una reducción significativa, con un tamaño del efecto grande (d de Cohen = 5,896). Este estudio confirma que el entrenamiento en intervalos de alta intensidad a largo plazo es eficaz para reducir los niveles de glucosa en sangre en ayunas a rangos normales en pacientes con diabetes mellitus tipo 2.
Palabras clave: Glucosa en sangre, HIIT, sensibilidad a la insulina, resistencia a la insulina, pacientes con diabetes tipo 2

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Introduction

Diabetes mellitus is a metabolic disorder characterized by high blood glucose levels and uncontrolled disease resulting from either absolute or relative insulin deficiency (Cai et al., 2023). Owing to this insulin deficiency, glucose metabolism is disrupted, leading to an accumulation of glucose in the blood, as it is not adequately absorbed by body cells (Al-Sowayan & Zakaria, 2022). Various studies have shown that diabetes mellitus has become one of the most common chronic diseases in nearly all countries (Arroyave et al., 2020). Currently, 463 million people are living with diabetes mellitus, representing 9.3% of the population, and approximately half of them are unaware of their condition. In many cases, the symptoms of diabetes mellitus take a long time to appear or be noticed by patients, making it a silent disease of the 21st century (De Oliveira Teles et al., 2022). Research has shown that diabetes mellitus contributes to an annual global mortality rate of approximately 3 million people, with a consistent increase in the global diabetes incidence each year (Feng et al., 2024).

The most common form of diabetes is type 2 diabetes (Galicia-Garcia et al., 2020). This type of diabetes, characterized by hyperglycemia due to insulin resistance or relative insulin insufficiency, leads to cardiovascular diseases and causes cardiovascular damage (Liu et al., 2019). Several studies have indicated that type 2 diabetes mellitus accounts for more than 90% of diagnosed diabetes cases. Type 2 diabetes mellitus is recognized as a cause of premature death and is associated with several acute medical conditions, such as cardiovascular disease (CVD), neuropathy, retinopathy, and kidney disease (Damaskos et al., 2020). Physical exercise is an essential nonpharmacological therapeutic modality for diabetes patients (Al-Rawaf et al., 2023). Interventions involving physical exercise can enhance cardiopulmonary and metabolic adaptations, potentially delaying the progression of diabetes and improving its prognosis (Myers et al., 2019). Lack of time is one of the most common barriers to routine physical exercise for diabetes patients. In recent decades, high-intensity interval training (HIIT) has gained popularity because it requires less time and provides better responses in terms of endothelial function, functional capacity, body composition, and quality of life (Wu, et al., 2021). It is considered effective in preventing and treating type 2 diabetes mellitus (Al-Rawaf, et al., 2023). HIIT is an exercise protocol that alternates short periods of intense exercise (>85% of VO_2max or maximum heart rate) with short rest periods. In patients with type 2 diabetes mellitus, HIIT effectively improves

glycemic control, glycosylated hemoglobin, and cardiorespiratory fitness (Mateo-Gallego et al., 2022).

Research conducted by Aispuru-Lanche et al. (2023) demonstrated that low-volume high-intensity training (HIT) can rapidly improve glucose control and induce skeletal muscle adaptations associated with enhanced metabolic health in patients with type 2 diabetes. A study by Kanaley et al. (2022) indicated that in individuals with type 2 diabetes, implementing structured high-intensity interval exercise (HI-IE) over 12 weeks could be as effective as moderate-intensity continuous exercise (MI-CE). Both interventions were equally effective in reducing total body fat but had minimal effects on glycated hemoglobin A1c (HbA1c) in relatively well-controlled type 2 diabetes patients. Research by Atakan et al. (2021) provided evidence of the health benefits of 8 weeks of high-intensity interval training (HIIT) in type 2 diabetes patients. HIIT significantly improved overall glycemic control and pancreatic β-cell function in these patients. Additionally, both groups experienced reductions in abdominal fat mass. Other research by Metcalfe & Vollaard (2024) showed that brief bouts of reduced-exertion high-intensity interval training (REHIT) were well tolerated by middle-aged men with type 2 diabetes and that this type of training was superior to a fivefold greater total volume of moderate-intensity walking in improving VO_2max. Additionally, research conducted by Silva et al. (2022) demonstrated that high-intensity interval training (HIIT), particularly HIIT-30:30, is a promising measure for enhancing autonomic modulation in patients with type 2 diabetes compared with continuous moderate-intensity training. Therefore, this study aimed to demonstrate the effects of high-intensity interval training on reducing blood glucose levels in patients with type 2 diabetes mellitus.

Materials and methods

Study design

The research employs a pre-experimental design with a one-group pretest–posttest design. A total of 20 male patients aged 40–60 years with a body mass index (BMI) of 25–35 kg/m² and a history of type 2 diabetes mellitus on the basis of medical records were recruited from a hospital in Sorong city, West Papua Province, Indonesia, to voluntarily participate in the study. Before active participation, all the respondents were given both verbal and written information explaining the study. Informed consent was obtained prior to the commencement of the study. All procedures implemented in this research adhered to ethical principles for research involving human subjects, were based on the World Medical Association Declaration of Helsinki, and received approval from the Health Research Ethics Commission of the Health Polytechnic of the Ministry of Health of Sorong, Indonesia (No: DM.03.05/4/015/2023).

High-intensity interval training protocols

The high-intensity interval training (HIIT) program was implemented and supervised by professional officers from the Department of Sport Education, Faculty of Teacher and Education, Universitas Pendidikan Muhammadiyah Sorong (Indonesia). HIIT was performed with an intensity of 80–90% HRmax, frequency 3x/week for 8 weeks. Each session of the HIIT program was done in 4 sets of 4-6 repetitions, total duration 30-60 minutes including work and rest. HIIT was applied with three training models, namely outdoor running, ergocycle, treadmill, each of which was applied on different days. In this study, only cardiorespiratory training was performed and strength training was not included. The heart rate can be monitored via the HIIT using the Polar H10 heart sensor (Rejeki et al., 2024). Details of the HIIT scheme are presented in Table 1.

Table 1.
Scheme of high-intensity interval training

Frequency	Intensity	Time	Type	Models	Rest
3x/week for 8 weeks	80–90% HRmax	30-60 minutes including work and rest	Interval with 4 sets of 4-6 repetitions	Outdoor running, ergocycle, treadmill	Rest between sets 2.5 minutes and rest between repetitions 1 minute

Data collection

Data collection involved measuring anthropometric parameters, blood pressure, and blood glucose levels before and after the HIIT intervention. Blood glucose testing was conducted by pricking the middle finger with a needle, placing the blood sample at the end of a blood glucose meter, and reading the results displayed on the meter's screen. Details of the parameters and equipment used in data collection are presented in Table 1.

Table 2.
Details of the research parameters and instruments

Parameters	Tool	Unit	References
Weight	Digital Scale (OMRON HN-289, Osaka, JAPAN)	kg	Putera et al., 2023
Height	Portable Stadiometer Seca 213	m	Pranoto et al., 2023
Blood pressure	OMRON Model HEM-7130 L, Omron Co., Osaka, Japan	mmHG	Raharjo et al., 2021
Blood glucose	ONETOUCH™ BASIC™ Plus Meter	mg/dL	Philis-Tsimikas et al., 2011

Statistical analysis

The data analysis techniques included descriptive analysis to determine the mean values and standard deviations. Normality testing was performed via the Shapiro–Wilk test, while hypothesis testing was conducted via paired sample t tests with a significance level of 5%, and effect size was evaluated via Cohen's d. Cohen's d classified effect sizes as small (d = 0.2), medium (d = 0.5), and large (d ≥ 0.8) (Sullivan & Feinn, 2012). All the statistical analyses were carried out via SPSS version 21 for Windows 10.

Results

The results of the descriptive analysis of patient characteristics, including demographics, anthropometry, and blood pressure, are presented in Table 2. The differences in weight, body mass index, blood pressure, and blood glucose levels between pre-HIIT and post-HIIT are shown in Figure 1.

Table 3.
Descriptive analysis characteristics of patients

Parameters	Unit	n	Mean	Std. Deviation
Age	yrs	20	48.60	6.51
Height	m	20	1.69	0.07
Weight	kg	20	83.90	6.77
Body mass index	kg/m²	20	29.74	4.17
Systolic blood pressure	mmHg	20	134.25	5.19
Diastolic blood pressure	mmHg	20	81.75	5.91
Blood glucose	mg/dL	20	179.25	19.56

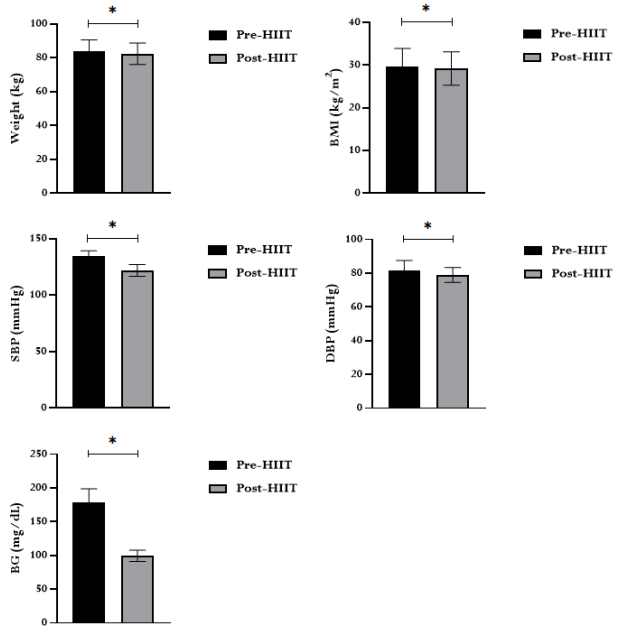

Figure 1. Analysis of weight, body mass index, blood pressure, and blood glucose between pre-HIIT and post-HIIT.
Description: *Significant at pre-HIIT (p ≤ 0.001). Data were obtained via paired sample t tests and are presented as the means ± standard deviations. BMI: body mass index; SBP: systolic blood pressure; DBP: diastolic blood pressure; BG: blood glucose.

The results of the paired sample t test analysis between pre-HIIT and post-HIIT revealed significant improvements in several parameters: weight (83.90±6.77 kg to 82.46±6.34 kg, p ≤ 0.001), BMI (29.74±4.17 kg/m² to 29.21±3.94 kg/m², p ≤ 0.001), systolic blood pressure (SBP) (134.25±5.19 mmHg to 122.00±5.23 mmHg, p ≤ 0.001), diastolic blood pressure (DBP) (81.75±5.91 mmHg to 78.95±4.41 mmHg, p ≤ 0.001), and blood glucose (BG) (181.50±17.85 mg/dL to 99.50±8.26 mg/dL, p ≤ 0.001).

Discussion

This study aimed to demonstrate the long-term effects of high-intensity interval training (HIIT) on reducing blood glucose levels in patients with type 2 diabetes mellitus. The main findings of this study indicate that an 8-week HIIT intervention is effective in lowering fasting blood glucose levels to normal ranges in patients with type 2 diabetes mellitus. This finding is consistent with previous research reporting that 12 weeks of HIIT is effective in improving glucose control and insulin sensitivity in individuals with type 2 diabetes mellitus (Al-Rawaf et al., 2023). Furthermore, HIIT has been shown to enhance glycemic control and pancreatic β-cell function, maintain insulin secretion, and improve insulin sensitivity in patients with type 2 diabetes mellitus (Banday et al., 2020). HIIT has also been reported to have positive effects on glycemic control in patients with type 2 diabetes mellitus (Liu et al., 2019). These findings suggest that HIIT is a beneficial exercise strategy for improving health outcomes in patients with type 2 diabetes mellitus.

High-intensity interval training (HIIT) is an effective exercise strategy for reducing risk factors associated with type 2 diabetes mellitus (de Oliveira Teles et al., 2022). da Silva et al. (2019) demonstrated that HIIT can positively impact insulin sensitivity, potentially due to its ability to acutely increase nonoxidative glucose disposal or chronically reduce intra-abdominal adipose tissue, both of which contribute to improved insulin sensitivity (Al-Rawaf et al., 2023; da Silva et al., 2019). Additionally, HIIT can enhance skeletal muscle oxidative capacity and glycemic control in adults with type 2 diabetes (Islam & Gillen, 2023). Therefore, HIIT appears to be a viable and time-efficient alternative exercise protocol compared with other training methods: it involves short bursts of high-intensity exercise performed repeatedly with intervals of active or passive recovery (Liu et al., 2019). Several recent studies reported that, compared with conventional training programs, HIIT is more effective at improving health benefits (Lazić et al., 2024).

In this study, an 8-week HIIT protocol significantly improved random blood glucose levels in patients with type 2 diabetes mellitus. This effect can be attributed to the role of physical exercise as a crucial component of diabetes management, particularly in patients who are overweight or obese (Feng, et al., 2024). Skeletal muscle adaptations that occur during HIIT can lead to changes in the expression or activity of proteins involved in glucose metabolism in both rodent and human skeletal muscle (Callahan et al., 2021).

Although there are only a few observations in human muscle, insulin signaling that stimulates glucose uptake can increase under certain physical training conditions. The response of increased glucose transport occurs in contracting muscles and is potentially mediated by various intramyocellular signals, including the activation of AMPK, Akt phosphorylation, NO production, and calcium-mediated mechanisms such as CaMK and PKC (Vertyshev et al., 2023). The insulin-sensitizing effects of acute activity only last for approximately 48 hours if they are not accompanied by other activities. However, long-term activity can induce increased insulin sensitivity in muscles, as evidenced by increased expression or activity of signaling proteins affecting skeletal muscle glucose uptake. This is likely due to increased expression or activity of signaling proteins that facilitate glucose uptake in skeletal muscle, possibly through upregulation of GLUT-4 protein expression in response to regular activity in both healthy individuals and those with skeletal muscle insulin resistance (Merz & Thurmond, 2020).

This study offers significant insights into the potential of high-intensity interval training (HIIT) as an effective exercise strategy for improving glycemic control in patients with type 2 diabetes mellitus. One of the strengths of this study is its focus on a structured 8-week HIIT intervention, which demonstrated clear benefits in reducing blood glucose levels and enhancing insulin sensitivity. Additionally, the use of well-established protocols and the inclusion of a relatively homogenous patient population strengthen the validity of our findings.

However, this study is not without limitations. The relatively short duration of the intervention limits our ability to make conclusions about the long-term sustainability of the observed benefits. Additionally, the sample size, while adequate for detecting significant effects within the study period, may not fully capture the variability in response among the broader population of patients with type 2 diabetes mellitus. Another limitation is the lack of a control group engaged in a different form of exercise, which could have provided a more robust comparison of HIIT with other exercise modalities.

Despite these limitations, our findings contribute to the growing body of evidence supporting the use of HIIT as a viable and time-efficient alternative to traditional exercise regimens for managing type 2 diabetes mellitus. Future research should focus on longer-term interventions and larger, more diverse populations to further validate these results and explore the mechanisms underlying the observed benefits.

Conclusion

In conclusion, long-term high-intensity interval training (HIIT) intervention has been proven effective in reducing fasting blood glucose levels to normal ranges in patients with type 2 diabetes mellitus. Therefore, the adaptations resulting from HIIT on glucose homeostasis can inhibit the potential development of type 2 diabetes mellitus by increasing insulin sensitivity and reducing insulin resistance.

Conflict of interest

The authors declare that they have no conflicts of interest related to this article.

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