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Regular high-intensity ergocycle training effective in reduction in BMI, percentage of body fat, HbA1c, and improving muscle mass in in patients with type 2 diabetes

El entrenamiento regular en bicicleta ergonómica de alta intensidad es eficaz para reducir el IMC, el porcentaje de grasa corporal y la HbA1c y mejorar la masa muscular en pacientes con diabetes tipo 2

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Abstract. This study aims to examine the effects of high-intensity ergocycle training on four key parameters crucial for managing type 2 diabetes (T2D): Body Mass Index (BMI), body fat percentage, Hemoglobin A1C (HbA1c), and muscle mass. A total of 24 male patients with T2D, aged 41-65, participated in the study and underwent a high-intensity ergocycle training intervention, conducted three times per week for eight weeks. Parameters such as HbA1c, BMI, PBF, and SM were observed before and after the intervention. Data analysis techniques included paired sample t-tests and independent sample t-tests with a significance level of 5%. The results indicated a significant reduction in HbA1c, BMI, and PBF, as well as a significant increase in SM before and after the high-intensity ergocycle training intervention ($p \leq 0.05$). Additionally, we observed a reduction in Δ-HbA1c, Δ-BMI, Δ-PBF, and an increase in Δ-SM between groups ($p \leq 0.05$). These findings demonstrate that regular high-intensity ergocycle training is significantly effective in reducing BMI, body fat percentage, and HbA1c levels while increasing muscle mass in patients with T2D. This result provides solid evidence that high-intensity ergocycle training can be used as a modality to improve insulin resistance in patients with T2D.
Keywords: Healthy lifestyle, metabolic health, regular exercise, insulin sensitivity, type 2 diabetes

Resumen. Este estudio tiene como objetivo examinar los efectos del entrenamiento en bicicleta estática de alta intensidad en cuatro parámetros clave cruciales para controlar la diabetes tipo 2 (DT2): índice de masa corporal (IMC), porcentaje de grasa corporal, hemoglobina A1C (HbA1c) y masa muscular. Un total de 24 pacientes varones con diabetes tipo 2, de entre 41 y 65 años, participaron en el estudio y se sometieron a una intervención de entrenamiento en ergociclo de alta intensidad, realizada tres veces por semana durante ocho semanas. Se observaron parámetros como HbA1c, IMC, PBF y SM antes y después de la intervención. Las técnicas de análisis de datos incluyeron pruebas t para muestras pareadas y pruebas t para muestras independientes con un nivel de significancia del 5%. Los resultados indicaron una reducción significativa en HbA1c, IMC y PBF, así como un aumento significativo en SM antes y después de la intervención de entrenamiento en bicicleta ergo de alta intensidad ($p \leq 0,05$). Además, observamos una reducción en Δ-HbA1c, Δ-BMI, Δ-PBF y un aumento en Δ-SM entre grupos ($p \leq 0,05$). Estos hallazgos demuestran que el entrenamiento regular en bicicleta ergo de alta intensidad es significativamente efectivo para reducir el IMC, el porcentaje de grasa corporal y los niveles de HbA1c, al tiempo que aumenta la masa muscular en pacientes con diabetes tipo 2. Este resultado proporciona evidencia sólida de que el entrenamiento en ergociclo de alta intensidad se puede utilizar como modalidad para mejorar la resistencia a la insulina en pacientes con diabetes tipo 2.
Palabras clave: Estilo de vida saludable, salud metabólica, ejercicio regular, sensibilidad a la insulina, diabetes tipo 2

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Introduction

In recent decades, there has been a significant increase in T2D cases, largely attributed to lifestyle changes (Yang et al., 2024; Lee et al., 2016). In 2021, the International Diabetes Federation (IDF) reported that more than 537 million people are living with diabetes, and this number is projected to rise to 643 million by 2030 (Hossain et al., 2024; IDF, 2023). The global prevalence of diabetes in the 20-79 age group was estimated at 10.5% (536.6 million people) in 2021, increasing to 12.2% (783.2 million) by 2045 (Sun et al., 2022). This condition is not only an individual health issue but also places a substantial burden on global healthcare systems due to its wide-ranging complications (AIHW, 2024), such as cardiovascular disease, neuropathy, nephropathy, and retinopathy (Crawford & Laiteerapong, 2024). These complications often result from inadequate glycemic control and the accumulation of body fat, particularly visceral fat, which is correlated with insulin resistance (American Diabetes Association (ADA), 2024). Obesity, which is highly prevalent in patients with T2D, exacerbates insulin resistance and leads to chronic hyperglycemia (Wondmkun, 2020). Central obesity, where fat accumulates around key organs, drastically increases the risk of cardiovascular complications (Gallo et al., 2024). In everyday life, many T2D patients face difficulties in losing weight and controlling blood glucose despite dietary modifications or the use of medications (Vázquez et al., 2023). Pharmacological management of T2D, including the use of metformin, sulfonylureas, or Sodium-Glucose Transport Protein 2 (SGLT2) inhibitors, remains a cornerstone in controlling blood glucose levels (Wang et al., 2020). However, pharmacological therapies are often associated with side effects such as hypoglycemia, weight gain, or kidney complications with long-term use (Alhassani et al., 2021). Therefore, non-pharmacological approaches such as lifestyle modifications, including diet and exercise, are essential for improving T2D management outcomes. Successful lifestyle interventions can also reduce reliance on medications and minimize the risk of long-term complications (Pot et al., 2020). The combination of a

2025, Retos, 62, 966-973

sedentary lifestyle, a diet high in sugar and fat, and a lack of physical activity are key factors that trigger this metabolic imbalance (Deng et al., 2024; Fianu et al., 2024).

Physical activity has been shown to effectively help control blood glucose levels, lower BMI, and reduce the risk of complications in T2D patients (Cannata et al., 2020). However, many patients struggle to commit to moderate or low-intensity exercise programs, which are time-consuming (Zhu & Li, 2019). In recent decades, High-Intensity Interval Training (HIIT) has emerged as a more efficient exercise method to address time constraints while providing significant benefits in diabetes management (de Mello et al., 2022). This exercise involves high-intensity periods followed by short recovery intervals, resulting in significantly increased metabolism even after the workout is completed (Feng et al., 2024). Additionally, HIIT offers the advantage of optimizing fat reduction and muscle mass gain in a relatively shorter time (Gaweł et al., 2024; Lazić et al., 2024).

Several studies have demonstrated that HIIT provides significant benefits for T2D patients in controlling glycemia and improving metabolic health (de Oliveira Teles et al., 2022; Liu et al., 2019; Mateo-Gallego et al., 2022; Feng et al., 2024; Cassidy et al., 2017). However, most of these studies have focused on glycemic parameters such as insulin sensitivity and HbA1c control, with little attention given to changes in body composition, such as reduced BMI, decreased body fat, and increased muscle mass, which are also crucial in managing T2D (Fu et al., 2024). Given the central role of visceral fat in insulin resistance, as well as the importance of muscle mass as a primary organ for glucose uptake (Atakan et al., 2021; Hwang et al., 2019), further investigation is needed. Additionally, studies have shown that HIIT cycling is effective in improving aerobic capacity, reducing body fat, and enhancing insulin sensitivity across various populations, though there is still limited literature specifically evaluating ergocycle use in the context of T2D (Durrer et al., 2017). Therefore, this study aims to examine the effects of high-intensity ergocycle training on four key parameters important in managing T2D: BMI, body fat percentage, HbA1c, and muscle mass, with the hope of providing a more efficient and practical intervention for diabetes patients in everyday life.

Material and methods

Study design

This study utilized a true-experimental design with a pretest-posttest control group (Pranoto et al., 2024). A total of 22 male patients, aged 41-65 years, with a body mass index (BMI) of 27.5-34.5 kg/m², and a history of T2D based on medical records were recruited from a hospital in Sorong City, West Papua Province, Indonesia. Before participating actively, all respondents were informed both verbally and in writing about the details of the study. Informed consent was obtained before the study began. All procedures were conducted under ethical principles for research involving human subjects as outlined in the World Medical Association's Declaration of Helsinki, and the study was approved by 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 ergocycle training programs

The high-intensity ergocycle training program was implemented by pedaling a Monark 828 E Version 1010 ergo cycle stationary bicycle (Monark, Vansbro, Sweden) (Rejeki et al., 2021), with an intensity of 80-90% HRmax, training session duration of 20-30 minutes, frequency 3x/week for 8 weeks. During exercise, control your heart rate using the Polar Chest Strap H10 (Rejeki et al., 2024).

Data collection

Data were collected by measuring body weight using a Digital Scale (OMRON HN-289, Osaka, Japan) (Putera et al., 2023). Height was measured with a Portable Stadiometer Seca 213 (Pranoto et al., 2023). BMI was calculated by dividing body weight (kg) by height squared (m²) (Raharjo et al., 2021). Body fat percentage (PBF) and skeletal muscle mass (SM) were measured using a TANITA Body Composition Analyzer DC-360 (TANITA Corporation, Inc., IL 60005, USA) (Pranoto et al., 2023). HbA1c concentrations were measured using an automated XN-9000 hematology analyzer (Sysmex, Kakogawa, Japan) (Chou et al., 2022).

Statistical analysis

Data analysis was performed using descriptive statistics to determine the mean and standard deviation. Normality was evaluated using the Shapiro–Wilk test. An independent sample t-test was used to compare differences between groups, while a paired sample t-test was applied to assess differences in pre- and post-intervention data within each group. Effect sizes were evaluated using Cohen's d. Cohen categorized effect sizes as small ($d = 0.2$), medium ($d = 0.5$), and large ($d \geq 0.8$) (Sullivan & Feinn, 2012).

Results

Details of the results of the analysis of general characteristics of patients are presented in Table 1. Based on the results of the study, the levels of HbA1C, BMI, PBF were significantly lower and SM was higher between before and after the high-intensity ergocycle training intervention ($p \leq 0.05$) which can be seen in Figure 1-3. In addition, we also observed a decrease in Δ-HbA1C, Δ-BMI, Δ-PBF and an increase in Δ-SM between groups ($p \leq 0.05$) which are presented in detail in Table 2.

Based on Figure 1, it can be seen that there was no significant difference in HbA1c between pre and post in the control group (8.09±1.18 to 8.11±1.16 %, p=0.184), while in the treatment group there was a significant difference in HbA1c between pre and post (8.11±1.02 to 6.63±0.84 %, p=0.000).

Table 1.
General characteristics of patients

Parameters	G1; n=12	G2; n=12	p-value
Age (yrs)	52.33±5.47	52.08±7.05	0.924
Body height (m)	1.70±0.06	1.71±0.06	0.921
Body weight (kg)	84.67±5.02	85.08±6.49	0.862
Body mass index	29.31±2.93	29.28±2.35	0.983
Systolic blood pressure (mmHg)	134.17±5.15	131.58±6.82	0.307
Diastolic blood pressure (mmHg)	80.83±5.57	82.25±5.79	0.548
Resting heart rate (bpm)	83.83±3.01	83.50±3.63	0.809

Description: Data are presented as mean ± SD. *p*-value was obtained by independent sample t-test analysis.

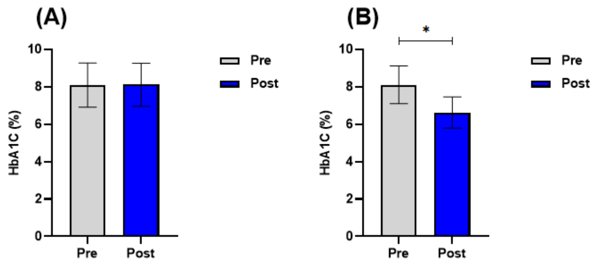

Figure 1. The differences in HbA1c (%) levels between pre and post in each group. Description: Data are presented as mean ± SD. *p*-value was obtained by paired sample t-test analysis. (*) Significant at pre in G_2 ($p \leq 0.05$). (A) Control group (G_1); (B) Treatment group (G_2).

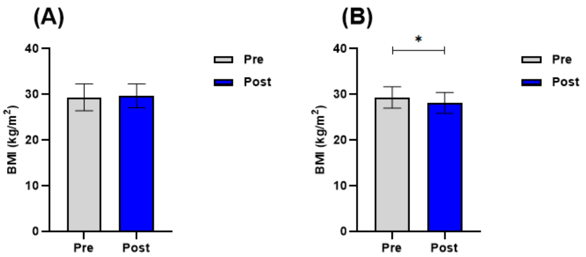

Figure 2. The differences in BMI (kg/m^2) between pre and post in each group. Description: Data are presented as mean ± SD. *p*-value was obtained by paired sample t-test analysis. (*) Significant at pre in G_2 ($p \leq 0.05$). (A) Control group (G_1); (B) Treatment group (G_2).

Based on Figure 2, it can be seen that there was no significant difference in BMI between pre and post in the control group (29.31±2.93 to 29.67±2.63 kg/m^{2}p = 0.174), while in the treatment group there was a significant difference in BMI between pre and post (29.28±2.35 to 28.11±2.29 kg/m^2, p=0.000).

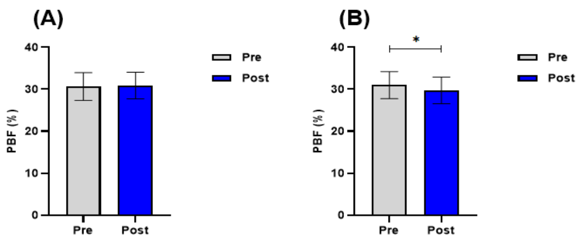

Figure 3. The differences in PBF (%) between pre and post in each group. Description: Data are presented as mean ± SD. *p*-value was obtained by paired sample t-test analysis. (*) Significant at pre in G_2 ($p \leq 0.05$). (**A**) Control group (G_1); (**B**) Treatment group (G_2).

Based on Figure 3, it can be seen that there was no significant difference in PBF between pre and post in the control group (30.65±3.29 to 30.88±3.16 %, p=0.093), while in the treatment group there was a significant difference in PBF between pre and post (30.98±3.23 to 29.74±3.18 %, p=0.000).

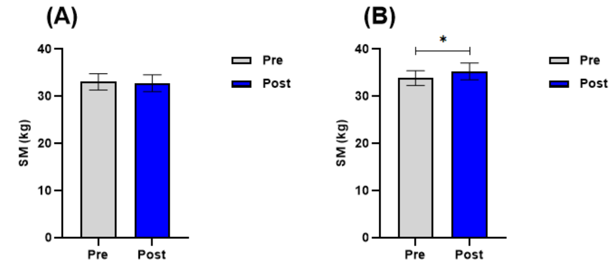

Figure 4. The differences in SM (kg) between pre and post in each group. Description: Data are presented as mean ± SD. *p*-value was obtained by paired sample t-test analysis. (*) Significant at pre in G_2 ($p \leq 0.05$). (**A**) Control group (G_1); (**B**) Treatment group (G_2).

Based on Figure 4, it can be seen that there was no significant difference in SM between pre and post in the control group (33.04±1.72 to 32.76±1.76 kg, p=0.081), while in the treatment group there was a significant difference in SM between pre and post (33.83±1.57 to 35.26±1.76 kg, p=0.000).

Table 2.
Differences in HbA1C, BMI, PBF, and SM levels between groups

Parameter	G1; n=12	G2; n=12	Effect size	p-value
Pre-HbA1C (%)	8.09±1.18	8.11±1.02	0.018	0.978
Post-HbA1C (%)	8.11±1.16	6.63±0.84*	1.473	0.002
Δ-HbA1C (%)	0.02±0.05	-1.48±0.41*	5.201	0.000
Pre-BMI (kg/m^2)	29.31±2.93	29.28±2.35	0.011	0.983
Post-BMI (kg/m^2)	29.67±2.63	28.11±2.29	0.633	0.135
Δ-BMI (kg/m^2)	0.37±0.64	-1.18±0.24*	3.212	0.000
Pre-PBF (%)	30.65±3.29	30.98±3.23	0.101	0.805
Post-PBF (%)	30.88±3.16	29.74±3.18	0.359	0.388
Δ-PBF (%)	0.23±0.44	-1.24±0.26*	4.123	0.000
Pre-SM (kg)	33.04±1.72	33.83±1.57	0.479	0.257
Post-SM (kg)	32.76±1.76	35.26±1.76*	1.418	0.002
Δ-SM (kg)	-0.29±0.52	1.43±0.33*	3.969	0.000

Description: Data are presented as mean ± SD. p-value was obtained by independent sample t-test analysis. (*) Significant at G_1 ($p \leq 0.05$). Effect size evaluation using Cohen's d. (Δ) Delta (post – pre). (-) No effect size was observed.

Discussion

The results of this study demonstrate that high-intensity ergocycle training significantly reduced BMI, body fat, and HbA1c, while simultaneously increasing muscle mass in patients with T2D. These findings support previous evidence regarding the effectiveness of high-intensity training in improving metabolic parameters in T2D patients (Cavalli et al., 2024). This study contributes empirical data on body composition changes.

The significant reduction in BMI and body fat in the intervention group is likely related to enhanced lipolysis and increased fat oxidation triggered by high-intensity exercise (Liu et al., 2020). HIIT has been shown to improve muscle oxidative capacity and regulate triglycerides (TG) and lowdensity lipoproteins (LDL) by enhancing mitochondrial biogenesis (Mahatme et al., 2022). This effect is further amplified by excess post-exercise oxygen consumption (EPOC), where the body continues to burn calories at a higher rate even after the exercise is completed (Jiang et al., 2024; Sindorf et al., 2021). The reduction in visceral fat is crucial because this fat is directly linked to insulin resistance and systemic inflammation, which are the primary causes of metabolic dysfunction in diabetic patients (Al-Rawaf et al., 2023).

The significant reduction in HbA1c indicates improved long-term glycemic control in T2D patients (Aneis et al., 2015). The molecular mechanisms underlying this change involve enhanced insulin sensitivity in skeletal muscle, which is the primary tissue for insulin-mediated glucose uptake (Francois et al., 2015). HIIT has been shown to increase AMPK (Adenosine Monophosphate-activated Protein Kinase) activity (Eid et al., 2024), which plays a crucial role in increasing glucose transport through the translocation of GLUT4 (glucose transporter type 4) to the cell membrane (Kakoti et al., 2024). AMPK activation also promotes fatty acid oxidation and the use of glucose as an energy source by muscles (Spaulding & Yan, 2022). This increased capacity for muscle glucose uptake and utilization may explain the significant reduction in HbA1c in the intervention group.

The decrease in HbA1c may also be influenced by improved inflammatory profiles resulting from high-intensity exercise (Xu et al., 2024). HIIT is known to reduce levels of pro-inflammatory cytokines such as TNF-α and IL-6 while increasing adiponectin, an adipokine that has anti-inflammatory effects and enhances insulin sensitivity (Saberi et al., 2024). This reduction in systemic inflammation contributes to improved insulin signaling at the cellular level, thereby enhancing overall glycemic control (Guo et al., 2024).

The significant increase in muscle mass observed in T2D patients in this study suggests that HIIT also stimulates muscle hypertrophy through activation of the mammalian target of the rapamycin (mTOR) pathway, which regulates muscle protein synthesis (Sherafati-Moghadam et al., 2022). Increased muscle mass not only enhances the body's capacity to absorb glucose but also increases basal metabolic rate (BMR), aiding in long-term weight and body composition management (Matsuura et al., 2024). Furthermore, increased muscle mass is particularly beneficial for T2D patients, as skeletal muscle is the primary tissue for glucose storage, meaning that higher muscle mass is directly linked to improved insulin sensitivity (Haines et al., 2020).

From a physiological perspective, HIIT performed using an ergocycle provides significant cardiovascular benefits (Wang et al., 2024; Atakan et al., 2021; Maillard et al., 2018). This exercise improves aerobic capacity and cardiovascular function, which is critical in reducing the risk of cardiovascular complications in T2D patients (Atakan et al., 2021; da Silva et al., 2019). Increased blood flow and vascular function resulting from HIIT also enhance glucose and oxygen distribution to the muscles during exercise, further improving energy metabolism and glycemic control (Shishira et al., 2024).

This study has certain limitations that should be considered when interpreting the findings. Firstly, the relatively short duration of the intervention limits our ability to draw conclusions about the long-term effects of high-intensity ergocycle training on glycemic control, body composition, and cardiovascular health in individuals with T2D. A longer study period would be beneficial for assessing whether the observed improvements are sustainable over time. Secondly, the small sample size restricts the generalizability of the results to a broader population. A larger, more diverse sample would provide greater statistical power and increase the likelihood that these findings are applicable to individuals with varying degrees of diabetes severity, comorbidities, and fitness levels. Furthermore, this study primarily focused on a specific mode of high-intensity interval training (HIIT) using an ergocycle, which may not be equally accessible or feasible for all patients due to equipment availability and individual preferences. Future studies should aim to explore the effectiveness of alternative HIIT modalities and investigate factors that may influence adherence to this type of exercise in real-world settings. Addressing these limitations in future research will be essential for confirming the robustness of our findings and refining exercise-based interventions as part of T2D management strategies.

These findings have important clinical implications. HIIT using an ergocycle can be adopted as part of an effective T2D management program, focusing not only on glycemic reduction but also on body composition improvements and cardiovascular capacity enhancement. However, further research is needed to explore the long-term effects of this intervention and whether it can be applied to a broader population with varying levels of T2D severity.

In conclusion, this study demonstrates that high-intensity ergocycle training is an effective intervention for improving key health indicators in patients with T2D, including reductions in BMI, body fat, and HbA1c levels, alongside gains in muscle mass. These findings suggest that a structured, intensive exercise regimen can play a valuable role in diabetes management by offering a safe and impactful approach to enhancing metabolic and body composition outcomes. Nonetheless, to fully understand the potential of this intervention, further research is warranted to assess its long-term sustainability and applicability across diverse patient populations with varying levels of diabetes severity. Such studies would provide greater clarity on the role of high-intensity training in routine diabetes care and its adaptability to broader clinical practice.

Conclusion

This study shows that regular high-intensity ergocycle training is significantly effective in reducing BMI, body fat percentage, and HbA1c while increasing muscle mass in patients with T2D. This intervention provides efficient results in a shorter period compared to moderate-intensity exercise, due to its ability to enhance fat burning and insulin sensitivity through metabolic improvements. These findings are clinically relevant as the reduction of visceral fat and increase in muscle mass directly impact improved insulin resistance, which is key in managing T2D.

Conflict of interest

The authors declare that they have no competing interests.

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