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FULL PAPER

The effects of high-intensity interval training on blood sugar levels in type 2 diabetes mellitus patients: A study in southwest Papua

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The prevalence of diabetes worldwide is increasing; other infectious diseases, such as obesity-related diseases, include hypertension, heart disease, dyslipidemia, and diabetes mellitus (DM). Physical exercise is known to control blood sugar. This study aims to determine the effect of high-intensity interval training on blood sugar in people with type 2 diabetes mellitus. We conducted a pre and post-test laboratory experiment with 20 participants who underwent HIIT, including outdoor running, treadmill exercises, and exercise bikes, with a 1:3 work-to-rest ratio. Blood sugar levels were assessed before and after the intervention. Our study found a statistically significant decrease in blood sugar levels following the HIIT intervention (p-value = 0.001). These results suggest that high-intensity interval training can effectively lower blood sugar levels in individuals with type 2 diabetes mellitus.

KEYWORDS

High-intensity interval training; blood glucose; type 2 diabetes mellitus; exercise; metabolic syndrome.

Introduction

Today sport is necessary for everyone, not just a hobby, especially for those over 30 years old. Because over the age of 30 years, there is a degeneration process, and those who are less active will be susceptible to disease. Continuous exercise will obtain a fit and healthy body condition because regular exercise supports healthy blood circulation throughout the body, ensuring that blood flows smoothly [1]. Everyone can carry out efforts to improve health through simple and inexpensive activities. Apart from meal management, exercise is a simple and inexpensive effort to improve health as long as it is accompanied by knowledge and understanding of proper sports health [2]. Exercise for people who are not sick is natural or commonplace, but what about those suffering or affected by illness? For those who are sick, of course, there will be many obstacles in doing sports, even though those who suffer from an illness also need to exercise; this is intended to manage their illness. Exercise for sick people should be

adapted to the situation and condition of the disease they are suffering from [3].

The rapid advances in science and technology, developments in the economic sector, and unhealthy lifestyles that are not well controlled can lead to the emergence of various serious diseases [4]. Degenerative diseases began to replace other chronic diseases. One of the most prominent degenerative diseases today is diabetes mellitus. Diabetes mellitus is a world health problem; the number is increasing and developing in many countries [5]. In Indonesia, the number of people with diabetes also continues to increase [6]. Based on data from the Sorong City and Regency Health Office (2022), the number of diabetics has reached 225 people, and this number has increased by 30% from the previous year.

Related to the large number of people with diabetes mellitus, better management is needed to deal with diabetes mellitus, and this is because diabetes mellitus is a significant cause of morbidity and death globally [6]. Type 2 diabetes accounts for more than 90% of diagnosed cases of diabetes mellitus. Type 2 diabetes (T2D) is a metabolic disease characterized by hyperglycaemia due to insulin resistance or relative insulin insufficiency, which can cause cardiovascular disease and cause cardiovascular damage [7]. Type 2 diabetes (T2D) is recognized as a cause of premature death and is associated with several severe medical conditions, such as cardiovascular disease (CVD), neuropathy, retinopathy, and kidney disease. Exercise is one of the cornerstones of treating and preventing type 2 diabetes [8]

Physical exercises also reduces the need for insulin for daily work as long as it is done with attention to the correct dosage. In the long term, exercise lowers the blood glucose amount, which is the primary goal of treating diabetes [9]. One type of exercise that can be applied to people with type 2 diabetes mellitus is high-intensity interval training. High-Intensity Interval Training (HIIT) consists of 4 to 6 repetitions, short bouts (30 seconds) of the maximum effort punctuated by brief periods (30 to 60 seconds) of rest or active recovery [10]. The exercises are usually done on a stationary bicycle, and one session lasts about 10 minutes. High-Intensity Interval Training (HIIT) improves skeletal muscle oxidative capacity, glycaemic control, and insulin sensitivity in adults with type 2 diabetes [11]. High-intensity exercise can have a beneficial effect on insulin sensitivity. High-intensity exercise can result in an acute increase in non-oxidative glucose elimination or a chronic preferential reduction in intra-abdominal adipose tissue, contributing to increased insulin sensitivity. In addition, HIIT can have more positive effects on cardiopulmonary fitness [12].

High-intensity interval training includes interval training where the sessions are short and interspersed with rest periods. Therefore, in its implementation, it is necessary to pay attention to work and rest intervals which can be called work relief. The ratio of recovery to work can be expressed in a ratio of 1:3 and 1:5. The ratio of 1:3 implies that the recovery interval time is equal to twice the work interval time. In contrast, 1:5 implies the recovery interval equals four work interval times [13,14]. These two ratios have not been applied to people with type 2 diabetes because they affect blood sugar levels and VO_2 max. On the other hand, there are risk factors for type 2 diabetes mellitus in people with overweight/obesity (BMI) so that in this case, BMI also needs to be considered as a modification and better management of exercise among people with type 2 diabetes mellitus.

In this study, our primary objective is to investigate the impact of high-intensity interval training (HIIT) on blood sugar levels in individuals with type 2 diabetes mellitus. We aim to determine whether HIIT can effectively lower blood glucose levels in this population. As the prevalence of type 2 diabetes continues to rise, it is imperative to

explore effective exercise interventions that may contribute to better disease management and overall health. By examining the HIIT effects on blood sugar control, we aim to provide insights that can inform more targeted and personalized treatment strategies for individuals with type 2 diabetes.

Results and discussion

The age of the respondents in this study was between 41-60 years old. Most respondents were 41-45 years old 7 people (35%), and then the respondents aged 46-50 amounted to 4 people (20%). Respondents aged 51-55 were 5 people (25%), and respondents aged 56-60 were 4 people (20%). Body mass index in this study, respondents with obesity I consisted of 11 respondents and obesity II consists of 9 respondents. This clarification makes it clear that there were no participants in the Underweight and Normal categories, and all 20 participants fall under the Obesity I and Obesity II categories (Table 1).

TABLE 1 Sample population

	Category	Frequency	Percentage (%)
Age	41-45	7	35%
	46-50	4	20%
	51-55	5	25%
	56-60	4	20%
	Total	20	100%
BMI	Underweight	0	0%
	Normal	0	0%
	Overweight	0	0%
	Obesity I	11	55%
	Obesity II	9	45%
	Total	20	100%

The data presented comes from collecting pre-test data conducted on April 2023 and post-test data carried out on June 2023. The statistical results of the pre-test and post-test data on Blood Glucose can be explained in Table 2.

TABLE 2 Description of pre-test and post-test data on blood sugar test results

Treatment	Statistics	Results of *Pre-Test*	Results of *Post-Test*
HIIT	Average	179,25	134
	SD	19,55	10,46
	Highest	210	150
	Lowest	150	120
	Normality	0,657	0,051
	Independent Test	0,0001	

In Table 2, it is explained that the high-intensity interval training before exercise obtained an average of 179.25 mg/dL after being given treatment. The average decrease was obtained to 134 mg/dL, so the decrease in fasting blood sugar in the high-intensity interval training was 45.25 mg/dL. Before exercise, the highest blood sugar level was 210 mg/dL. After the HIIT exercise, the highest blood sugar level was 120. Meanwhile, the lowest blood sugar level before HIIT exercise was 150 mg/dL. After physical exercise, the lowest blood sugar level was 120 mg/dL. Normality results using Shapiro-Wilk test

showed that all data were normally distributed (p> 0.05), whereas based on the effect test using an independent test, there was a significant difference in the pre and post-test (p<0.05). This shows that giving HIIT training can significantly reduce blood sugar in people with type 2 diabetes mellitus (Figure 1).

Before the HIIT intervention, the average blood sugar level was 179.25 mg/dL. After completing the HIIT program, the average blood sugar level significantly decreased to 134 mg/dL. The standard deviation (SD) for blood sugar levels reduced from 19.55 mg/dL before HIIT to 10.46 mg/dL after HIIT, indicating a more consistent effect of HIIT on blood sugar levels. The highest blood sugar level recorded before HIIT was 210 mg/dL, which decreased to 150 mg/dL after HIIT. Similarly, the lowest blood sugar level decreased from 150 mg/dL before HIIT to 120 mg/dL after HIIT. The Shapiro-Wilk test for normality demonstrated that all data points had p-values greater than 0.05, suggesting that the data followed a normal distribution. An independent t-test was conducted to compare blood sugar levels before and after the HIIT intervention. The test yielded a p-value of 0.0001, indicating a highly significant difference between pre-test and post-test blood sugar levels. These results indicate that High-Intensity Interval Training had a substantial and positive impact on reducing blood sugar levels in individuals with type 2 diabetes mellitus. The findings provide strong support for the effectiveness of HIIT as an intervention for managing blood sugar in this population.

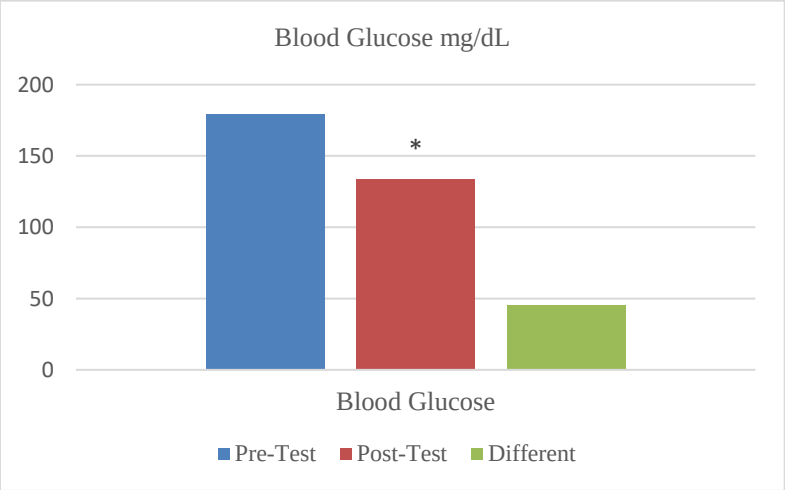

FIGURE 1 Blood sugar test results

Type 2 diabetes mellitus is a metabolic disease characterized by hyperglycemia due to insulin resistance or relative insulin insufficiency, which can cause cardiovascular disease and cause cardiovascular damage [15]. Patients with type 2 diabetes mellitus with a body mass index ≥ 25 mean that the patient is overweight/obese. This condition is a disorder that is more challenging to manage. A body mass index of≥ 25 will increase body mass, reducing motion acceleration [16]. Body mass index ≥ 25 will lead to more significant energy requirements on the aerobic system to carry out body movements and generally causes much earlier fatigue when given a training load with short rest intervals [17]. Fat deposits when the body mass index is ≥ 25 can affect the cardiovascular system [18].

High-Intensity Interval Training with a Work-Relief Ratio of 1:3 is defined as a working duration of 20 to 60 seconds at an intensity of 85% to 95% HRmax, 85% to 100% VO_2 max with recovery between sets of 3 minutes. High-Intensity Interval Training with a ratio of working time and rest time of 1:3 has not provided sufficient recovery of adenosine

triphosphate (ATP) and phosphocreatine (PCr) which is only around 84% to 89%, so it is not sufficient to allow substrate restoration and can result in inadequate recovery [19]. However, it supports endurance because physiological adaptation occurs when short rest intervals are combined with high training volumes. Abdi *et al.*'s research (2021) has also shown that the short-duration high-intensity interval training protocol can manage glucose-related indices, including HbA1c and insulin resistance [20].

In this study, there was a decrease in blood sugar levels when given HIIT. That is because, during HIIT, there is a mechanism for using endogenous fuel and fuel from the blood, which can cause a decrease in glucose levels in the body after activities where HIIT is done for more than 20 minutes [21]. ATP production is dominated by anaerobic glycolysis [22]. Anaerobic glycolysis is the primary source of glycogen or glucose so that blood glucose will decrease [23]. The results of the analysis showed that there was a significant decrease in blood glucose. That is because, during HIIT, there is a mechanism for using endogenous fuel and fuel from the blood, which can cause a decrease in glucose levels in the body after activities where HIIT is done for more than 20 minutes [21]. ATP production is dominated by anaerobic glycolysis. Anaerobic glycolysis is the primary source of glycogen or glucose so that blood glucose will decrease [24].

When performing HIIT, the muscles use glucose stored in the muscles, and if glucose is deficient, the muscles fill the void by taking glucose from the blood [25]. Muscle cells use more glucose and other nutrient fuels than usual for muscle contraction. The speed of glucose transport into used muscles can increase up to 10 times during physical activity. This will result in a decrease in blood glucose, thereby increasing blood glucose control [26].

The outcomes demonstrated a relationship between HIIT and blood glucose. Low blood sugar is a result of HIIT. More energy sources will be consumed the more complex the workout is. As a result, more blood sugar is used up, resulting in a drop in blood sugar levels. Therefore, low values will be obtained from fasting blood sugar testing. Exercise makes insulin receptors more sensitive, increasing the amount of blood glucose used for energy consumption [27].

The study observed a significant decrease in blood sugar levels following High-Intensity Interval Training (HIIT). This decrease in blood sugar can be attributed to the physiological responses associated with HIIT. HIIT involves short bursts of intense exercise followed by recovery periods. During HIIT, there is a rapid utilization of glucose for energy, which can lead to a reduction in blood sugar levels [21].

It's important to acknowledge the physiological mechanisms behind this statement and provide a supporting reference. This enhanced explanation better supports the findings of the study.

Experimental

This study used experimental research with a one-group pre and post-test design. The population in this study was 225 people with type 2 diabetes mellitus. All population subjects were used as data sources, so in this study, the sampling was carried out using a purposive sampling technique. Purposive sampling is a sampling technique with certain characteristics. The characteristics of the samples taken in this study were having Diabetes Mellitus type 2 for ≥ 1 year so that the resulting 20 samples. Samples were taken at all hospitals in Sorong City, West Papua Province, and the research was conducted in April-June 2023. This research has also received permission from the health research ethics commission of the Health Polytechnic of the Ministry of Health of Sorong with No. DM.03.05/4/015/2023.

Participants in this study underwent a structured High-Intensity Interval Training

(HIIT) program. The HIIT protocol consisted of the following details:

- **Duration**: The HIIT sessions were conducted over a 4-week period. Each week included three sessions of HIIT, resulting in a total of 12 sessions.
- **Frequency**: Participants engaged in HIIT three times per week, with at least one rest day between sessions to allow for recovery.
- **Intensity**: HIIT sessions consisted of 4 to 6 repetitions of short, high-intensity exercise intervals lasting approximately 30 seconds. These intense intervals were interspersed with brief recovery periods of 30 to 60 seconds.
- **Exercise Modalities**: The HIIT exercises were performed using a variety of equipment, including outdoor running, treadmills, and exercise bikes.
- **Descriptive Statistics**: Descriptive statistics, such as means and standard deviations, were calculated to summarize the characteristics of the data.
- **T-Test**: A two-sample t-test with correlation was used to compare the pre-test and post-test blood sugar levels. This test assessed whether there was a significant difference in blood sugar levels before and after the HIIT intervention.
- The statistical analysis was conducted using the SPSS 21 for Windows Evaluation Version, with a significance level of 5% ($\alpha = 0.05$).

This structured HIIT program aimed to improve skeletal muscle oxidative capacity, glycemic control, and insulin sensitivity in adults with type 2 diabetes [11]. The work-to-rest ratio was maintained at 1:3, with recovery periods equaling three times the work interval time. These specific HIIT parameters were selected to optimize the metabolic responses in individuals with type 2 diabetes mellitus.

Including these details in the Experimental section provides a clear understanding of the HIIT protocol used in the study.

Respondents were given physical exercise with high-intensity interval training with a ratio of 1:3. The ratio of 1:3 means 1 working time with 3 breaks from working time. The exercises provided are in the form of outdoor running, treadmills and exercise bikes. This training program is based on High-Intensity Interval Training (HIIT) which involves repeated exercises with high-intensity effort followed by varying recovery periods. Work time increases range from 5 seconds to 8 minutes in length and are performed at 80% to 95% of each individual's maximal heart rate, the maximum amount of time the heart beats in one minute without fatigue. Recovery time is the same as during work hours and is usually done at 40% to 50% of the individual's maximal heart rate. Continuous exercise with 20 to 60 minutes of work and rest.

Prior to blood sugar testing, participants were instructed to fast for a minimum of 8 hours. This fasting period ensured that blood sugar measurements were taken under consistent conditions, allowing for more accurate assessment of the impact of high-intensity interval training (HIIT) on blood sugar levels. Fasting status was verified upon arrival at the testing facility.

The normality test determines whether the data has a normal distribution. The test used is the Shapiro Wilk test. The criterion used to determine whether a distribution is normal is if the distribution is declared normal at $p > 0.05$ (5%). The data obtained from the pre-test (pre-test) and post-test (post-test) will be statistically analysed using the t-test using the SPSS computer program with a significance level of 5% or 0.05. The t-test aims to determine whether or not low and moderate-intensity aerobic exercise affects sugar levels. Hypothesis testing was carried out using a two-sample t-test with correlation, using SPSS 21 for Windows Evaluation Version.

Conclusion

This study aimed to investigate the impact of High-Intensity Interval Training (HIIT) on blood sugar levels in individuals with type 2

diabetes mellitus. The findings of this study contribute to a deeper understanding of the potential benefits of HIIT in the management of blood sugar in this population. Our results demonstrated a significant decrease in blood sugar levels following a structured 4-week HIIT program. The average blood sugar levels reduced from 179.25 mg/dL before the intervention to 134 mg/dL after HIIT, indicating the effectiveness of this training modality in improving glycaemic control. These findings align with previous research highlighting the HIIT role in enhancing insulin sensitivity and reducing blood sugar levels. While the results are promising, it is essential to acknowledge the study's limitations. This research was conducted with a relatively small sample size (20 participants), which may limit the generalizability of the findings. In addition, the study did not include a control group for comparison. Future research could benefit from larger sample sizes, longer follow-up periods, and control groups to further investigate the long-term effects of HIIT on blood sugar control and the potential impact on other aspects of health and wellness. In conclusion, the study underscores the potential benefits of High-Intensity Interval Training in improving blood sugar levels in individuals with type 2 diabetes mellitus. While the findings are encouraging, further research with larger and more diverse samples is needed to confirm and expand upon these results. HIIT may offer a valuable and time-efficient exercise option for individuals with diabetes, but a comprehensive approach to diabetes management should consider factors beyond exercise alone.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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