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Research article

The Effectiveness of Various Physical Activities on Glycemic Control in Individuals with Prediabetes Mellitus in Semarang Municipality

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Abstract

Currently, diabetes mellitus is a prevalence in Indonesia, with a rate of 2.1% based on relevant diagnoses or symptoms. It is estimated that by 2030, the number of individuals suffering form diabetes mellitus will reach 21.3 million. Conversely, the proportion of individuals with prediabetes is 2-4 times higher than those with diabetes. Physical activity has been identified as a preventive measure for prediabetes. Several studies have demonstrated the significant impact of physical activity on glycemic control. This study aimed to determine the effectiveness of different physical activities on glycemic control in prediabetic clients residing in Semarang municipality. A randomized control trials with a pretest-posttest design was conducted on 60 prediabetic clients using different treatments, including healthy / slow walking, brisk walking, and a combination of both slowly and brisk walking. The data of study were analyzed using univariate, and bivariate analysis using repeated ANOVA. All statistical analysis were carried out using SPSS version 22. The average level of glycemic control before intervention in the healthy walking group was 5.57%, which decreased to 5.46% after intervention. The combination group decreased from 5.93% to 5.78%, and in the slowly walking group decreased from 5.74% to 5.71%. However, there was no significant effect of slowly walking on glycemic control (HbA1c levels). In contrast, brisk walking and the combination of slowly walking and brisk walking had a significant effect on the glycemic control ($p<0.05$). The combination of physical activity group demonstrated the greatest impact on glycemic control ($p<0.05$).

PENDAHULUAN

In recent times, diabetes mellitus has emerged as a significant global health problem. Epidemiologically, the prevalence of individuals with diabetes mellitus across all age groups was 2.8% in 2000 and is projected to increase to 4.4% by 2030 [1]. The number of individuals affected by diabetes mellitus is expected to almost double by 2035, reaching approximately 592 million cases [1]. The World Health Organization (WHO) reports that 422 million individuals worldwide suffer from diabetes mellitus, with a prevalence of 8.5% occurring in the adults age group [2].

In Indonesia, the prevalence rate of diabetes mellitus based on relevant diagnoses or symptoms is reported to be 2.1%, and it is

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projected to reach 21.3 million by 2030 (Ministry of Health of Indonesia, 2028). In Central Java, diabetes mellitus ranks second among non-communicable diseases after hypertension, with the number of cases tending to increase each year. According to the report of the 3rd quarter of 215 of the Provincial Health Office of Central Java, the number of diabetes mellitus cases increased from 110,860 in 2013 to 121,203 in 2014 (Semarang City Health Office, 2020). In addition, the number of people with prediabetes has also shown an increasing trend, with the prediabetes population rising from 11.6% in 2003 to 35.3% in 2011.

Prediabetes is a significant metabolic condition that predisposes individuals to a high likelihood of developing diabetes, and it is associated with a higher risk of pathological disorders such as diabetic retinopathy, neuropathy, nephropathy, and macrovascular complications. Those with prediabetes are at an increased risk for complications such as chronic kidney disease (CKD), cardiovascular disease, coronary heart disease, and stroke. Studies have shown that individuals with prediabetes have a higher prevalence of diabetic retinopathy (7.9%) and peripheral neuropathy compared to those with normal glucose tolerance [3].

Maintaining healthy behavior is crucial for individuals with diabetes mellitus who require long-term care. The World Health Organization (WHO) recommends glycemic control as a key health behavior to effectively manage diabetes mellitus [2]. Long-term glucose concentration control, which should be relatively stable, is achieved through HbA1c level examinations that can be used for treatment planning. Good glycemic control, with an A1c level less than 7%, provides significant benefits for people with type 2 diabetes mellitus in reducing the risk of heart disease by 78%. Conversely, poor glycemic control can lead to mortality in elderly individuals with type 1 diabetes mellitus.

The management of blood sugar levels is individuals with type 2 diabetes mellitus can be achieved through various interventions, including physical activity. Literature has demonstrated a positive association between physical activity and type 2 diabetes mellitus. Self-management training for type 2 diabetes mellitus has been shown to enhance patients' knowledge, self-management frequency can accuracy of blood sugar, and self-reported dietary behaviors [4]. Furthermore, regular physical activity has been linked to a reduced risk of developing Impaired Glucose Tolerance (IGT) into type 2 diabetes mellitus. Previous studies have also reported that aerobic and resistance training can enhance insulin sensitivity in individuals with type 2 diabetes mellitus [5]. This increased insulin sensitivity can subsequently lead to decline in the concentration of blood glucose levels.

Physical inactivity has adverse effects on the health status of individuals with type 2 diabetes mellitus. Irregular physical activity increases the risk of developing diabetes mellitus, and if left untreated for an extended period, it leads to undesirable complications such as heart disease and stroke, neuropathy in the legs resulting in gangrene and amputation, diabetic retinopathy leading to blindness, and kidney failure. Conversely, regular physical activity ha s a positive impact on glycemic control and can prevent diabetes mellitus. The Ministry of Health of Indonesia (2018) reports that regular physical activity can lower the level of Hemoglobin A1c (HbA1c) below the threshold of 48 mmol/mol (6.5%) [6]. HbA1c forms when glucose in the bloodstream non-enzymatically reacts with the N-terminal valine in the beta chain in hemoglobin. Therefore, the higher the glucose level in the bloodstream, the higher the HbA1c value [7].

Physical activity is classified into three categories: light-intensity physical activity, moderate-intensity physical activity, and vigorous- intensity physical activity [2].

Light- intensity physical activity involves activities that require minimal effort, such as slow walking, sitting, standing, fishing, and playing music. Moderate- intensity physical activity requires more effort and leads to a significant increase in heart rate. Examples of moderate- intensity physical activity include brisk walking, dancing, gardening, housework, painting, and carrying items weighing less than 20 kilograms. On the other hand, vigorous-intensity physical activity is characterized by activities that require significant effort and lead to a considerable increase in heart and breathing rates. Examples of vigorous-intensity physical activity include running, walking on an incline, cycling quickly, aerobics, swimming, and carrying or moving objects weighing more than 20 kilograms [2]. Many studies concerning of physical activity have been reported, but the studies were conducted independently. However, the combined effect of physical activity on glycemic control is very limited, therefore the objective of this study was to determine the effectiveness of different physical activities on glycemic control in prediabetic clients residing in Semarang municipality.

METHOD

Study design

This study was a randomized control trial (RCT) using a pretest – posttest design.

Samples

The study was conducted in 2021 within the working area of a public health center (Puskesmas – Pusat Kesehatan Masyarakat) located in Semarang municipality. The study enrolled 60 literate prediabetic clients who lived with their families, actively participated in PROLANIS (Programs for the management of chronic diseases), completed the entire study protocol. Exclusion criteria included chronic kidney disease (CKD), anemia (hemoglobin levels below normal values), and refusal to participate. Participants were randomly assigned to one of three groups: group 1 underwent slowly walking, group 2 underwent brisk walking, and group 3 underwent a combination of slowly walking and brisk walking.

Intervention

The intervention in this study was given differently in each study group. Group 1 was given a slowly walking intervention which was carried out 5 times per week with a minimum duration of 20 minutes for each walk intervention. Group 2 was given a brisk walking interventions 5 times per week with a minimum duration of 15 minutes each time. Group 3 was given an intervention of a combination of physical activity (slow walking and brisk walking) which was carried out for 4 weeks with a minimum duration of 25 minutes each day for slowly walking on day 1, 2, 3 and 4, and a minimum duration of 25 minutes each day for brisk walking on day 5, 6, and 7. The initial measurement (pre-test) of glycemic control was carried out using the indicator of HbA1c levels, and the second measurement (post-test) was taken after 3-month treatment period.

Measurement and data collection

The study employed an observation sheet as the primary data collection tool to measure glycemic control by assessing HbA1c levels. Additionally, the media for taking blood preparations, such as a 3-cc syringe, were utilized to collect blood samples for the analysis of HbA1c levels. Chemical reagents were also included as part of the materials necessary to conduct the analysis of HbA1c levels. These tools and materials were selected based on their established reliability and validity in measuring glycemic control in similar research studies.

Data analysis

In this study, univariate data analysis was used to analyze the mean and standard

deviation, including the minimum and maximum values. Bivariate data analysis was conducted using a repeated ANOVA statistical test to determine the effect of intervention among the three intervention groups. A post-hoc test was then performance to identify which intervention was the most effective in stabilizing glycemic control as measured by HbA1c levels. The level of confidence used in this study was 95%, with an error rate of 5%. All statistical analyses were carried out by SPSS version 26.

Ethical considerations

In this study, the research samples were provided with information about the overall research and was provided their consent to participate by signing a consent form. The study received approval from the Health Research Ethics Committee of Politeknik Kesehatan Kemenkes Semarang – Minitry of Health of Indonesia, with the approval number 535/EA/KEPK/2021.

RESULTS

Participant Demographic Information

Table 1 illustrates that in general the characteristics of the study samples in the three study groups were comparable (homogeneous), except for the HbA1c level.

HbA1c development (before and after intervention)

Figure 1 demonstrates discernible differences in the initial HbA1c levels (pre-test) among the three groups, thereby imparting a consequential impact on the post-test HbA1c levels. Under such conditions, the assessment of the impact of brisk walking activity, and the combined effects of slow walking and brisk walking in comparison to slow walking alone, would inevitably lead to an overestimation. Hence, to oabtain prcise measurements of the effect, controlling for the initial HbA1c data is imperative.

Effectiveness of Physical Activity in Lowering HbA1c

Table 2 presents the outcomes of the examination of the efficacy of physical activity in reducing HbA1c levels, without adjusting for HbA1c levels at pre-test. The findings of this study are tentative as the obserbed effect size remains influenced by pre-HbA1c data. Hence, to obtain an accurate estimation of the activity effect, it is imperative to control for pre-HbA1c data using multivariate tests.

HbA1c development before and after intervention

Figure 2 displays the evolution of HbA1c levels among pre diabetes clients, before and after engaging in physical activity within the three groups, while adjusting for pre-HbA1c data. Following the implementation of pre-HbA1c data analysis, Figure 2 indicates that the initial HbA1c data were relatively consistent at a level of 5.75. In the brisk walking group, the HbA1c levels reduced to 5.61. Similarly, in the slow walking group, the reduction was only to 5.71. Based on the outcomes of the three interventions, it is apparent that the brisk walking and combination group exhibited a greater decrease in HbA1c levels compared to the slow walking group.

The Effectiveness of Physical Activity in Lowering HbA1ct test

Table 3 demonstrates the efficacy of physical activity in reducing HbA1c levels, following the implementation of a regression model with a multivariate t test, aimed at controlling for pre-HbA1c data. As depicted in Table 3, clients with pre-diabetic mellitus, who engaged in brisk walking, achieved a reduction in HbA1c by 0.09 as compared to patients with prediabetes who underwent slow walking, with statistically significant decrease (p= 0.041). Brisk walking led to a reduction of HbA1c by 7%. Moreover, the samples of this study who performed a combination of

brisk walking and slow walking recorded an 11% reduction in HbA1c levels compared to those who only engaged in slow walking, with a statistically significant decrease (p=0.013).

Table 1
Characteristics of samples

Characteristics	Physical Activity									*p*
	Brisk Walking			Combination (Brisk walking & slowly walking)			Slowly Walking			
	n	Mean	SD	n	Mean	SD	n	Mean	SD	
Age	20	39.4	9.93	20	40.1	7.19	20	41,2	5.24	0.756*
HbA1c	20	5.6	0.54	20	5.9	0.20	2-	5,7	0.51	0.045*
Education										
Elementary school	2	10%		4	20%		4	20%		0.509**
Primary school	3	15%		5	25%		2	10%		
Secondary school	9	45%		9	45%		12	60%		
Tertiary school	6	30%		2	10%		2	10%		

*one-way Anova **Fisher Exact

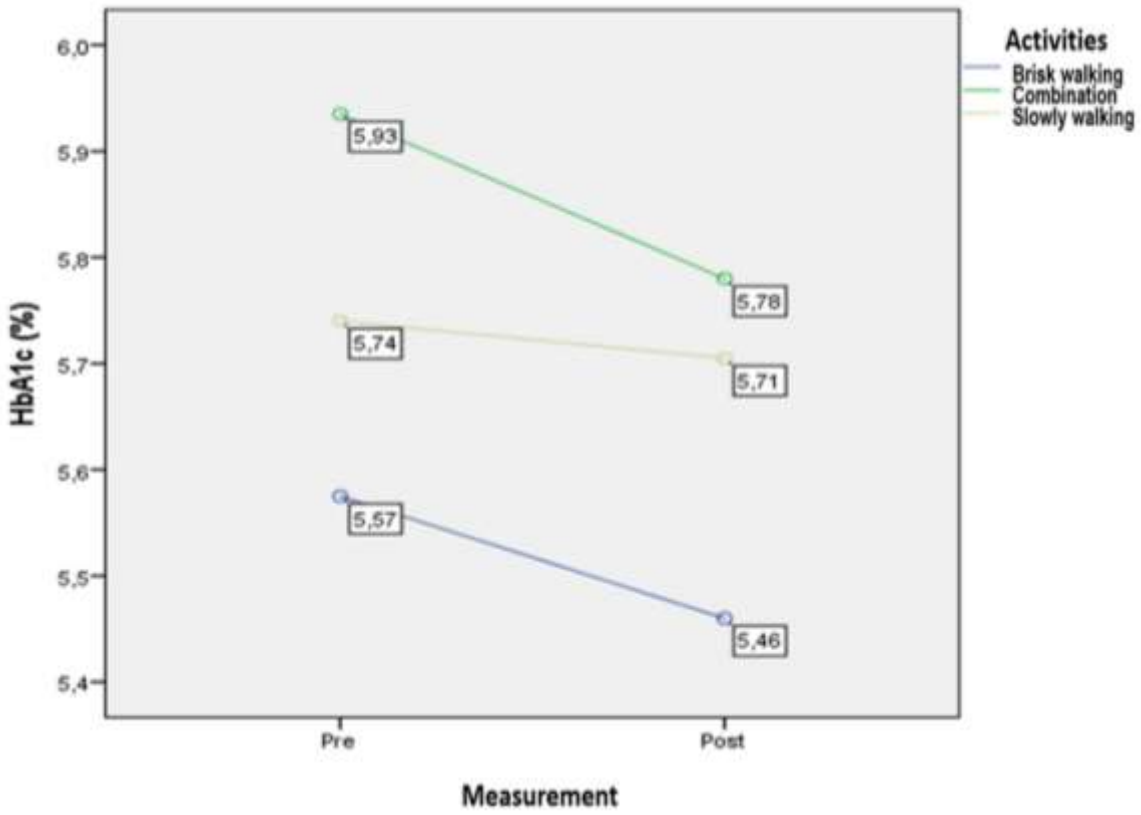

Figure 1
HbA1c development (before and after intervention)

Table 2
Effectiveness of Physical Activity in Lowering HbA1c

Activities	B	Std. Error	t	*p*	95% Confidence Interval		Partial Eta Squared
					Lower Bound	Upper Bound	
Brisk walking	-0.25	0.14	-1.76	0.084	-.524	.034	5%
Combination	0.07	0.14	0.54	0.593	-.204	.354	1%
Slowly walking	Reference group						

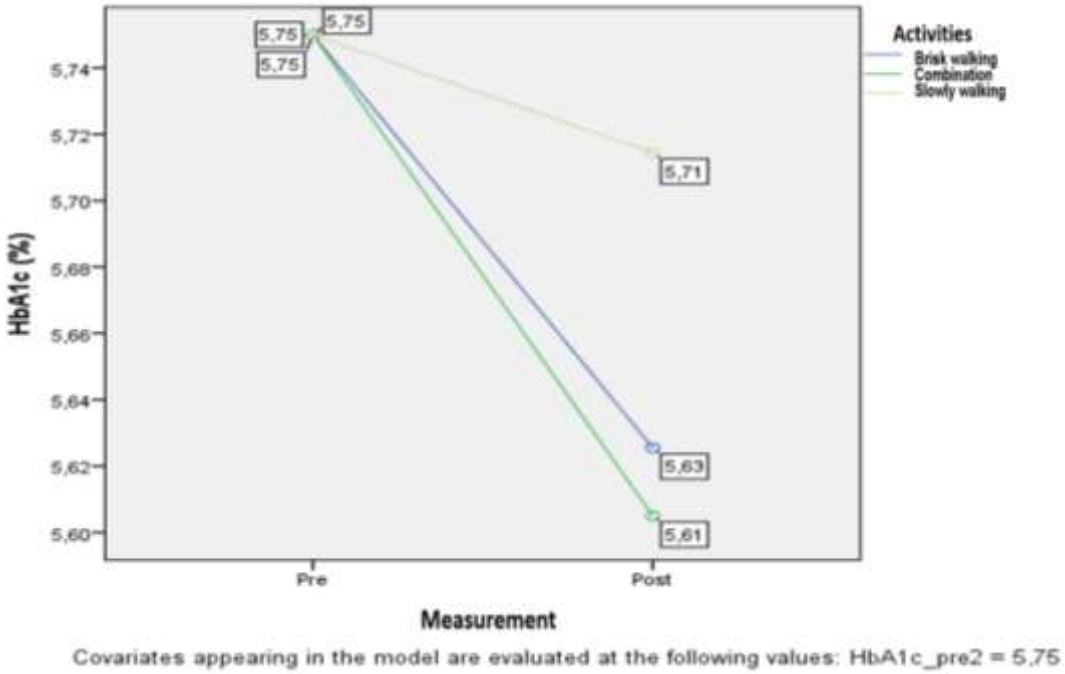

Figure 2
HbA1c development before and after intervention

Table 3
Effectiveness of Physical Activity in Lowering HbA1c

Activities	B	Std. Error	t	*p*	95% Confidence Interval		Partial Eta Squared
					Lower Bound	Upper Bound	
Brisk walking	-0.09	0.04	-2.09	0.041	-.174	-.004	7%
Combination	-0.11	0.04	-2.56	0.013	-.195	-.024	11%
Slowly walking	Reference group						

DISCUSSION

Effect of Physical Activity on HbA1c Levels

The findings suggest a reduction in HbA1c levels in all three study groups following physical activity. The brisk walking group was observed to achieve a reduction in HbA1c levels to 5.61, whereas the combination walking and brisk walking group could reduce HbA1c to 5.63. Conversely, the slow walking group could only achieve a reduction in HbA1c levels to 5.71. Based on these observations, it is evident that the brisk walking and combination groups were able to achieve a

greater decrease in HbA1c levels compared to the slow walking group.

The results of this study suggest that physical activity can have a significant impact on glycemic control or HbA1c levels. Regular physical activity or exercise has the potential to decrease the levels of HbA1c formed by the glycation of N-terminal valine in the beta chain of hemoglobin, leading to a normalization of HbA1c levels. This decrease in HbA1c levels may be attributed to the reduction in blood glucose levels resulting from energy utilization during physical activity, as supported by previous research studies [7; 8].

Physical activity encompasses all types of body movements that require energy expenditure, including slowly walking, brisk walking, and a combination of both, which were investigated in this study. During physical activity, skeletal muscles undergo hydrolysis of ATP to produce energy. One mole of ATP hydrolysis in muscle tissue generates 31 kJ (7.3 kcal) of energy and produces ADP and inorganic phosphate (Pi) as byproducts. The body utilizes three energy metabolism pathways to produce ATP during physical activity: phosphocreatine (PCr) hydrolysis, anaerobic glycolysis of glucose, and burning of stored carbohydrates, fats, and proteins [9]. This metabolic process allows glucose reserves in the blood to be utilized for energy during physical activity. The intensity of physical activity correlates with the amount of energy utilized, with heavier physical activity requiring more energy reserves.

The results of this study indicate that the lowest ability to reduce HbA1c levels is in the group of leisurely walking physical activity. Casual walking is included in the category of light-intensity physical activity, namely physical activity that requires light effort that does not cause the respiratory and heart rates to increase significantly when compared to moderate-intensity physical activity and vigorous-intensity physical activity [2]. While brisk walking physical activity and the combination of brisk walking and leisurely walking are physical activities that have a significant impact on the use of the body's energy stores, namely carbohydrate stores (blood glucose, muscle and liver glycogen), and fat stores in the form of triglycerides to contribute to the rate of energy production in the body [9]. This condition has a direct impact on the use of energy sources including blood sugar levels so that it has an impact on the value or level of glycemic control, namely HbA1c levels.

The study findings suggest that leisurely walking has the least ability to reduce HbA1c levels, while brisk walking and the combination of brisk and leisurely walking have a significant impact on the body's energy stores, including carbohydrate and fat stores [2]. Brisk walking and the combination of brisk and leisurely walking are considered moderate to vigorous-intensity physical activities that lead to an increase in heart and respiratory rates. This, in turn, contributes to the rate of energy production in the body, which has a direct impact on blood sugar levels and glycemic control, as reflected by HbA1c levels [9]. In contrast, leisurely walking is classified as a light-intensity physical activity that does not significantly increase heart and respiratory rates, and therefore has a limited impact on glycemic control.

The Most Effective Physical Activity in Lowering HbA1c Levels

The study also found that regular physical activity in the form of walking can have a positive impact on glycemic control, as it helps to decrease blood glucose levels by using it for energy during physical activity. This is because physical activity requires energy expenditure from skeletal muscles, which leads to the hydrolysis of ATP to produce energy. Furthermore, there are three energy metabolism pathways that can be used by the body to produce ATP, including the hydrolysis of

phosphocreatine, anaerobic glycolysis of glucose, and the burning of stored carbohydrates, fats, and proteins. This process allows glucose reserves in the blood to be used to meet the energy needed during physical activity.

The study found that both brisk walking and a combination of brisk walking and leisurely walking had a significant effect on lowering HbA1c levels in patients with pre-diabetes mellitus type 2, but the combination of physical activities resulted in a greater reduction in HbA1c levels compared to brisk walking alone. Therefore, the study concluded that combined physical activity may have a better effect on glycemic control in patients with pre-diabetes mellitus type 2.

This study investigated the effects of a 4-week physical activity regimen, comprising both brisk and slow walking, on energy metabolism. Participants engaged in walking activities for a minimum of 25 minutes each day, with the first 4 days consisting of a combination of slow and brisk walking and the subsequent 3 days solely brisk walking. The primary energy source for this metabolic process is carbohydrates, which undergo glycolysis to generate ATP molecules. Carbohydrates are obtained from blood glucose or muscle glycogen, and glucose formed during the process can be stored as glycogen in the liver and muscles or delivered to cells that require energy [9]. Regular physical activity, such as brisk walking, is crucial to achieving optimal energy metabolism efficiency.

The combination group in this study also incorporated leisurely walks into their physical activity regimen. This approach enabled participants to experience a sense of comfort following adequate physical exertion to elevate their heart and respiratory rates. The comfort derived from this activity minimized the potential for stress that could lead to increased blood sugar levels. Prolonged elevation of blood sugar levels in blood vessels can be indicative of higher HbA1c levels, which can have detrimental effects on an individual's health. Therefore, incorporating leisurely walks into a physical activity regimen can help maintain optimal blood sugar levels and reduce the risk of associated complications [10].

Implication and limitations

The findings of this study have significant implication for the management of individuals with prediabetes, particularly in stabilizing glycemic control. However, it is important to acknowledge the limitations of this study, as several factors may influence glycemic control, including diet, alcohol consumption, and Body Mass Index (BMI), which were not entirely controlled for in this study. Additionally, family support can also impact the pattern of physical activity performed, although this was controlled for with standard operating procedures (SOPs) for physical activity. Thus, further research is necessary to explore the interplay between these factors and the impact on glycemic control in individual with prediabetes.

CONCLUSION

Slow walking did not have s significant effect on glycemic control (HbA1c levels), however, both brisk walking and the combination of slow walking and brisk walking had a significant impact on glycemic control (HbA1c levels) ($p<0.05$). Notably, the combination of slow and brisk walking demonstrated superior efficacy in glycemic control compared to the group that solely engaged in slow walking.

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