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A School-Based Aerobic Exercise Program to Improve Blood Sugar Levels Among Adolescents at Risk of Type 2 Diabetes

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Abstract

Background: The prevalence of type 2 diabetes mellitus (T2DM) continues to increase among adolescents due to sedentary lifestyles and poor health behaviors. Early preventive interventions, particularly physical activity integrated into school settings, are essential to minimize the risk of future metabolic disorders. This study aimed to determine the effect of a school-based aerobic exercise program on blood sugar levels among adolescents at risk of T2DM.
Methods: A quasi-experimental pre-test and post-test control group design was conducted among 60 adolescents aged 13–15 years in Bandung City who were identified as having moderate to high diabetes risk using the FRIDEM application. Participants were assigned into an intervention group (n = 30) and control group (n = 30). The intervention group performed structured aerobic exercise for 30 minutes, three times per week over four weeks, while the control group followed their usual school routine. Fasting blood glucose was measured before and after the intervention. Data were analyzed using paired t-test and ANCOVA.
Results: There was a significant decrease in fasting blood glucose in the intervention group from 123.00 ± 15.70 mg/dL to 100.97 ± 10.80 mg/dL ($p < 0.001$). In contrast, the control group showed a slight increase from 110.77 ± 14.12 mg/dL to 115.70 ± 17.55 mg/dL ($p = 0.077$). ANCOVA indicated a significant difference in post-test blood glucose values between groups after controlling for baseline levels ($p < 0.001$).
Conclusion: A structured school-based aerobic exercise program effectively reduced blood sugar levels among adolescents at risk for type 2 diabetes mellitus. Incorporating regular aerobic exercise into school curricula may serve as an important preventive strategy to improve metabolic health and reduce diabetes risk in youth.

Keywords: Aerobic exercise, adolescents, blood sugar, diabetes risk, school-based intervention, prevention

INTRODUCTION

Diabetes mellitus is one of the most common chronic metabolic diseases worldwide and continues to increase in prevalence each year (1,2). It results from impaired insulin production or insulin resistance, leading to prolonged hyperglycemia and increased risk of severe complications (3). Globally, more than 422 million people live with diabetes, and this burden is projected to escalate if preventive actions are not strengthened (3). According to the International Diabetes Federation (4), 537 million adults aged 20–79 years are diagnosed with diabetes, representing a 24% increase over recent years. Indonesia ranks fifth worldwide, with a national prevalence that continues to rise (4,5). Bandung City alone reported over 44,000

confirmed cases in 2022, demonstrating a persistent sharp increase compared to the previous year (6).

Modifiable behavioral and environmental risk factors play a major role in the development of type 2 diabetes mellitus (T2DM), including poor diet, physical inactivity, obesity, inadequate sleep, and unmanaged stress (7,8). Individuals with unmanaged risk factors are more likely to progress from prediabetes to diabetes within 3–4 years (9). Thus, early prevention, especially during adolescence, is a critical strategy in minimizing future disease burden (10).

Adolescence is recognized as a vulnerable developmental stage due to rapid physical, psychosocial, and lifestyle changes that influence long-term health behaviors (11,12). Many adolescents adopt unhealthy dietary patterns, consume excessive sugary drinks, smoke, and engage in sedentary lifestyle activities such as prolonged screen time (9,13,14). Current data show alarming trends: 159,014 adolescents aged 15–24 years in Indonesia have been diagnosed with diabetes (15). Moreover, insufficient physical activity contributes significantly to elevated diabetes risk among youth, with national statistics indicating that one-third of adolescents fail to meet recommended physical activity levels (16).

Regular physical activity is essential for energy expenditure, improved insulin sensitivity, weight management, and overall metabolic health among adolescents (17). During exercise, skeletal muscles increase glucose uptake, contributing to improved glycemic control and helping prevent persistent hyperglycemia (18,19). Aerobic exercise is considered an easy, enjoyable, and widely acceptable form of physical activity for young people, including activities such as walking, running, cycling, and gymnastics (20,21). Prior studies in adults have demonstrated that aerobic exercise can significantly reduce blood glucose levels among individuals with T2DM (22).

However, despite strong evidence supporting aerobic exercise for glycemic control in adult populations with established diabetes, limited research has specifically examined its preventive effects in adolescents at elevated risk of T2DM in school settings. Adolescents represent a large and accessible population group, making schools a strategic venue for implementing structured physical activity interventions. Moreover, validated tools such as the FRIDEM application now enable early identification of adolescents at risk for diabetes, presenting new opportunities for targeted prevention programs.

Therefore, this study aims to evaluate the effectiveness of a structured, school-based aerobic exercise program in improving blood sugar levels among adolescents at risk of type 2 diabetes mellitus. The findings are expected to provide evidence-based recommendations for early intervention and contribute to diabetes prevention strategies within educational environments.

METHODS

Study design

This study used a quasi-experimental pre-test and post-test control group design to investigate the effectiveness of a school-based aerobic exercise program on blood sugar levels among adolescents at risk of type 2 diabetes mellitus.

Sample

The study was conducted at a junior high school in Bandung City, West Java, Indonesia, with the target population consisting of 8th-grade students who had been screened for diabetes risk using the FRIDEM application.

A total of 60 adolescents were selected through purposive sampling based on the screening results and were then divided equally into the intervention group (n = 30) and the control group (n = 30). Eligible participants were adolescents aged 13–15 years, classified as having a moderate or high risk of diabetes, physically capable of performing exercise, and had obtained written parental consent and personal assent. Adolescents who were already diagnosed with diabetes mellitus, experienced physical limitations that prevented physical activity, or developed severe illness during the study period were excluded from participation. The sample size was calculated using G*Power version 3.1 for a paired t-test with a significance level of 0.05, power of 0.80, and an effect size of 0.50, which indicated that a minimum of 52 participants was required. To anticipate potential dropouts, the number was increased to 60 participants.

Intervention

The intervention consisted of a structured aerobic exercise program conducted three times

per week for 30 minutes per session over a period of four weeks. The exercise included moderate-intensity rhythmic aerobic movements and was supervised by physical education teachers and the research team to ensure participant safety and adherence. The control group did not receive any structured physical activity and continued with their regular school routine.

Measure

Blood sugar levels were measured using a standardized glucometer under fasting conditions at two time points: before the intervention (baseline) and at the end of the four-week intervention period. Diabetes risk was assessed prior to the intervention using the FRIDEM application as a validated early detection tool for adolescents.

Data analysis

Data were analyzed using SPSS version 25. Descriptive statistics were presented as frequencies, percentages, means, and standard deviations. The paired t-test was used to assess changes in blood sugar levels within each group, and the independent t-test was used to compare differences in outcomes between the intervention and control groups. A p-value of less than 0.05 was considered statistically significant.

Ethical condiseration

Ethical approval was obtained from the Institutional Review Board of the Nursing Research Ethics Committee. Permissions from the school and written consent from parents or guardians, as well as assent from the students, were secured before data collection. Data collection procedures included participant screening, baseline measurement, implementation of the exercise program, and post-intervention measurement. After completion of the study, results and feedback were provided to the participants and their parents.

RESULTS

This section presents both univariate and bivariate analyses. Univariate findings describe respondent characteristics, while bivariate analyses examine differences in blood glucose levels within and between groups using paired t-test and ANCOVA.

Respondents in both groups showed comparable baseline characteristics. Independent t-test results indicated no statistically significant differences in age, height, weight, or diabetes risk score between groups ($p > 0.05$), confirming homogeneity (Table 1).

Table 1. Characteristics of respondents: age, height, weight, and diabetes risk score in intervention and control groups

Variables	Intervention (n = 30) Mean ± SD	Min–Max	Control (n = 30) Mean ± SD	Min–Max	*p-value*
Age (years)	13.82 ± 0.53	13–15	13.80 ± 0.41	13–14	0.278
Height (cm)	159.37 ± 10.79	141–185	155.70 ± 8.47	133–177	0.675
Weight (kg)	49.53 ± 13.61	32–105	48.20 ± 10.77	32–72	0.148
DM risk score	2.67 ± 1.09	1–6	2.53 ± 1.53	1–7	0.707

Gender distribution was identical between groups with 17 females and 13 males in each group. The chi-square test demonstrated no significant difference ($p = 0.134$), indicating homogeneity of categorical data.

Table 2. Distribution of respondents based on gender in intervention and control groups

Gender	Intervention (n = 30) n (%)	Control (n = 30) n (%)	*p-value*
Female	17 (56.7%)	17 (56.7%)	0.134
Male	13 (43.3%)	13 (43.3%)	

Fasting blood glucose in the intervention group notably decreased following the aerobic exercise program. Conversely, the control group showed a slight increase (Table 3).

Table 3. Pre- and post-intervention fasting blood glucose levels

Variables	Intervention Group (n = 30) Mean ± SD (Min–Max)	Control Group (n = 30) Mean ± SD (Min–Max)
Pre-test	123.00 ± 15.70 (97–172)	110.77 ± 14.12 (80–142)
Post-test	100.97 ± 10.80 (80–124)	115.70 ± 17.55 (85–157)

The intervention group demonstrated a statistically significant reduction in blood glucose levels after the aerobic exercise program ($p < 0.001$). In contrast, no significant change occurred in the control group ($p > 0.05$) (Table 4).

Table 4. Paired sample t-test results for intervention and control groups

Group	t	*p-value*	Interpretation
Intervention	8.921	0.000	Significant decrease
Control	-1.834	0.077	Not significant

ANCOVA results confirmed a significant difference in post-intervention blood glucose levels between the intervention and control groups after adjusting for pre-test values ($p = 0.000$). These findings indicate that the aerobic exercise program had a meaningful effect on improving glycemic outcomes among adolescents at risk for type 2 diabetes (Tabel 5).

Table 5. ANCOVA analysis comparing post-test glucose levels between groups

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	14970.111	35	427.717	3.085	0.003
Intercept	20977.062	1	20977.062	151.298	0.000
Group	2398.294	1	2398.294	17.298	0.000
GDS_Pre	10055.961	34	295.764	2.133	0.028
Error	3327.539	24	138.647		
Total	700751.000	60			
Corrected Total	18297.650	59			

DISCUSSION

This study examined the effects of a school-based aerobic exercise program on blood sugar levels among adolescents at risk for type 2 diabetes mellitus. The results showed a significant decrease in fasting blood glucose in the intervention group, while the control group experienced a slight increase. These findings suggest that regular aerobic exercise contributes to improved glycemic control among adolescents with elevated diabetes risk. The reduction in blood glucose levels observed in the intervention group is consistent with (22), who reported that structured aerobic exercise significantly lowered blood glucose levels in individuals with type 2 diabetes compared to those who did not receive the intervention. In the present study, the intervention group experienced a mean decrease from 123.00 mg/dL at baseline to 100.97 mg/dL post-intervention, while the control group exhibited an increase from 110.77 mg/dL to 115.70 mg/dL. These contrasting outcomes support the notion that lack of physical activity may accelerate dysregulation of glucose metabolism.

Physical inactivity is known to reduce glucose uptake in skeletal muscle, leading to elevated glucose circulating in the bloodstream (23). Aerobic exercise enhances insulin sensitivity and stimulates glucose transport into muscle cells through greater activation of GLUT-4 receptors, improving glycemic stability (19). The findings of this study are further supported by (24), who observed significant improvements in glucose levels after aerobic exercise interventions. Importantly, this study highlights the relevance of early preventive strategies during adolescence. Adolescents today are increasingly exposed to sedentary lifestyle behaviors, including prolonged screen-time, inadequate exercise, and poor diet, which contribute to the rising incidence of prediabetes and early-onset diabetes (13). By integrating aerobic exercise into school-based programs, early modification of risk behaviors becomes feasible and impactful. Previous evidence has emphasized that early lifestyle modification may delay or prevent the development of type 2 diabetes later in life (25). The ANCOVA results in our study confirmed that aerobic exercise had a statistically significant effect between groups ($p < 0.001$), even after

controlling for pre-intervention glucose values. This underscores the robustness of the intervention effect and demonstrates aerobic exercise as a reliable method for improving metabolic health in school settings.

This study provides practical implications for school health programs. Implementing regular, structured aerobic exercise sessions during physical education classes could serve as a sustainable strategy to prevent metabolic disorders in adolescents. Moreover, targeted screening tools such as the FRIDEM application can help identify students who may benefit most from early prevention efforts. While the results are promising, limitations should be considered. The intervention period was relatively short (four weeks), and long-term follow-up was not performed. Additionally, dietary intake and daily physical activities outside school were not controlled, potentially influencing glucose outcomes. Future studies should incorporate longer intervention durations, include broader lifestyle monitoring, and consider HbA1c assessments for more comprehensive glycemic evaluation.

CONCLUSION

The findings of this study demonstrate that a structured aerobic exercise program significantly improves fasting blood glucose levels among adolescents at risk of type 2 diabetes mellitus. Adolescents in the intervention group experienced a meaningful reduction in blood sugar levels, whereas the control group showed a slight increase. These results indicate that aerobic exercise performed three times per week for 30 minutes is an effective preventive strategy for improving glycemic control and reducing diabetes risk in youth populations. Strengthening school-based physical activity initiatives is therefore essential to support long-term metabolic health and reduce the future burden of diabetes.

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Author Contributions

SSA: Conceptualization, study design, data collection, data analysis, manuscript drafting.
SS: Supervision of intervention implementation, manuscript editing and revision.

Conflict of Interest

The authors declare that there are no conflicts of interest related to the publication of this study.

Data Availability

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request, subject to ethical approval and the protection of participant confidentiality.

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