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RISK FACTORS FOR DIABETES MELLITUS AND THEIR ASSOCIATION WITH BLOOD GLUCOSE LEVELS IN ADOLESCENTS

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ABSTRACT

The onset of Diabetes Mellitus (DM) among adolescents worldwide has been increased. **Objective:** This study aimed to analyze risk factors associated with DM among adolescents including family history, tobacco consumption, blood pressure, blood glucose levels, Body Mass Index (BMI), and physical activity. **Method:** This cross-sectional study included 211 individuals selected through simple random sampling. Data were obtained using a questionnaire to risk factors of DM (family history, tobacco consumption). Random Capillary Blood Glucose (RCBG) was measured by glucometer. BMI *Z* score was calculated using growth standard for adolescents. Blood pressure was determined by automatic monitor in accordance with the American Academy of Pediatrics (AAP) hypertension clinical guidelines. Physical activity were assessed using Physical Activity Questionnaire for Adolescent (PAQ-A). Then, analysis was carried out using the Spearman rank rho statistical test. **Results:** Among 211 adolescents, most were normoglycemic (79.6%), low physical activity (78.2 %), obesity (17.5 %), and having elevated blood pressure (46.0%). There was no significant relationship between family history of diabetes, smoking habits, blood pressure, BMI, physical activity and blood glucose levels ($p > 0.05$). **Discussions:** Although there was no significant relationship was found, however, the presence of multiple risk factors indicates that early metabolic risk may already exist, while the prediabetes phase in adolescents often remains unrecognized. **Conclusion:** These findings emphasize the importance of early preventive strategies and lifestyle interventions to reduce future metabolic risk. Future research is required to identify other risk factors of DM.

Keywords : Adolescents, diabetes mellitus, glucose, risk factors

BACKGROUND

In 2024, it is estimated that 589 million adults aged 20-79 were living with diabetes. Indonesia is among the top five countries with the highest number of people with diabetes in the 20–79 age group. The country with the highest number is China (148 million), followed by Indonesia (20.4 million), Japan (10.1 million), Thailand (6.4 million), and the Republic of Korea (5.0 million). Additionally, over 9.5 million people had type 1 diabetes in 2024, of whom 1.9 million children and adolescents under the age of 20 (International Diabetes Federation, 2025). These data indicate the importance of reducing the prevalence of diabetes mellitus (DM) in Indonesia, particularly as the onset of metabolic diseases, including DM, among children and adolescents has increased significantly. Adolescence, particularly during puberty, represents a critical developmental phase characterized by substantial biological and psychosocial

changes (Mastorci et al., 2024). This increase in incidence is also influenced by hormonal and metabolic changes, including reductions in insulin sensitivity and shifts in cardiometabolic risk factors.

Puberty is associated with significant hormonal changes that exacerbate insulin resistance and may accelerate the development of complications, particularly among adolescents with type 2 diabetes. Additionally, puberty may act as a triggering period for the onset of type 1 diabetes mellitus, with peak incidence observed between the ages of 10 and 14 years. Despite these risks, early stages of the disease are often asymptomatic, leading to prediabetes remaining largely undetected and frequently overlooked. (Boddu, Giannini, and Marcovecchio, 2025; Lawrence et al., 2023).

According to the American Diabetes Association (ADA), risk factors for pre-diabetes include a family history of diabetes, hypertension, a sedentary lifestyle, obesity, and dyslipidemia, particularly characterized by low levels of high-density lipoprotein (HDL) cholesterol (American Diabetes Association, 2019). These factors are closely linked to the rising prevalence of obesity, risk-taking behaviours such as alcohol, smoking, drugs among children and adolescents which represents a major global health challenge (Boddu, Giannini, and Marcovecchio, 2025). This condition poses a serious threat to Sustainable Development Goal (SDG) 3, which aims to ensure healthy lives and promote well-being for all. It is also associated with unhealthy dietary patterns, including frequent consumption of fast food. In addition, most students demonstrate insufficient levels of physical activity. These findings are consistent with global evidence indicating that unhealthy lifestyle behaviours contribute to the rising incidence of metabolic diseases among younger populations (Prabawati and Natalia, 2025). This issue is drawing increasing global attention identifying relevant risk factors for DM in adolescents. Future research is expected to focus on endothelial dysfunction, exposure risks, cardiometabolic risk, changes in gut microbiota, and the impact on comorbidities and health outcomes (Zhang et al., 2025).

Determinant factors such as Body Mass Index (BMI), dietary patterns, and physical activity are key factors in the development and progression of metabolic diseases during childhood and adolescence, alongside additional risk factors such as genetic predisposition, ancestry, ethnicity, life course events (e.g., puberty), and other environmental factors (Hashemi et al., 2022). The combination of these risk factors contributes to disturbances in glucose regulation, manifested as impaired glucose tolerance (IGT) or impaired fasting glucose (IFG), which can eventually progress to type 2 DM. The absolute risk of this progression largely depends on individual characteristics, such as age and BMI (International Diabetes Federation, 2025).

Based on the survey conducted by the West Kalimantan Provincial Health Office in 2022, early detection of risk factors of DM at SMA Muhammadiyah 1 Pontianak show the following percentages: smoking behavior 7.03%, lack of physical activity 72.97%, inadequate intake of fruits and vegetables 24.32%, overweight 3.83%, obesity 23.44%, hypertension 33.49%, and excessive blood sugar 0.48%. This indicates an increased risk of DM among adolescents. Furthermore, a preliminary study conducted at Muhammadiyah 1 Pontianak Senior High School, involving interviews with 20 students, identified several lifestyle-related risk factors. More than half of the respondents reported a preference for sugar-sweetened beverages over plain water, while a substantial proportion exhibited unhealthy habits.

These findings underscore the urgent need for further investigation into the magnitude and interactions of these risk factors in relation to blood glucose levels among adolescents, particularly in urban settings in Indonesia, such as Pontianak. Elucidating these relationships is essential for developing targeted health promotion programs, preventive strategies, and early screening initiatives to reduce the burden of diabetes mellitus in adolescent populations. Therefore, this study aims to examine the risk factors influencing blood glucose levels among adolescents at SMA Muhammadiyah 1 Pontianak.Top of Form

METHODS

The method used in this study is an analytical method with an observational cross-sectional design (Hardani et al., 2020). Research conducted at Muhammadiyah 1 Pontianak Senior High School in August, 2023. The population size was 449 adolescents aged 15-19. The number of respondents was calculated using the Slovin formula, accounting for a 5% margin of error, resulting in sample size of 211 people (Tejada, Raymond, & Punzalan, 2012). The respondents were selected by purposive sampling. Inclusion criteria were students aged over 15 years who were enrolled at Muhammadiyah 1 Pontianak Senior High School.

Participants completed a structured questionnaire with sociodemographic (age, sex, family history) and general clinical information, such as smoking status. Data collection involved on-site measurement of blood pressure, blood glucose, BMI, and physical activity. Blood pressure was measured by the automatic monitor (Omron). Blood pressure values were classified using the 2017 American Academy of Pediatrics (AAP) hypertension clinical guidelines (Flynn et al., 2017). In the 2017 AAP Hypertension Clinical Guidelines, blood pressure values in adolescents ≥13 years of age were classified as normal (<120/<80 mmHg), elevated (120/<80 to 129/<80 mmHg), stage 1 hypertension (130/80 to 139/89 mmHg), or stage 2 hypertension (≥140/≥90 mmHg) (Sudikno et al., 2023).

The BMI *Z* score was calculated using the 2017 WHO growth standard for adolescents aged 15–18. BMI-for-age is defined using standard deviations (SD) from the median: Thinness: - 3 SD to <- 2 SD, healthy weight -2 SD to +1 SD, overweight + 1 SD to +2 SD and obese > + 2 SD (Ministry of Health of the Republic of Indonesia, 2020).

The data were obtained by measuring blood glucose levels in adolescents using a glucometer and glucose stick (Easy Touch). The examination tools and materials used in this research were 70% alcohol swab, cotton, autoclick, lancet, and glucometer. The glucose test was Random Capillary Blood Glucose (RCBG) performed (it was taken without standardizing the time since the last meal). The level of glucose was measured using the Children and Adolescents: Standards of Care in Diabetes 2023, and the following interpreted result was found: level of > 200 mg/dL considered Hyperglycemia, Hypoglycaemia occurs when the blood glucose level is < 70 mg/dl and normoglycemia 70-200 mg/dl (American Diabetes Association, 2019; Arslanian et al., 2018; ElSayed et al., 2022).

Physical activity was assessed using Physical Activity Questionnaire for Older Adolescent (PAQ-A), by Kawalski, which has favourable validity and reliability across multiple countries (Andriyani et al., 2024; Kowalski et al., 2004). The item validity of the Indonesian version of PAQ-A shows reliability consistency (α-Cronbach of 0.77) and an excellent total intraclass correlation coefficient (ICC = 0.40 - 0.83) (Rahayu, Sumaryanti, and Arovah, 2022).

Questionnaires were administered in hard copy under the researchers' supervision, who attempted to ensure that no data were missing. PAQ-A consists of nine questions about daily physical activity during the week, in and outside the school for the last week. The first question contains 16 questions that specifically discuss the time adolescents spend on various type of physical activity and sports. Question 2-7 ask for their physical activity during leisure time, physical education, lunch, after school, evening, weekend. Item 8 ask the frequency of physical activity during each day of the last week, while the ninth question review changes in physical activity compared to the previous week. For the first eight items, the score ranges from 1-5 as follow: 1 (very low), 2 (low), 3 (moderate), 4 (high), 5 (very high), in which the highest score indicates a higher physically active level. Scores for items 1 and item 8 are the average of the responses. The final score of PAQ-A is the average of items 1 to 8. Assigned PAQ scores ≤ 2 as "low activity," > 2 and ≤ 3 as "moderate activity," and > 3 as "high activity" (Chen et al., 2008).

Kolmogorov-Smirnov normality test was conducted before performing correlation analysis. The results of the normality test using Kolmogorov-Smirnov showed that all variables were not normally distributed ($p < 0.05$) (Table 1). The correlation test used in this study was the Spearman test with a significance level of 5%. Data analyzed using SPSS version 16.0. Participants were provided with written consent, and the research protocol was approved by the Human Ethics Committee of Muhammadiyah Institute of Technology and Health West Kalimantan (approval number 137/II.I.AU/KET.ETIK/V/2023).

RESULTS

Based on Table 2, the study included 211 adolescents, with a nearly equal distribution of males (50.24%) and females (49.76%). Based on Table 3, approximately one-third of participants (34.12%) reported a family history of DM, most (95.73%) reported no smoking. More than half of the adolescents had normal blood pressure (54.03%), while 13.27% were classified as having stage 1 or stage 2 hypertension. The majority of respondents were normoglycemic (88.15%), and nearly one-third were classified as overweight or obese (29.03%) and physical activity levels were predominantly low (78.20%). Table 4 presents the correlation between selected risk factors and blood glucose levels indicating that family history of DM, smoking habits, blood pressure, BMI, and physical activity were not significantly associated with blood glucose levels ($p > 0.05$), with correlation coefficients ranging from -0.106 to 0.068, reflecting very weak relationships.

DISCUSSION

Overall, the findings indicate that although several metabolic and lifestyle risk factors were present, none showed a statistically significant correlation with blood glucose levels in this adolescent. Youth-onset DM type 2 is an emerging global public health concern and associated with genetic, environmental, and metabolic factors that differ among individuals and populations (Boddu, Giannini, and Marcovecchio, 2025).

In this study, family history of DM was not significantly associated with blood glucose levels, suggesting that genetic predisposition alone may not be sufficient to influence glycemic status during adolescence. Previous studies have shown that youth-onset type 2 DM is a more severe and progressive condition than adult-onset type 2 diabetes. For preventive, genetic susceptibility can be detected as early as the first decade of life, in otherwise clinically healthy children and adolescents with a family

history of type 2 DM (Bombaci et al., 2025; Rodriquez and O'Sullivan, 2023).

Smoking behavior was reported by only a small proportion of respondents, and smoking habits were not significantly associated with blood glucose levels. Adolescents in this study may not have been exposed to cigarette smoking for a sufficient duration; therefore, the mechanism by which cigarettes increase insulin resistance may not yet have had a significant impact and smoking causing chronic inflammation of tissues and vessels, it is also related to changes in lipid metabolism (Holanda and Pereira, 2024).

Blood pressure abnormalities were observed in a notable proportion of respondents, including elevated blood pressure and stage 1 and stage 2 hypertension. Although no significant association was found between blood pressure and blood glucose levels in this study, this finding remains important, given that metabolic dysregulation progesses with age (Sriranjan et al., 2025).

In addition to optimizing glycemia, control of hypertension is important to prevent and slow the progression of nephropathy, but primary hypertension is common in patients with pediatric DM type 2. Primary hypertension is the most common cause of hypertension in adolescents and is especially common in those with obesity (Holanda & Pereira, 2024).

Based on the measurement of nutritional status, nearly one-third of respondents were classified as overweight or obese. Excess adiposity is a key contributor to insulin resistance and a major driver of type 2 DM. Nevertheless, BMI was not significantly correlated with blood glucose levels in this study. This finding may be attributed to the predominance of normoglycemia among participants, suggesting that metabolic compensation mechanisms. Although obesity is a well-established risk factor, the coexistence of smoking and low physical activity may further increase the risk of DM (Holanda & Pereira, 2024).

Physical activity levels among respondents were predominantly low. However, no significant relationship was found between physical activity and blood glucose levels. This result may reflect, as the metabolic effects of low physical activity often manifest after prolonged exposure rather than in the short term. International guidelines recommend that children and adolescents to Moderate-to Vigorous Aerobic Physical Activity (MVPA) for at least 60 min, in addition to 3 days per week of vigorous exercises and activities (Huerta-Uribe et al., 2023).

The majority of adolescents in this study exhibited normoglycemic blood glucose levels, with only a small proportion presenting hyperglycemia. This supports the notion that adolescence is a critical window for prevention, during which risk factors may be present but have not yet translated into overt metabolic dysfunction (Carducci et al., 2025). Early identification of these risk factors is therefore essential to prevent progression to dysglycemia and type 2 DM in adulthood.

Overall, the findings highlight that while diabetes-related risk factors are prevalent among adolescents, their direct association with blood glucose levels may not yet be evident. These results underscore the importance of early lifestyle interventions targeting physical activity, healthy weight maintenance, and cardiometabolic risk awareness in school-based settings. Longitudinal studies are warranted to clarify the temporal relationship between adolescent risk factors and future glycemic outcomes.

Several limitations should be considered when interpreting the findings of this study. First, the cross-sectional design limits the ability to establish causal relationships between diabetes risk factors and blood

glucose levels. Longitudinal designs would be better suited to examine the progression of metabolic risk over time. Second, blood glucose levels were assessed using random capillary blood glucose measurements without standardization of fasting status or time since the last meal. While this method is appropriate for population-level screening, variability in recent dietary intake may have influenced individual glucose measurements. Third, several important variables that could potentially influence blood glucose levels in adolescents were not investigated, including biochemical profiles (e.g., lipid levels), dietary patterns, psychosocial factors, stress levels, and environmental and socioeconomic variables. Finally, the low proportion of participants with hyperglycemia may have constrained the ability to detect statistically significant associations. Studies with larger and more heterogeneous populations may provide greater insight into the relationship between adolescent risk factors and glycemic status.Top of Form

CONCLUSION

This study showed that none of the examined risk factors were significantly associated with blood glucose levels. Most respondents were normoglycemic, despite the high prevalence of modifiable risk factors such as low physical activity, overweight and obesity, and elevated blood pressure. These findings highlight the importance of early preventive efforts and lifestyle interventions during adolescence to reduce future metabolic risk. Longitudinal studies are needed to assess the progression of these risk factors into adulthood.

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