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The Relationship between Body Mass Index, Blood Glucose Levels, and Blood Pressure among Adolescents
(A Case Study at SMK Indonesia Putera Blitar)

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Abstract. The increasing prevalence of adolescent obesity may contribute to metabolic disorders such as type 2 diabetes mellitus and hypertension. This study aimed to examine the relationship between body mass index (BMI), blood glucose levels, and blood pressure among adolescents. This study employed a case study design involving students from a vocational high school. A total of 73 students were selected using purposive sampling. Data was analyzed using the Spearman rank correlation test. The analysis revealed a weak positive correlation between BMI and random blood glucose levels (r_s = 0.381) and between BMI and mean blood pressure (r_s = 0.536). A total of 28.8% of the students had elevated blood glucose levels, particularly among those classified as overweight or obese. Increased BMI may promote the accumulation of free fatty acids and chronic inflammation, which can impair GLUT4 translocation and contribute to hyperglycemia. This condition may be exacerbated by physiological insulin resistance during puberty, increasing the risk of pancreatic beta-cell exhaustion. Elevated blood pressure may be influenced by hyperleptinemia, which activates the sympathetic nervous system and the renin–angiotensin–aldosterone system. BMI was significantly and positively associated with random blood glucose levels and mean blood pressure, indicating that higher BMI may increase the risk of metabolic disorders among adolescents. Schools are recommended to conduct regular health screenings every semester and promote balanced nutrition education and structured physical activity programs.

Keywords: Body Mass Index, Blood Glucose, Blood Pressure, Adolescents.

1. INTRODUCTION

The prevalence of obesity among adolescents is increasing and is associated with metabolic disorders such as diabetes and hypertension. Adolescents are in a phase of rapid growth and development. During adolescence, changes in lifestyle, unhealthy eating habits, frequent consumption of fast food, and insufficient physical activity may adversely affect health and lead to obesity [1]. According to WHO, more than 390 million children and adolescents aged 5–19 years were overweight in 2022, increasing from 8% in 1990 to 20% in 2022. The prevalence of obesity also increased from 2% to 8% during the same period [1]. In Indonesia, the prevalence of overweight and obesity among children aged 5–12 years was 20%, among those aged 13–15 years was 16.5%, and among adolescents aged 16–18 years was 13.5% [2].

Other survey findings indicate that type 2 diabetes mellitus is increasingly common at younger ages, with an average age of approximately 13.5 years [3]. The prevalence of hypertension among adolescents has also increased from 4.32% to 7.89% [4]. Type 2 diabetes mellitus is not only a health issue among adults but is also found in obese adolescents because of dietary patterns and lifestyle. Obesity also affects the cardiovascular system by increasing vascular resistance and cardiac workload, can gradually increase blood pressure. If this condition persists without preventive measures, it may progress to hypertension. Hypertension in adolescents can increase the likelihood of various cardiovascular diseases in adulthood, including heart disease and stroke [5]. A high BMI reflects overweight or obesity, which may increase the risk of metabolic and cardiovascular disorders, including diabetes mellitus, hypertension, and chronic disease [6]. The aim of this study was to describe the relationship between Body Mass Index, blood glucose levels, and blood pressure in adolescents.

2. METHODS

A case study design was used. The independent variable was Body Mass Index, while the dependent variables were random blood glucose level and mean arterial pressure. The study sample consisted of 73 adolescents enrolled at SMK Indonesia Putera Blitar who voluntarily participated and were selected using purposive sampling. Data collection instruments included a GEA BR 9015B weighing scale, a GEA height measuring device, an OMRON HEM 7120 sphygmomanometer, and an Easy Touch GCU glucometer. Data were collected by the researchers during the morning school break from May to July 2026. Ethical approval was granted by the Health Research Ethics Committee of STIKes Patria Husada Blitar, Number 06/PHB/KEPK/425/05.26, dated May 22, 2026.

3. RESULTS AND DISCUSSION

The characteristics of students at SMK Indonesia Putera Blitar are presented in Table 1.

Table 1. Characteristics of students at SMK Indonesia Putera Blitar (n=73)

No.	Characteristics	f	%
1	Sex:		
	Female	71	97.3
	Male	2	2.7
2	Age:		
	16 years	5	6.8
	17 years	50	68.5
	18 years	18	24.7
3	Family Medical History:		
	None	63	86.3
	Diabetes	3	4.1
	Hypertension	7	9.6
4	Blood glucose level:		
	Low	9	12.3
	Normal	43	58.9
	High	21	28.8
5	Body Mass Index:		
	Severely Underweight	1	1.4
	Underweight	0	0.0
	Normal	55	75.3
	Overweight	13	17.8
	Obese	4	5.5

Table 2. Measurement results among students at SMK Indonesia Putera Blitar (n=73)

No.	Variable	Minimum	Maximum	Mean ± SD
1	Body weight (kg)	35.00	89.00	53.01 ± 11.00
2	Height (cm)	141.00	165.00	154.30 ± 5.21
3	Body Mass Index	15.06	34.77	22.22 ± 4.20
4	Random Blood Glucose	54.00	160.00	111.49 ± 28.16
5	Systolic Blood Pressure	88.00	144.00	114.86 ± 15.25
6	Diastolic Blood Pressure	55.00	100.00	75.62 ± 5.21
7	Mean Arterial Pressure	67.33	107.67	88.70 ± 11.47

Table 3. Relationship between Body Mass Index, Random Blood Glucose, and Mean Arterial Pressure

Variable	p-value	Spearman correlation
BMI – Random Blood Glucose	0.001	0.381
BMI – Mean Arterial Pressure	0.000	0.536

The cross-tabulation between Body Mass Index and random blood glucose is presented in Table 4.

Table 4. Cross-tabulation between Body Mass Index and Blood Glucose Levels

Body Mass Index (BMI)	Random Blood Glucose							
	Low		Normal		High		Total	
	f	%	f	%	f	%	f	%
Severely underweight	0	0.0	1	1.4	0	0.0	1	1.4
Underweight	0	0.0	0	0.0	0	0.0	0	0.0
Normal	8	11.0	36	49.3	11	15.1	55	75.3
Overweight	1	1.3	4	5.5	8	11.0	13	17.8
Obese	0	0.0	2	2.7	2	2.7	4	5.5
Total	9	12.3	43	58.9	21	28.8	73	100.0

Table 1 shows the clinical profile of the students, with 28.8% having random blood glucose levels above the normal range. The identification of metabolic and blood pressure risks during adolescence highlights the importance of regular assessment of nutritional status and adolescents' physiological health.

Table 3 shows a positive relationship between Body Mass Index (BMI) and random blood glucose ($r_s = 0.381$), categorized as weak. This relationship indicates that an increase in body mass relative to height tends to be accompanied by an increase in blood glucose levels among adolescents. This finding is consistent with previous research indicating that increased BMI is an independent predictor of impaired blood glucose regulation at a young age. Individuals with BMI values above the normal range consistently show lower insulin sensitivity ratios. Reduced sensitivity causes glucose in the bloodstream to be inadequately taken up by peripheral tissue cells [7]. Thus, these empirical data confirm that changes in body composition resulting from weight gain may begin to exert physiological effects on glucose metabolism as early as adolescence.

In Table 4, the proportion of students with high blood glucose levels increased markedly in the higher-BMI groups. Among overweight students, 8 of 13 students, equivalent to 11% of the total sample, had blood glucose levels above normal. Meanwhile, among obese students, half of the group, namely 2 of 4 students (2.7% of the total sample), also had high blood glucose levels. This increase in blood glucose among students with excess body weight is supported by research showing that the prevalence of prediabetes and impaired fasting glucose is directly proportional to the degree of obesity during adolescence. High body fat accumulation during school age has been shown to trigger increased baseline insulin resistance before the full clinical manifestation of diabetes mellitus [8]. Therefore, the presence of high blood glucose among students in the overweight and obese categories underscores the importance of vigilance regarding the risk of type 2 diabetes mellitus.

On the other hand, Table 2 shows an interesting finding among students with normal nutritional status: 11 of 55 students (15.1% of the total sample) also had high blood glucose levels. Elevated blood glucose among some adolescents with normal nutritional status indicates that BMI is not the sole determinant of glucose homeostasis. This finding is supported by evidence that body-fat distribution, such as visceral and intramyocellular fat, can promote insulin resistance even when overall BMI is within the normal category. In addition to internal fat composition, a diet high in simple sugars and a sedentary lifestyle strongly influence fluctuations in random blood glucose levels [9]. A transient rise in random blood glucose among adolescents with normal BMI may also be influenced by consumption of sweet foods or beverages shortly before measurement. High intake of rapidly absorbed carbohydrates can trigger a temporary rise in blood glucose before the insulin regulatory system responds adequately.

The findings of this study emphasize that adolescence is a critical period for metabolic development. Although the strength of the correlation between BMI and blood glucose in this sample was weak (rs = 0.381), its cumulative long-term health effects should not be overlooked. Cohort studies have demonstrated that elevated blood glucose and BMI during adolescence significantly increase the risk of developing type 2 diabetes mellitus in young adulthood [10]. Therefore, routine BMI measurement in school settings can serve as a practical and affordable early detection measure. Education on balanced dietary patterns and regular physical activity should also be integrated into school health programs. Early intervention during school age is expected to reduce obesity incidence and prevent progression of metabolic disorders. Regular monitoring of nutritional status and blood glucose among adolescents is a crucial investment in creating a healthy and productive younger generation.

The mechanism by which body fat accumulation, reflected by an above-normal BMI, affects blood glucose and blood pressure is illustrated in Figure 1.

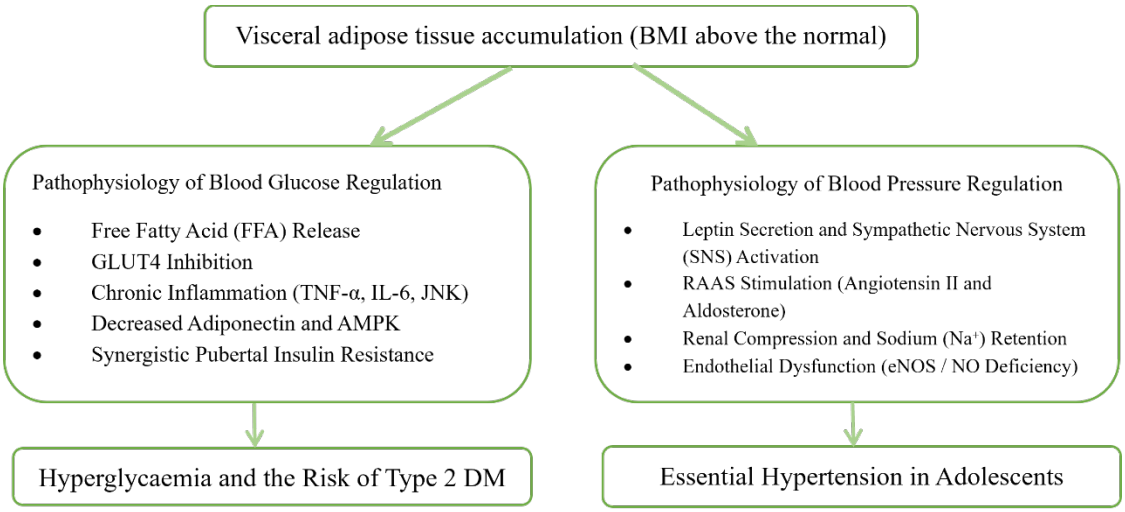


Figure 1. Pathophysiological Mechanisms of Body Fat Accumulation Affecting Blood Glucose

The main mechanism linking increased Body Mass Index (BMI) to elevated blood glucose levels begins with the accumulation of free fatty acids (FFAs) in the bloodstream. When BMI increases because of adipose tissue accumulation, adipocytes, particularly in visceral regions, undergo hypertrophy and lose their ability to store triglycerides efficiently. This adipocyte hypertrophy promotes excessive lipolysis, releasing large amounts of free fatty acids into the circulation. Based on molecular mechanistic studies, elevated circulating FFAs compete with glucose for uptake into skeletal muscle and liver cells. FFAs entering peripheral tissues are converted into intracellular lipid metabolites such as diacylglycerol (DAG) and ceramides. Accumulation of DAG and ceramides subsequently activates protein kinase C (PKC), which inhibits phosphorylation of insulin receptor substrate-1 (IRS-1) at tyrosine residues. Inhibition of the IRS-1 signaling pathway directly impairs translocation of glucose transporter type 4 (GLUT4) vesicles to the cell membrane. Without adequate GLUT4 availability on the muscle cell membrane, glucose uptake from the bloodstream is impaired, resulting in accumulation of glucose in circulation, or hyperglycemia [9].

In addition to free fatty acid accumulation, adipose tissue accumulation in individuals with high BMI triggers a state of chronic low-grade systemic inflammation. Enlarged adipocytes experiencing local hypoxia attract infiltration of M1 macrophages into adipose tissue. These pro-inflammatory macrophages, together with adipocytes, secrete inflammatory cytokines such as tumor necrosis factor-alpha (TNF-α), interleukin-6 (IL-6), and monocyte chemoattractant protein-1 (MCP-1). A systematic review explains that the pro-inflammatory cytokine TNF-α actively stimulates c-Jun N-terminal kinase (JNK) and inhibitor of kappa B kinase (IKK-β) in insulin-target cells. Activation of JNK and IKK-β induces serine phosphorylation of IRS-1, impairing insulin signaling. At the same time, levels of the anti-inflammatory, insulin-sensitizing hormone adiponectin decline markedly in individuals with high BMI. Reduced adiponectin decreases the activity of AMP-activated protein kinase (AMPK) in the liver, which normally suppresses gluconeogenesis [11]. As a result of impaired suppression of gluconeogenesis and severe inhibition of insulin signaling, hepatic glucose production continues in an uncontrolled manner, increasing blood glucose levels.

A specific mechanism that exacerbates the effect of increased BMI on blood glucose levels in adolescents is physiological insulin resistance during puberty. During adolescent growth, secretion of growth hormone (GH) and insulin-like growth factor 1 (IGF-1) increases substantially from the pituitary gland. Research has documented that the growth hormone surge during puberty naturally reduces insulin sensitivity by 25%–30% in adolescents. In adolescents with normal BMI, the pancreas can compensate physiologically by increasing insulin secretion adequately to maintain stable blood glucose levels. However, in adolescents with high BMI or obesity, insulin resistance caused by excess fat accumulation interacts synergistically with physiological pubertal insulin resistance. This dual interaction creates a substantial workload for pancreatic beta cells, which must continuously secrete increased amounts of insulin. Over time, pancreatic beta cells may experience metabolic exhaustion and endoplasmic reticulum stress, resulting in a relative decline in insulin secretory capacity [12]. The inability of the pancreas to meet the high insulin demand ultimately causes failure of glucose control and contributes to increased random blood glucose levels in adolescents with high BMI.

The mechanism by which BMI affects blood pressure begins with activation of the sympathetic nervous system (SNS) due to hyperleptinemia originating from visceral adipose tissue. Leptin stimulates the hypothalamic vasomotor center, which promotes activation of the renin–angiotensin–aldosterone system (RAAS). Angiotensin II induces peripheral arteriolar vasoconstriction, whereas aldosterone promotes sodium and water retention in the renal tubules. In addition, perirenal fat accumulation mechanically compresses the renal parenchyma, altering the pressure–natriuresis relationship. Concurrently, inflammation reduces endothelial nitric oxide synthase (eNOS) expression, decreasing production of the vasodilator nitric oxide (NO) and promoting arterial stiffness [13], [14].

Based on this study, the implications for adolescent health are as follows:

1. Increased BMI accompanied by elevated blood glucose levels among adolescents increases the risk of youth-onset type 2 diabetes mellitus. Historically, type 2 diabetes mellitus has been regarded as a degenerative disease that primarily affects adults and older individuals. However, epidemiological studies have demonstrated that an increase in BMI during adolescence is directly associated with a substantial increase in the incidence of type 2 diabetes mellitus before the age of 30. Type 2 diabetes mellitus diagnosed during adolescence has been shown to follow a considerably more aggressive clinical course than disease with onset at an older age. Adolescents with type 2 diabetes mellitus experience a decline in pancreatic beta-cell function approximately four times faster than adults with the disease [10]. The rapid progression of this disease underscores the need for serious attention and early intervention to prevent permanent metabolic deterioration at a young age.
2. The emergence of cardiometabolic complications and early microvascular complications affecting the blood vessels of adolescents. Chronically elevated blood glucose levels can trigger non-enzymatic glycation of proteins in the vascular walls. Adolescents with hyperglycemia associated with a high BMI are at increased risk of developing retinopathy and nephropathy within several years after disease onset. In addition to small-vessel damage, hyperglycemia in the presence of a high BMI is often accompanied by disturbances in lipid profiles, such as elevated triglyceride levels. This combination of metabolic risk factors accelerates the formation of atherosclerotic plaques in the coronary and carotid arteries beginning during adolescence. Consequently, the risk of myocardial infarction and stroke in young adulthood increases significantly due to vascular structural changes that begin during adolescence [11].
3. The development of cognitive impairment and decreased academic performance among students. High and unstable blood glucose levels can disrupt the continuous supply of energy to the adolescent brain. Previous research has indicated that poor blood glucose regulation is associated with mild neurophysiological disturbances during developmental stages. Extreme fluctuations in random blood glucose levels may frequently lead to physical fatigue, decreased concentration, and drowsiness during school hours. In the long term, these conditions may impair working memory and problem-solving abilities among adolescents [7]. This indicates that metabolic disturbances associated with a high BMI may not only cause physical health problems but may also adversely affect adolescents' educational prospects.
4. The need for changes in health promotion strategies and school-based primary prevention policies. The positive correlation between BMI and blood glucose levels indicates that preventive programs should be initiated before severe clinical symptoms develop. The implementation of integrated screening that combines anthropometric measurements with periodic blood glucose testing among school-aged adolescents is therefore recommended [8]. Schools can play an active role by providing adequate sports and physical activity facilities and limiting the sale of sugar-rich foods and beverages in school canteens. Healthy lifestyle education involving family participation can be highly effective in establishing sustainable dietary habits. This comprehensive preventive approach represents a rational strategy for protecting the cardiovascular and metabolic health of younger generations in the future.

4. CONCLUSIONS

Based on the analysis and discussion, the following conclusions can be drawn:

1. BMI is associated with random blood glucose (r_s = 0.381) and mean arterial pressure (r_s = 0.536) in adolescents.
2. Students classified as overweight and obese showed a tendency toward above-normal blood glucose levels and hypertension.
3. Increased BMI during adolescence has long-term implications for the increased risk of youth-onset type 2 diabetes mellitus and elevated blood pressure.

Recommendations:

1. Regular School Screening: Conduct measurements of body weight, height/BMI, and regular monitoring of blood pressure and random blood glucose every semester.
2. Nutrition Education Intervention: Conduct balanced nutrition education programs and limit consumption of ultra-processed foods and sugar-sweetened beverages in the school environment.
3. Physical Activity Promotion: Implement structured exercise programs for at least 150 minutes per week to improve students insulin sensitivity.

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