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Influence of BAZ on fasting blood glucose levels as a prediabetes indicator in adolescents in Jambi City

Pengaruh IMT/U terhadap kadar glukosa darah puasa sebagai indikator pradiabetes pada remaja di Kota Jambi

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Abstract

Prediabetes is an intermediate stage of impaired glucose tolerance (IGT). If left unresolved for 3-5 years, it can significantly increase the risk of developing diabetes mellitus. Body mass index (BMI) for age score (BAZ) is a key indicator of lifestyle choices that influence the risk of prediabetes. Objective: To investigate the interaction between BAZ and fasting blood glucose as a prediabetes indicator. The methods. This cross-sectional study was conducted at Senior High School 2 in Jambi City in 2019. A total of 140 participants aged 15-18 years were included, meeting criteria such as parental/guardian consent, willingness to participate, and fasting from 11 p.m. to 7:30 a.m. Independent variables included a family history of diabetes mellitus, family history of obesity, consumption of carbohydrates, fats, sugary drinks, waist-to-height ratio, physical activity, and BMI. The dependent variable, prediabetes, was measured using fasting blood glucose with a spectrophotometer biochemical analyzer AE-600N at a wavelength of 500 nm. Data were analyzed using the chi-squared test and multiple logistic regression analysis, The results showed a significant interaction between BMI and prediabetes (p=0,026; OR=4,34) after confounding factor analysis of family history of diabetes (p=0,050; OR=3,00), physical activity (p=0,020; OR=5,012), and sugar-sweetened beverages (p=0,018; OR=4,21), even after adjusting for other independent variables. In conclusion, BAZ > 1 SD was the dominant factor associated with an increased risk of prediabetes.

Keywords: Glucose intolerance, insulin sensitivity, in paired glucose

Abstrak

Prediabetes merupakan tahap peralihan dari toleransi glukosa terganggu (TGT). Jika tidak ditangani selama 3-5 tahun, kondisi ini dapat secara signifikan meningkatkan risiko berkembangnya diabetes melitus. Indeks massa tubuh menurut umur (IMT/U) adalah indikator kunci yang mencerminkan pilihan gaya hidup yang mempengaruhi risiko prediabetes. Tujuan penelitian untuk mengetahui interaksi antara IMT/U dengan kadar glukosa darah puasa sebagai indikator prediabetes. Metode penelitian menggunakan desain potong lintang, telah dilakukan di SMA 2 Kota Jambi, pada tahun 2019. Sebanyak 140 peserta berusia 15-18 tahun diikutsertakan yang memenuhi kriteria inklusi. Variabel independen meliputi riwayat keluarga dengan diabetes melitus, riwayat keluarga dengan obesitas, perilaku konsumsi karbohidrat, lemak, minuman manis, rasio lingkar pinggang terhadap tinggi badan, aktivitas fisik, dan IMT. Variabel dependen, yaitu prediabetes, diukur menggunakan glukosa darah puasa dengan spektrofotometer biokimia AE-600N pada panjang gelombang 500 nm. Data dianalisis menggunakan uji chi-square dan analisis regresi logistik berganda. Hasil menunjukkan adanya interaksi signifikan antara IMT dengan prediabetes (p=0,026; OR=4,34), setelah faktor perancu dianalisis seperti riwayat keluarga dengan diabetes (p=0,050; OR=3,00), aktivitas fisik (p=0,020; OR=5,012), dan minuman manis (p=0,018; OR=4,21), bahkan setelah penyesuaian untuk variabel independen lainnya. Kesimpulan, bahwa IMT/U diatas 1 SD merupakan faktor dominan yang berhubungan dengan peningkatan risiko prediabetes.

Kata Kunci: Gangguan glukosa, intolerance glukosa, sensitivitas insulin

Introduction

Prediabetes could be a condition in which blood glucose levels are higher than typical with one of the indicators, specifically impeding fasting glucose 110 to125 mg/dL. The prevalence of prediabetes aged 12-19 years is 17,7% (Menke et al., 2016). In 2045, the prevalence of prediabetes is predicted to increase from 8,3% to 7,3% in 2017 (Davidson et al., 2021). The proportion of adolescents (> 15 years) with prediabetes in Indonesia in 2018 was 14,9%, 2023 it and 10,8% (Kementerian Kesehatan RI, 2024). In Jambi, adolescents aged 14-18 years had a 17,9% risk of prediabetes (Junita et al., 2021). Uncontrolled prediabetes in their teens has a high probability of developing diabetes 40-55% for 3-5 years as an adult), and eventually, 70% will develop diabetes mellitus during their lifetime (Monhaty, 2018). Risk factors for prediabetes include waist-to-height ratio (WHtR), physical activity, and sugar-sweetened beverages, which are important markers of obesity and blood glucose levels (Putra & Junita, 2018; Putra & Junita, 2022).

People with WHtR values > 0,5 cm have fasting blood sugar levels that are higher than typical limits and are classified as having prediabetes (Dutta et al., 2020; Putra & Junita, 2022; Vasquez et al., 2019; Zhang et al., 2021). This is reinforced by studies that found that 11,4% of adolescents with high RLPTB were at risk of prediabetes (Lee et al., 2021). In general, WHtR is an indicator of body fat deposits related to abdominal obesity and insulin resistance if the excessive distribution of ectopic fat on the visceral causes abnormal fat metabolism by means of fat tissue increasing plasma concentrations of free fatty acids, adipokines, and pro-inflammatory cytokines, thereby exacerbating the development of prediabetes (Liu et al., 2021)

Physical activity has benefits that are advantageous not only in weight loss but also in directing blood glucose levels and insulin sensitivity of the adipose tissue. Performing physical activity 30 until60 min/day or 150 min/week specific moderate and heavy intensity can increase insulin sensitivity. A meta-analysis of 24 studies showed that physical activity has a positive effect on insulin secretion, which is a marker of insulin resistance and provides blood glucose stability (Park & Hwang, 2020). The underlying mechanism is that physical activity suppresses gluconeogenesis by activating mitochondrial oxidative capacity and reducing glucose production (Seo et al., 2021).

Risk factors that cause prediabetes include the consumption of unhealthy foods such as a diet with higher fat and carbohydrate intake, less fiber intake, and a high intake of sweet or sugary drinks, which are strongly associated with various degenerative diseases. In the last five years, many drinks with high sugar content and calories have appeared, which range from to 38-96 grams and 299-515 kcal of energy per serving. Sugar-sweetened beverages with high-fructose corn syrup/HFCS (55% fructose), (45% glucose), or sucrose (50% fructose, 50% glucose) (Li et al., 2019; Min et al., 2017). Consumption of 10 g/day of added sugar from sugary drinks is associated with 0,04 mmol/L higher fasting glucose (Ma et al., 2016; Wang et al., 2014).

Consumption of high carbohydrates and fat is also associated with prediabetes. This study showed that people who consume carbohydrates have a nearly 4x increased risk of developing prediabetes. Individuals who consume saturated fat will increase risk by 2,5 times for the occurrence of prediabetes (Khoiriyah et al., 2018). Consumption of carbohydrates with a high glycemic index increases blood glucose levels compared with the consumption of foods with a low glycemic index (Lobos et al., 2017; Rahmad, 2021).

Obesity has also been associated with prediabetes. Prevalence In 1156 otherwise healthy adolescents, 21% were found to have prediabetes to diagnosis type 2, and decreased first-phase insulin secretion has been demonstrated in obese adolescents with impaired fasting glucose, impaired glucose tolerance, or both compared to adolescents with normal glucose metabolism(Bacha et al., 2010). A study using C-peptide modeling of oral glucose tolerance test results showed that the glucose sensitivity of first-phase insulin secretion progressively decreased as glucose metabolism worsened in obese adolescents with impaired fasting glucose alone or impaired glucose tolerance under both conditions (Narasimhan & Weinstock, 2014). Whole-body insulin sensitivity (hormonal effects in all insulin-responsive tissues and organs) is decreased in overweight children and adolescents with impaired glucose tolerance compared to that in similarly overweight adolescents with normal glucose intolerance (Arslanian et al., 2018).

Therefore, this study aimed to determine the interaction between BMI and fasting blood glucose levels as an indicator of prediabetes in adolescents aged 15-18 years at State Senior High School, 2 Jambi City.

Methods

This was an analytical observational study with a cross-sectional design conducted from August to September 2019 with students of SMAN 2 in Jambi City. This study was approved by the Health Research Ethics Commission of the Health Polytechnic of the Jambi Ministry of Health (approval number: LB.02.06/2/14/2019).

The population in this study included all students of senior high school in two Jambi City aged 15-19 years in 2020 with a sample of 140 people using the calculation formula in the OpenEpi application from the target population of 2020 youth, with (p) 10,9%, which is the proportion of diabetes mellitus at the age of> 15 years (Kementerian Kesehatan RI, 2018), absolute precision (d) 5%, design effect (for cluster surveys-DEFF) 1,0, and confidence level (CI) 95%. Simple random sampling was employed, and students were randomly selected from each class with an equal allocation. The inclusion criteria required students to be aged 15-18 years and willing to fast from 11:00 PM to 7:30 AM for blood glucose testing. Permission was obtained from the parents/guardians. The exclusion criteria for athletes were sick conditions such as fever, diarrhea, or congenital degenerative diseases such as type 1 DM.

The collected variables included data on general characteristics, including age, sex, and several risky behaviors, such as smoking behavior (smokers and/or passive smokers), family history of diabetes mellitus with an operational definition of a grandmother and/or parents medically diagnosed with diabetes mellitus, and a history of obesity. family (obese mothers and/or fathers) using a general questionnaire. Carbohydrate consumption behavior was divided into two categories, namely risky if carbohydrate intake was >400 g/day for men and >300 g/day for women, and not at risk if carbohydrate consumption was ≤400 g per day for men, and 300 g/day for women, the behavior of consuming fiber is divided into 2 groups, namely at risk if consuming fiber <25g/day and not at risk if consuming fiber ≥25g/day, then the behavior of consuming sweet drinks is divided into two categories namely risky if consumption of sweetened drinks containing (sugar, sucrose, fructose, sorbitol, aspartame) >12g/day and not at risk if consuming sweetened drinks containing (sugar, sucrose, fructose, sorbitol, aspartame) ≤12g/day, and total fat consumption behavior is at risk if total fat consumption is >85 gram per day for men or 70 gramper day for women and are not at risk if total fat consumption is ≤85 g/day (men) and then 70 g/day (women) (Ly et al., 2014).

Physical activity was measured using the short version of the International Physical Activity Questionnaire (IPAQ-SF). guidelines that have been translated into Bahasa (Chan et al., 2017) using the interview method and then processed using the IPAQ-SF guidelines scoring protocol with the help of the IPAQ-SF automatic report, which is divided into risk categories if metabolic equivalents of task (MET) <600 METs-min/week and not at risk if MET ≥600 METs-min/Sunday. The second independent variable was the ratio of waist circumference to height, measured using a meter (cm), and microtoises with risk (≥0,5 cm) and not-at-risk (<0,5 cm) categories. Body Mass Index was measured using a microtoise for height and an AND digital scale. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m2) for all participants. The BMI standard is the 2020 WHO anthropometric standard, with a risk category of BAZ > 1SD, and not at risk if BAZ ≤ 1 SD.

The dependent variable of the study was fasting blood glucose as an indicator of prediabetes risk, which was categorized as at risk of prediabetes if fasting blood sugar levels were 110–125 mg/dL and not at risk of prediabetes if fasting blood sugar levels were <100 mg/dL (Echouffo-Tcheugui & Selvin, 2020). A blood sample was placed in a cooler box and subjected to the biosystem method using an AE-600N biochemical analyzer spectrophotometer at a wavelength (λ) of 500 nm at the Laboratory of the Health Analyst Department of the Jambi Ministry of Health Polytechnics.

Data analysis was conducted in three stages: univariate analysis, which included presenting subject characteristics via frequency distribution, and bivariate analysis, which utilized the chi-square test with a significance level of p<0,05. For subject characteristics and independent variables, a G test (log-likelihood ratio) was carried out to determine the relationship with the risk of adolescent prediabetes; if the p-value <0,25, the variable will be continued in the multivariate analysis stage, then the multivariate analysis used is multiple logistic regression because the variables are scaled nominally to determine which factors are dominantly linked to the risk of prediabetes in adolescents (p < 0,05).

Result and Discussion

Independent variables related to the risk of prediabetes were the ratio of waist circumference to height, body mass index, physical activity, carbohydrate consumption, and sugary drink consumption. Adolescents with a waist-to-height ratio (WHtR) > 0,5 cm had a 2,6 times risk of developing prediabetes (p=0,05) than adolescents with (WHtR) ≤ 0,5 cm Adolescent body mass index by category BAZ >+1SD was associated with the risk of prediabetes (OR=3,395; p=0,03). Adolescents with a physical activity risk of <600 MET minutes/week has 4,3 times risk of prediabetes than those with a risk of > 600 MET minutes/week (p=0,02). Adolescents with carbohydrate consumption behavior of more than 300 – 400 g/day were associated with prediabetes, as evidenced (OR = 4,058; p= 0,01 The last variable related to the incidence of prediabetes was consumption of sweet drinks (OR= 4,333; p= 0,01) (Table 1).

Table 1. Bivariate analys of determinant factors with prediabetes risk

Determinant variable	Prediabetes		OR (95% CI Lower - Upper)	p-value
	Yes= 25	No=115		
	n (%)	n (%)		
WHtR				
High risk	12 (28,6)	30 (34,5)	2,615 (1,076 – 6,357)	0,05
Not risk	13 (13,3)	85 (80,5)		
Family history of diabetes mellitus				
High risk	8 (32)	17 (68)	2,713 (1,013 – 7268)	0,80
Not risk	17 (20,5)	98 (94,5)		
Family history of obesity				
High risk	1 (11,1)	8 (88,9)	0,557 (0,067 – 4,668)	0,92
Not risk	24 (23,4)	107 (81,7)		
Body Mass Index for Age Zscore (BAZ)				
High risk	8 (36,4)	14 (63,6)	3,395 (1,237 – 9,314)	0,03
Not risk	17 (14,4)	101 (85,6)		
Physical activity				
High risk	22 (23,4)	72 (76,6)	4,380	0,02
Not risk	3 (6,5)	43 (93,5)	(1,237 – 15,502)	
Carbohydrate consumption behavior				
High risk	9 (39,1)	14 (60,9)	4,058	0,01
Not risk	16 (13,7)	101 (86,3)	(1,508 – 10,917)	
Fiber consumption behavior				
High risk	25 (18,9)	107 (81,1)	0,811 (0,746 – 0,880)	0,37
Not risk	0 (0)	8 (100)		
Fat consumption behavior				
High risk	14 (23,3)	46 (76,7)	1,909 (0,797 – 4,572)	0,21
Not risk	11 (13,8)	69 (86,2)		
Sugar sweetened-beverages				
High risk	21 (25)	63 (75)	4,333 (1,399 –	0,01
Not risk	4 (7,1)	52 (92,9)	13,422)	

The results of the analysis (Table 1) showed that seven variables were associated with prediabetes risk: WHtR, BAZ, family history of diabetes mellitus, physical activity, carbohydrate consumption, fat consumption, and sugary consumption. Furthermore, multivariate analysis modeling was conducted for these variables. Tests conducted with the G test (log-likelihood ratio) had a p-value <0,25 and could be used as a modeling candidate (Table 2).

Tabel 2. Interaction determinant factors with prediabetes risk

Regression Model	Variable	p-value	OR (Odds Ratio)
	WHtR	0,809	1,184
	Body Mass Index for Age Zscore (BAZ)	0,191	2,888
	Family history of Diabetes	0,024	3,938
Model 1	Physical activity	0,025	4,994
	Carbohydrate consumption behavior	0,432	1,645
	Fat consumption behavior	0,231	2,012
	Sugar sweetened-beverages	0,046	3,614
Model 2	Body Mass Index for Age Zscore (BAZ)	0,021	3,817
	Family history of Diabetes	0,050	3,004
	Physical activity	0,020	5,012
	Sugar sweetened-beverages	0,018	4,215
Interaction Model	Body Mass Index for Age Zscore (BAZ)	0,026	4,340

As shown in Table 2, there were three variables with a p-value <0,05: family history of DM, physical activity, and sugary drink consumption. The body mass index variable was included in the second model. The second model of multiple logistic regression analysis included four variables, namely body mass index, family history, physical activity, and sugary drink behavior, which were included in the interaction analysis. The interaction model shows that the variable body mass index is a determinant factor that interacts with the risk of prediabetes in adolescents (p = 0,026; OR = 4,340). Family history of diabetes has been shown to increase the incidence of diabetes. Paramita & Lestari (2021) found that a family history of type 2 diabetes mellitus had a 6x risk for their first offspring to experience disturbed fasting glucose levels (OR=6,27).

Waist circumference-to-height ratio (WHtR) is a simple anthropometric measurement that has the potential to be a predictor of health in children, adolescents, and adults. In this study, the ratio of waist circumference and height was related to the risk of prediabetes (Table 1). This is consistent with the results of a Study Vasquez et al. (2019) WHtR value ≥0,54 has the best sensitivity and specifications for predicting the risk of prediabetes, especially fasting blood glucose levels in adolescents aged 16-17 years. Studies in India have shown that fasting blood glucose is a risk factor for prediabetes because the WHtR value is greater than the indicator (>0,5) (Djap et al., 2018).

Simple anthropometric measurements can use WHtR to have a stronger relationship with prediabetes and cardiometabolic risk factors in children, adolescents, and adults than body mass index (Jiang et al., 2021). The waist-to-height ratio indicates abdominal or central obesity, which leads to elevated levels of free fatty acids, adipokines, and proinflammatory markers in the blood. This condition is closely linked to excessive insulin secretion and increased adipose tissue, impairing glucose tolerance and causing chronic inflammation in fat tissue, insulin resistance, and damage to pancreatic beta cells (Zhang et al., 2021).

The waist circumference-to-height ratio represents abdominal or central obesity, which leads to increased concentrations of free fatty acids, adipokines, and proinflammatory substances in the plasma and is therefore positively associated with insulin hypersecretion, which leads to increased obesity. Adipose tissue can impair glucose tolerance, leading to chronic inflammation of adipose tissue (Tseng et al., 2021).

The energy obtained, one of which is from carbohydrate intake, must be expended through physical activity, which means that the body needs to carry out processes to manage glucose as an energy source so that it is not stored too much in the body, which will increase fat density and blood glucose and sugar levels to prediabetes. Based on the results of the multivariate analysis of the interaction determinant factors with prediabetes risk, physical activity was a risk factor for prediabetic adolescents after correction for WHtR variables, carbohydrate intake, and total fat intake (p=0,02; OR=5,012), which was lower than the physical activity level of ≥600 MET minutes/week.

Physical activity is beneficial for improving cardiorespiratory fitness, glycemic control, reducing insulin resistance, improving lipid profiles, and physical activity in the use of blood glucose. When performing physical activities, the muscles contract as a result of the breakdown of glucose in the muscles, which is then converted into energy. If physical activity is carried out at <600 MET min/week, there is a disturbance in insulin tension, causing an increase in blood glucose or hyperglycemia (Huang et al., 2021). Studies have shown that individuals aged 18-59 years with mild physical activity experience prediabetes {Formatting Citation}. Studies in Korea also show consistent results that individuals with low physical activity levels have higher fasting blood glucose levels (> 100 – 125 mg/dL) and are thus at risk of prediabetes (Park & Hwang, 2020). Physical activity can suppress gluconeogenesis by activating the oxidative capacity in the mitochondria, thereby reducing glucose production (Seo et al., 2021).

The food and drink consumption behavior of adolescents in this study was a risk factor for prediabetes. The prevalence of prediabetes risk in this study was 17,9% higher than that reported in a previous study, because adolescent carbohydrate and sugary drink intake was not assessed in this study (Solikhah, 2019). Bivariate analysis (Table 2) of the risk of prediabetes increased in adolescents with a behavior of consuming carbohydrates of more than 300 – 400 g/day related to prediabetes, as evidenced by the value of p = 0,009. The last variable related to the incidence of prediabetes was consumption of sweet drinks (p= 0,01). Three candidate variables, namely consumption behavior of carbohydrates, total fat, and sugary drinks, were included in the multivariate logistic regression analysis (p <0,25). According to Nanditha et al. (2016), nutritional transitions occur in most Asian countries with changes in consumption patterns, increased intake of carbohydrates and fats, and reduced consumption of fiber and vegetables, all of which are highly relevant to the risk of prediabetes. Carbohydrates in food are usually in the form of glucose, and excessive consumption can cause blood sugar levels to rise, continually increasing the risk of developing prediabetes. The type and digestibility of ingested carbohydrates can influence post-meal plasma levels as well as the inflammatory response, which forms the foundation for the emergence of insulin resistance, metabolic syndrome, prediabetes, and type 2 diabetes mellitus. (Barazzoni et al., 2017).

Carbohydrates are the main source of glucose production in the body if they do not normalize the causes of hyperglycemia, hypoglycemia, and glycemic fluctuations that interact with the gut microbiota, affecting the number of organs, such as the bone, muscle, adipose tissue, and liver. This can lead to the expansion of adipose tissue and deposition of ectopic fat into the liver and muscle, decreasing the ability of the body to produce antioxidant enzymes and resulting in the rejection of insulin resistance and blood sugar disorders that are related to the development of prediabetes and the impact of complications that encourage organ damage.

The results of the multivariate analysis in the first- and second-risk models (Table 2) showed that the consumption of sweet drinks was a dominant predictor of adolescent prediabetes (OR=4,215; p=0,018). Shin et al. (2018) found that the consumption of sweet drinks >1 time/day increased fasting blood sugar levels in both men and women (p<0,0001 and p=0,007, respectively). An increase in the consumption of sweet drinks inevitably increases the sugar and energy consumption (Seferidi et al., 2018).

Adolescent habits and ease of finding sweet drinks such as carbonated soda drinks, energy drinks, sweet tea with various flavors, and instant juice drinks from packaged powders (Rodríguez et al., 2016). These unhealthy behaviors place adolescents at risk of prediabetes (Kwak et al., 2019). This study is supported by the study by Lee et al. (2020), which showed that 13 weeks rats given Coca-Cola, coffee with milk sugar, and chocolate drinks with added sugar had higher fasting blood sugar levels than the control group (p<0,05).

The body mass index for age score (BAZ) was a predictor of prediabetes risk in adolescents (p=0,026; OR: 4,340) (Table 2). Excess body fat is closely related to insulin resistance, which increases the risk of prediabetes (Gupta et al., 2018). The body mass index serves as an indicator of an individual consuming surplus energy, leading to the accumulation of excess fat in the visceral area, and contributing to abdominal obesity. Concurrently, sugary beverage intake diminished insulin and leptin levels in the bloodstream, diminished insulin sensitivity, attenuated the suppression of postprandial ghrelin, and increased fasting blood sugar levels (p=0,028) (Li et al., 2019; Teshima et al., 2015).

Excess visceral fat is associated with the abnormal distribution of fat in unintended areas and altered release of adipokines. Individuals who are obese, but exhibit a higher proportion of visceral fat to subcutaneous fat, tend to have reduced levels of adiponectin and leptin, even when their body mass index and body fat percentages are similar. Reduced adiponectin levels are associated with increased fat deposition in the muscles and liver. Similarly, lower leptin levels have been associated with decreased insulin sensitivity. The association between obesity and prediabetes is due to fat accumulation in unintended areas. When fat accumulates in critical organs such as muscles and the liver, it disrupts the insulin signaling pathway, resulting in increased insulin resistance (Guess, 2018).

This resistance is characterized by abnormalities in the non-oxidative pathway of glucose metabolism, elevated lipid levels within muscle cells, and increased fat accumulation in the visceral and hepatic tissues. The accumulation of fat in the liver plays a significant role in triggering insulin resistance, and its severity correlates with the presence of prediabetes in teenagers. The relationship between the lipid build-up in tissues responsive to insulin and tissue-specific insulin resistance may be mutually influential. The acute release of free fatty acids notably reduces muscle insulin sensitivity. Conversely, hepatic insulin resistance can exacerbate hyperinsulinemia and contribute to lipid deposition in the liver (Dutta et al. 2020; Zuniga and Deboer 2021).

The first phase involves immediate release of limited amounts of insulin pre-encapsulated in secretory granules in response to rising plasma glucose concentrations. This first phase was measured within the first 10 min of the hyperglycemic clamp. The second phase of secretion is a sustained response to persistently elevated glucose concentrations and involves the prolonged transport of insulin from the Golgi system to secretory granules and out of β-cells. The second phase was measured primarily within 10–120 minutes after the hyperglycemic clamp.

Although the first and second phases of insulin secretion can only be accurately quantified in response to a non-physiological intravenous glucose stimulus (hyperglycemic clamp or intravenous glucose tolerance test), both phases can be modeled in terms of their response to a more physiological oral glucose load (Lee et al., 2020). Alterations in second-phase insulin secretion occur later in the course of the disease and have only been observed in obese youth when both fasting glucose and glucose tolerance are impaired, or in overt prediabetes and type 2 diabetes (Weiss et al., 2017).

Beta-cell degradation typically occurs more rapidly in children and adolescents than in adults. It takes approximately 10 years for adults to transition from prediabetes to type 2 diabetes, with beta cell function declining by approximately 7% each year, whereas obese adolescents experience a decline in beta cell degradation of approximately 20-30% per year. The average time to transition from prediabetes to overt diabetes is two to five years (Narasimhan & Weinstock, 2014).

This study had several limitations. First, this study was not population-based and the sample size was relatively small. Second, the study design was cross-sectional; therefore, causation between prediabetes risk factors could not be proven. Third, information about the determinants was obtained from self-reports; however, this concern was mitigated by using a validated questionnaire. Fourth, the fasting process before blood collection could not be monitored, but a blood glucose examination was performed in a standardized laboratory at the Department of Health Analyst, Poltekkes, Ministry of Health, Jambi. Despite these limitations, we included several potential source risk factors that allowed a comprehensive risk assessment of prediabetes in adolescents.

Conclusion

Body mass index (BMI), as measured by fasting blood glucose levels, is a predictor of direct prediabetes among adolescents. Health and education departments need to create policies to limit foods high in sugar, salt, and fat in schools, which is a fundamental effort to improve nutrition and health among adolescents.

It is hoped that future studies can be carried out in a large number of samples and to check several other indicators of prediabetes, such as glucose during, glucose 2 h after eating, and HBA1C.

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References

Arslanian, S., Bacha, F., Grey, M., Marcus, M. D., White, N. H., & Zeitler, P. (2018). Evaluation and management of youth-onset type 2 diabetes: A position statement by the American diabetes association. *Diabetes Care*, *41*(12), 2648–2668. https://doi.org/10.2337/dci18-0052

Astuti, A. (2019). Usia, Obesitas dan Aktifitas Fisik Beresiko Terhadap Prediabetes. *Jurnal Endurance*, *4*(2), 319. https://doi.org/10.22216/jen.v4i2.3757

Bacha, F., Lee, S., Gungor, N., & Arslanian, S. A. (2010). From pre-diabetes to type 2 diabetes in obese youth: pathophysiological characteristics along the spectrum of glucose dysregulation. *Diabetes Care*, *33*(10), 2225–2231. https://doi.org/10.2337/DC10-0004

Barazzoni, R., Deutz, N. E. P., Biolo, G., Bischoff, S., Boirie, Y., Cederholm, T., Cuerda, C., Delzenne, N., Leon Sanz, M., Ljungqvist, O., Muscaritoli, M., Pichard, C., Preiser, J. C., Sbraccia, P., Singer, P., Tappy, L., Thorens, B., Van Gossum, A., Vettor, R., & Calder, P. C. (2017). Carbohydrates and insulin resistance in clinical nutrition: Recommendations from the ESPEN expert group. *Clinical Nutrition (Edinburgh, Scotland)*, *36*(2), 355–363. https://doi.org/10.1016/J.CLNU.2016.09.010

Chan, Y. Y., Lim, K. K., Lim, K. H., Teh, C. H., Kee, C. C., Cheong, S. M., Khoo, Y. Y., Baharudin, A., Ling, M. Y., Omar, M. A., & Ahmad, N. A. (2017). Physical activity and overweight/obesity among Malaysian adults: findings from the 2015 National Health and morbidity survey (NHMS). *BMC Public Health*, *17*(1). https://doi.org/10.1186/S12889-017-4772-Z

Davidson, K. W., Barry, M. J., Mangione, C. M., Cabana, M., Caughey, A. B., Davis, E. M., Donahue, K. E., Doubeni, C. A., Krist, A. H., Kubik, M., Li, L., Ogedegbe, G., Owens, D. K., Pbert, L., Silverstein, M., Stevermer, J., Tseng, C. W., & Wong, J. B. (2021). Screening for Prediabetes and Type 2 Diabetes: US Preventive Services Task Force Recommendation Statement. *JAMA*, *326*(8), 736–743. https://doi.org/10.1001/JAMA.2021.12531

Djap, H. S., Sutrisna, B., Soewondo, P., Djuwita, R., & Timotius, K. H. (2018). *Waist to height ratio (0 . 5) as a predictor for prediabetes and type 2 diabetes in Indonesia Waist to height ratio (0 . 5) as a predictor for prediabetes and type 2 diabetes in Indonesia*. 0–6. https://doi.org/10.1088/1757-899X/434/1/012311

Dutta, A., Kumar, A., & Kumari, S. (2020). Correlation between non-diabetic fasting blood glucose levels and 2-h post loading blood sugar levels with waist-to-height ratio in rural population of Malwa region of Central India. *National Journal of Physiology, Pharmacy and Pharmacology*, *10*(2), 1. https://doi.org/10.5455/NJPPP.2020.10.0931726112019

Echouffo-Tcheugui, J. B., & Selvin, E. (2020). Prediabetes and What It Means: The Epidemiological Evidence. *Annual Review of Public Health*, *42*, 59–77. https://doi.org/10.1146/annurev-publhealth-090419-102644

Guess, N. (2018). Dietary Interventions for the Prevention of Type 2 Diabetes in High-Risk Groups: Current State of Evidence and Future Research Needs. *Nutrients*, *10*(9), 1245. https://doi.org/10.3390/nu10091245

Gupta, A. K., Menon, A., Brashear, M., & Johnson, W. D. (2018). Prediabetes. In *Nutritional and Therapeutic Interventions for Diabetes and Metabolic Syndrome* (Second Edi). Elsevier Inc. https://doi.org/10.1016/B978-0-12-

812019-4.00002-7

Huang, L., Fang, Y., & Tang, L. (2021). Comparisons of different exercise interventions on glycemic control and insulin resistance in prediabetes: a network meta-analysis. *BMC Endocrine Disorders*, *21*(1). https://doi.org/10.1186/S12902-021-00846-Y

Jiang, Y., Dou, Y., Chen, H., Zhang, Y., Chen, X., Wang, Y., Rodrigues, M., & Yan, W. (2021). Performance of waist-to-height ratio as a screening tool for identifying cardiometabolic risk in children: a meta-analysis. *Diabetology & Metabolic Syndrome*, *13*(1), 66. https://doi.org/10.1186/s13098-021-00688-7

Junita, Siregar S, P. E. (2021). Interaksi Konsumsi minuman manis prediktor risiko prediabetes remaja Kota Jambi. *Riset Informasi Kesehatan*, *10*(2), 89–97. http://jurnal.stikes-hi.ac.id/index.php/rik/article/view/538/178

Kementerian Kesehatan RI. (2024). Survei Kesehata Indonesia. In *Badan Kebijakan Pembangunan Kesehatan, Jakarta* (Vol. 01).

Kesehatan Masyarakat, F., Kurnia Saraswati, S., Dhista Rahmaningrum, F., Naufal Zidane Pahsya, M., Paramitha, N., Wulansari, A., Rossa Ristantya, A., Magdalena Sinabutar, B., Estetika Pakpahan, V., & Nandini, N. (2021). Literature Review : Faktor Risiko Penyebab Obesitas. *MEDIA KESEHATAN MASYARAKAT INDONESIA*, *20*(1), 70–74. https://doi.org/10.14710/MKMI.20.1.70-74

Khoiriyah, D., Murbawani, E. A., & Panunggal, B. (2018). *Hubungan Asupan Karbohidrat dan Aktivitas Fisik dengan Prediabetes pada Wanita Dewasa*. https://ejournal.undip.ac.id/index.php/jgi/

Kuwabara, M., Kuwabara, R., Niwa, K., Hisatome, I., Smits, G., Roncal-Jimenez, C. A., Maclean, P. S., Yracheta, J. M., Ohno, M., Lanaspa, M. A., Johnson, R. J., & Jalal, D. I. (2018). Different Risk for Hypertension, Diabetes, Dyslipidemia, and Hyperuricemia According to Level of Body Mass Index in Japanese and American Subjects. *Nutrients 2018, Vol. 10, Page 1011*, *10*(8), 1011. https://doi.org/10.3390/NU10081011

Kwak, J. H., Jo, G., Chung, H. K., & Shin, M. J. (2019). Association between sugar-sweetened beverage consumption and incident hypertension in Korean adults: a prospective study. *European Journal of Nutrition*, *58*(3), 1009–1017. https://doi.org/10.1007/S00394-018-1617-1

Lee, G., Han, J. H., Maeng, H. J., & Lim, S. (2020). Three-Month Daily Consumption of Sugar-Sweetened Beverages Affects the Liver, Adipose Tissue, and Glucose Metabolism. *Journal of Obesity & Metabolic Syndrome*, *29*(1), 26. https://doi.org/10.7570/JOMES19042

Lee, H. J., Shim, Y. S., Yoon, J. S., Jeong, H. R., Kang, M. J., & Hwang, I. T. (2021). Distribution of waist-to-height ratio and cardiometabolic risk in children and adolescents: a population-based study. *Scientific Reports 2021 11:1*, *11*(1), 1–10. https://doi.org/10.1038/s41598-021-88951-9

Li, S., Cao, M., Yang, C., Zheng, H., & Zhu, Y. (2019). Association of sugar-sweetened beverage intake with risk of metabolic syndrome among children and adolescents in urban China. *Public Health Nutrition*, *23*(15). https://doi.org/10.1017/S1368980019003653

Lie, S., Morrison, J. L., Williams-Wyss, O., Suter, C. M., Humphreys, D. T., Ozanne, S. E., Zhang, S., MacLaughlin, S. M., Kleemann, D. O., Walker, S. K., Roberts, C. T., & Caroline McMillen, I. (2014). Periconceptional undernutrition programs changes in insulin-signaling molecules and microRNAs in skeletal muscle in singleton and twin fetal sheep. *Biology of Reproduction*, *90*(1). https://doi.org/10.1095/BIOLREPROD.113.109751

Liu, C., Wu, S., & Pan, X. (2021). Clustering of cardio-metabolic risk factors and pre-diabetes among U.S. adolescents. *Scientific Reports*, *11*(1), 5015. https://doi.org/10.1038/S41598-021-84128-6

Lobos, D. R., Vicuña, I. A., Novik, V., & Vega, C. A. (2017). Effect of high and low glycemic index breakfast on postprandial metabolic parameters and satiety in subjects with type 2 diabetes mellitus under intensive insulin therapy: Controlled clinical trial. *Clinical Nutrition ESPEN*, *20*, 12–16. https://doi.org/10.1016/j.clnesp.2017.04.082

Ly, T. T., Maahs, D. M., Rewers, A., Dunger, D., Oduwole, A., & Jones, T. W. (2014). Assessment and management of hypoglycemia in children and adolescents with diabetes. *Pediatric Diabetes*, *15*(S20), 180–192. https://doi.org/10.1111/pedi.12174

Ma, J., Jacques, P. F., Meigs, J. B., Fox, C. S., Rogers, G. T., Smith, C. E., Hruby, A., Saltzman, E., & McKeown, N. M. (2016). Sugar-sweetened beverage but not diet soda consumption is positively associated with progression of insulin resistance and prediabetes. *Journal of Nutrition*, *146*(12), 2544–2550. https://doi.org/10.3945/jn.116.234047

Menke, A., Casagrande, S., & Cowie, C. C. (2016). Prevalence of diabetes in adolescents aged 12 to 19 years in the United States, 2005-2014. In *JAMA - Journal of the American Medical Association* (Vol. 316, Issue 3, pp. 344–345). American Medical Association. https://doi.org/10.1001/jama.2016.8544

Min, J. E., Green, D. B., & Kim, L. (2017). Calories and sugars in boba milk tea: implications for obesity risk in Asian Pacific Islanders. *Food Science and Nutrition*, *5*(1), 38–45. https://doi.org/10.1002/fsn3.362

Monhaty, B. (2018). Prediabetes precursor to type 2 diabetes ,act today - block the road to diabetes. *Indian Journal of Research*, *7*(3), 188–189. https://doi.org/10.36106

Nanditha, A., Ma, R. C. W., Ramachandran, A., Snehalatha, C., Chan, J. C. N., Chia, K. S., Shaw, J. E., & Zimmet, P. Z. (2016). Diabetes in Asia and the Pacific: Implications for the Global Epidemic. *Diabetes Care*, *39*(3), 472–485. https://doi.org/10.2337/DC15-1536

Narasimhan, S., & Weinstock, R. S. (2014). Youth-onset type 2 diabetes mellitus: lessons learned from the TODAY study. *Mayo Clinic Proceedings*, *89*(6), 806–816. https://doi.org/10.1016/J.MAYOCP.2014.01.009

Park, K. S., & Hwang, S. Y. (2020). Lifestyle-related predictors affecting prediabetes and diabetes in 20-30-year-old young Korean adults. *Epidemiology and Health*, *42*, 1–9. https://doi.org/10.4178/epih.e2020014

Putra, E. S., & Junita. (2022). Rasio lingkar pinggang tinggi badan dan aktivitas fisik sebagai risiko prediabetes remaja Kota Jambi. *Riset Informasi Kesehatan*, *11*(1), 45–53. https://doi.org/10.30644/rik.v11i1.626

Rahmad, A. H. Al. (2021). Faktor risiko obesitas pada guru sekolah perempuan serta relevansi dengan PTM selama pandemi Covid-19. *Amerta Nutrition*, *5*(1), 31–40. https://doi.org/10.2473/amnt.v5i1.2021.

Rodríguez, L. A., Madsen, K. A., Cotterman, C., & Lustig, R. H. (2016). Added sugar intake and metabolic syndrome in US adolescents: Cross-sectional analysis of the National Health and Nutrition Examination Survey 2005-2012. *Public Health Nutrition*, *19*(13), 2424–2434. https://doi.org/10.1017/S1368980016000057

Seferidi, P., Millett, C., & Laverty, A. A. (2018). Sweetened beverage intake in association to energy and sugar consumption and cardiometabolic markers in children. *Pediatric Obesity*, *13*(4), 195–203. https://doi.org/10.1111/ijpo.12194

Seo, Y. G., Lim, H., Kim, Y. M., Ju, Y. S., Choi, Y. J., Lee, H. J., Jang, H. B., Park, S. I., & Park, K. H. (2021). Effects of circuit training or a nutritional intervention on body mass index and other cardiometabolic outcomes in children and adolescents with overweight or obesity. *PLoS ONE*, *16*(1 January), 1–21. https://doi.org/10.1371/journal.pone.0245875

Shin, S., Kim, S. A., Ha, J., & Lim, K. (2018). Sugar-sweetened beverage consumption in relation to obesity and metabolic syndrome among Korean adults: A cross-sectional study from the 2012–2016 Korean national health and nutrition examination survey (KNHANES). *Nutrients*, *10*(10). https://doi.org/10.3390/nu10101467

Solikhah, L. (2019). *Hubungan Konsumsi Ikan, Sarapan, Kualitas Tidur dan Rasio Lingkar Pinggang-Tinggi Badan dengan Kejadian Prediabetes pada Remaja Usia 14-18 Tahun*. https://digilib.uns.ac.id/dokumen/detail/78270/Hubungan-Konsumsi-Ikan-Sarapan-Kualitas-Tidur-dan-Rasio-Lingkar-Pinggang-Tinggi-Badan-dengan-Kejadian-Prediabetes-pada-Remaja-Usia-14-18-Tahun

Teshima, N., Shimo, M., Miyazawa, K., Konegawa, S., Matsumoto, A., Onishi, Y., Sasaki, R., Suzuki, T., Yano, Y., Matsumoto, K., Yamada, T., Gabazza, E. C., Takei, Y., & Sumida, Y. (2015). Effects of sugar-sweetened beverage intake on the development of type 2 diabetes mellitus in subjects with impaired glucose tolerance: the Mihama diabetes prevention study. *Journal of Nutritional Science and Vitaminology*, *61*(1), 14–19. https://doi.org/10.3177/JNSV.61.14

Tseng, T.-S., Lin, W.-T., Gonzalez, G. V, Kao, Y.-H., Chen, L.-S., & Lin, H.-Y. (2021). Sugar intake from sweetened beverages and diabetes: A narrative review. *World Journal of Diabetes*, *12*(9), 1530. https://doi.org/10.4239/WJD.V12.I9.1530

Vasquez, F., Correa-Burrows, P., Blanco, E., Gahagan, S., & Burrows, R. (2019a). A waist-to-height ratio of 0.54 is a good predictor of metabolic syndrome in 16-year-old male and female adolescents. *Pediatric Research*, *85*(3), 269–274. https://doi.org/10.1038/S41390-018-0257-8

Vasquez, F., Correa-Burrows, P., Blanco, E., Gahagan, S., & Burrows, R. (2019b). A waist-to-height ratio of 0.54 is a good predictor of metabolic syndrome in 16-year-old male and female adolescents. *Pediatric Research*, *85*(3), 269–274. https://doi.org/10.1038/s41390-018-0257-8

Wang, J. W., Light, K., Henderson, M., O'Loughlin, J., Mathieu, M. E., Paradis, G., & Gray-Donald, K. (2014). Consumption of added sugars from liquid but not solid sources predicts impaired glucose homeostasis and insulin resistance among youth at risk of obesity. *Journal of Nutrition*, *144*(1), 81–86. https://doi.org/10.3945/jn.113.182519

Weiss, R., Santoro, N., Giannini, C., Galderisi, A., Umano, G. R., & Caprio, S. (2017). Prediabetes in youths: mechanisms and biomarkers. *The Lancet Child and Adolescent Health*, *1*(3), 240–248. https://doi.org/10.1016/S2352-4642(17)30044-5

Zhang, F. L., Ren, J. X., Zhang, P., Jin, H., Qu, Y., Yu, Y., Guo, Z. N., & Yang, Y. (2021). Strong Association of Waist Circumference (WC), Body Mass Index (BMI), Waist-to-Height Ratio (WHtR), and Waist-to-Hip Ratio (WHR) with Diabetes: A Population-Based Cross-Sectional Study in Jilin Province, China. *Journal of Diabetes Research*, *2021*. https://doi.org/10.1155/2021/8812431

Zuniga, R. E., & Deboer, M. D. (2021). Prediabetes in adolescents: Prevalence, management and diabetes prevention strategies. *Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy*, *14*, 4609–4619. https://doi.org/10.2147/DMSO.S284401