ORIGINAL ARTICLE

The relationship between individual characteristics, sweet drink consumption, sleep quality, and stress levels with Impaired Fasting Glucose (IFG) levels among high school adolescents

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ABSTRACT

Background and aim: Prediabetes typically appears in the early stages of T2DM development, including IFG as one of the indicators. Globally, the prevalence of IFG is estimated to be increasing in low-income or developing countries, as Southeast Asia is the largest contributor. However, there is limited information on IFG in each age group, including adolescents, who are highly risk to adopting unhealthy lifestyles. This study aims to evaluate fasting blood glucose levels measured from capillary blood samples of high-school adolescents, aged 15–19 years, and its relationship with individual characteristics, consumption of sweetened beverages, sleep quality, and stress levels.

Method: This quantitative study employed a cross-sectional design. A total of 251 participants were selected using stratified and simple random sampling techniques. Data were collected through self-administered questionnaires, which included a demographic questionnaire, FFQ, PSQI, and DASS-42. In addition, direct measurements of height, weight, and fasting capillary blood glucose levels were conducted using standardized tools, including a glucometer. Data analysis involved univariate and bivariate, the chi-square test used to assess associations, conducted using SPSS version 27.

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Result: The study found that the prevalence of IFG among adolescents in the Alun-Alun Gresik Community Health Center (Puskesmas) working area was relatively high, about 32.3%. A significant impact was observed between BMI (*p*<0.001), family history of diabetes (*p*<0.001), consumption of sweet drinks (*p*=0.004), and age group (p=0.019) towards the incidence of IFG. In contrast, no significant relationship was identified between gender (*p*=0.643), sleep quality (*p*=0.973), or stress levels (*p*=(0.635).
Conclusion: These results underscore the need for increased awareness, early identification, and preventive interventions targeting at-risk adolescents to mitigate the progression to type 2 diabetes. (www.actabiomedica.it)

Key words: adolescent, IFG, sleep quality, stress level, sugary drink

Introduction

Diabetes is one of the leading causes of death worldwide, with its prevalence continuing to rise each year (1). Therefore, preventive measures are essential to curb the rising global prevalence of diabetes. In many cases of type 2 diabetes (T2DM), glucose intolerance appears in the early stages of the disease and gradually gets worse over time (2). Impaired Fasting Glucose (IFG) or Impaired Glucose Tolerance (IGT) is an intermediate stage before T2DM occurs, this condition is called prediabetes (3). Prediabetes refers to a condition where blood glucose levels are above normal but do not yet meet the criteria for a diabetes diagnosis. (4). According to the American Diabetes Association (ADA), prediabetes can be identified through blood glucose assessments, including Impaired Glucose Tolerance (IGT) with 2-hour plasma glucose levels between 140–199 mg/dL, Impaired Fasting Glucose (IFG) with fasting plasma glucose levels between 100–125 mg/dL, and glycated hemoglobin (HbA1c) levels ranging from 5.7% to 6.4% (5). Unfortunately, many individuals continue to underestimate the risk of prediabetes, often remaining unaware of its presence due to the absence of clear or noticeable symptoms. As a result, it frequently goes undetected until progression occurs. It is estimated that each year, approximately 5–10% of individuals with prediabetes advance to T2DM (6). The world estimate for IFG prevalence in 2021 is 5.8 % or 298 million individuals, and it is projected to increase to 6.5 % or 414 million individuals by 2045, with the largest increase occurring in low-income or developing countries (7). Data shows that Southeast Asian countries are the largest contributors of IFG, with a rate of 9.4% in 2021, which is estimated to increase to 9.6% in 2024 (7). IFG is not only a risk for the elderly, but also for adolescents and young adults. Based on a meta-analysis of 36 studies in the UK in 2021, the prevalence of IFG in the ≤ 20 age group was found to be 6.93%, which exceeds the global prevalence of IFG (8). In addition, NHANES (The National Health and Nutrition Examination Survey) has reported an increase in the prevalence of prediabetes among adolescents aged 12 to 19 years, from 11% in 1999-2002 to 27.8% in 2015-2020 (9). Therefore, it can be said that adolescents are a high-risk group for IFGI. In Indonesia, the prevalence of impaired fasting glucose (IFG) among adolescents has not yet been accurately identified through high-quality data. However, the IDF estimates that the overall prevalence of IFG in Indonesia in 2024 was 7.7% and is expected to increase to 8.3% by 2050 (10). Additionally, based on Riskesdas (National Health Survey) 2018 data, the proportion of people over 15 years old with impaired fasting glucose levels reached 13.1%, whereas only 1.8% of the population regularly check their blood sugar levels (11). This figure is notably high and aligns with the diabetes prevalence in East Java, which ranks sixth nationally at 2.1% surpassing the national diabetes prevalence of 1.5% across all age groups(11). One of the districts in East Java that contributes a notably high number of diabetes cases is Gresik Regency, with a prevalence of 3.44% (12). Glucose intolerance or prediabetes should be monitored closely, as it represents a critical window for intervention through appropriate treatment and preventive measures. Since diabetes is essentially a progression of IFG or IGT, both conditions are believed to share common underlying causes. One of the major contributing factors to the development of prediabetes is an unhealthy lifestyle, including poor dietary habits, physical inactivity, and other behavioral risk factors. Addressing these modifiable factors early is essential to reduce the risk of progression to type 2 diabetes and its associated complications (5). In addition, non-modifiable individual factors such as age, gender, and family history also play a significant role in influencing blood glucose levels (13). One easily observable indicator of lifestyle is Body Mass Index (BMI), a simple and widely used method for estimating an individual's nutritional status (14). According to global data for the 5–19 age group, an estimated 340 million children and adolescents are classified as overweight, including approximately 160 million who are obese. In Indonesia, the prevalence of obesity among children and adolescents reaches 9.2%, highlighting a significant public health concern (11,15). Adolescents represent a population that is particularly vulnerable to adopting unhealthy lifestyles, influenced by rapidly changing social factors and global developments (16). One notable social impact is the rapidly increasing trend in the consumption of sugary beverages among adolescents. This is supported by findings from the 2018 Basic Health Research Survey (Riskesdas), which reported that 56.4% of Indonesian adolescents aged 15–19 consumed sweetened drinks more than once per day (11). In parallel with these trends, living in an era of rapid change has intensified social and academic competitiveness, often leading to irregular daily routines. This lifestyle shift contributes to increased stress levels and decreased sleep quality among adolescents. Several studies have identified a correlation between poor sleep quality and elevated stress levels with alterations in blood glucose levels, suggesting their potential role in the development of prediabetes (17–19). Therefore, adolescents need to be more aware of the risk of elevated blood glucose levels resulting from unhealthy lifestyle habits, in order to prevent progression to diabetes. Preventive efforts can be made by increasing awareness and understanding of the factors that contribute to the risk of glucose intolerance. In line with this, the purpose of this study was to evaluate fasting blood glucose levels using capillary blood samples from high school students aged 15–19 years and its relationship with individual characteristics, consumption of sweetened beverages, sleep quality, and stress levels in the working area of the Alun-Alun Community Health Centre in Gresik Regency.

Method

This study employed a quantitative approach with an analytical observational research design, specifically a cross-sectional study. The study population consisted of students aged 15–19 years from Nahdlatul Ulama 1 Gresik High School and Darul Islam Gresik High School, both located within the working area of the Alun-Alun Health Center, Gresik Regency, with a total population of 797 students. A total of 251 respondents were selected as the sample, calculated using the binomial proportion formula for cross-sectional studies. Sampling was conducted using a combination of stratified random sampling and simple random sampling techniques to ensure representation across the entire population. Participants were selected based on predefined inclusion criteria, which are able to communicate clearly, currently studying at SMA NU 1 Gresik or SMA Darul Islam, not yet or currently diagnosed with prediabetes (history of blood sugar ≤125 dL/mg), willing to be a research respondent by fasting for at least 8 hours before blood draw, while the exclusion criteria were: diagnosed with type 1 and/or type 2 diabetes mellitus (fasting blood sugar > 120 dL/mg), could not be performed capillary blood draw, and unable to fast. The data collection was carried out over a period from December 2024 to April 2025. The independent variables examined in this study included individual characteristics (age, gender, BMI, and family history of diabetes), sugary drink consumption, sleep quality, and stress levels. Data collection utilized a self-assessment questionnaire, which comprised a demographic questionnaire, the Food Frequency Questionnaire (FFQ), the Pittsburgh Sleep Quality Index (PSQI), and the Depression Anxiety Stress Scale-42 (DASS-42). In addition, direct physical measurements were conducted to assess height, weight, and fasting capillary blood glucose levels using a glucometer, with a minimally invasive method via finger prick. The FFQ instrument used in this study was modified from the previous research by Haldin (20) and Sirajuddin, et al. (21). The brands of each type of sweet drink were selected based on a preliminary study using Google Forms and a survey around the target location, which included the frequency of consumption of contemporary sweet drinks, bottled/boxed instant drinks, sachet-based powdered drinks, soft drinks, and other types of sugary beverages. Scores were assigned based on the frequency of consumption, ranging from 0 (never) to 50 (>3 times per day), with consumption categories determined by the average score. The PSQI instrument measured sleep quality across seven components through a total of 19 questions, each scored from 0 to 3 (22). Then, total scores of each component are summed to be categorised as poor or good sleep quality. In previous studies, the Indonesian translation of the PSQI instrument has been used and tested for validity by Setyowati, et al. (23) The DASS instrument is a standardized questionnaire with 42 questions, which includes depression, anxiety, and stress assessments with 14 questions each (24). Nevertheless, in this study, only the 14-question stress dimension with a score range of 0 to 3 was used. The Indonesian translation of the DASS-42 questionnaire has been widely used and its validity and reliability in each dimension have been tested by Damanik (25). The BMI classification used in this study is based on the World Health Organization (WHO) asia pacific perspective (26).

BMI Classification	**BMI (kg/m2)**
Underweight	<18.5
Normal	18.5 – 22.9
Overweight	23 – 24.9
Obese	≥25
Obesity I	25 – 29.9
Obesity II	≥30

Body fat distribution is also one of the supporting factors in determining the risk of obesity (26). Therefore, in this study, waist circumference and blood pressure were not measured, and BMI was based only on the height and weight of respondents, which was conducted before the examination of fasting capillary blood glucose levels. Body height was measured using a 200 cm stature meter with 1 mm readability, and body weight was measured using digital scales with 100 gram readability. Impaired Fasting Glucose (IFG) was measured by drawing capillary blood from one of the participant's fingertips using a finger prick method by health workers from the Alun-alun Community Health Centre. Participants in this study were required to fast from eating and drinking, except for plain water, for at least 8 hours before the blood glucose test. Blood glucose level measurements began at 8 a.m. The devices used for testing were Humasens and Autocheck glucometers. All instruments used in this study were previously tested for validity and reliability. Data analysis was conducted in two stages: univariate, bivariate, and multivariate analysis. n this study, bivariate analysis employed the chi-square test and multivariate analysis employed simple logistic regression with a significance level of $\alpha=0.05$ using SPSS version 27 software.

Result

Based on the research conducted, the frequency distribution of each studied variable, as determined through univariate analysis, is presented as follows:

Based on Table 1, the fasting capillary blood glucose levels among respondents ranged from a minimum of 68 mg/dL to a maximum of 125 mg/dL. The mean fasting capillary blood glucose level was 98.93 mg/dL, with a standard deviation of 10.32 mg/dL. In this study, respondents were categorized as being at IFG if their fasting blood glucose levels were between 100–125 mg/dL, and as normal if their fasting blood glucose levels were below 100 mg/dL. 32.3% of respondents were categorized as being IFG. Regarding respondent characteristics, such as age groups, are based on the adolescent age categories defined by the Indonesian Ministry of Health, which states that adolescents are individuals aged between 12 and 25 years. This age range is grouped into early adolescence, which is adolescents aged 12 to 16 years, and late adolescence, which is adolescents aged 17 to 25 years, in thisstufy, the majority were in the late adolescent age group

Table 1. Frequency Distribution of Study Variables

Variable	n	%	Min	Max	Mean ± SD
Fasting Capillary Glucose (mg/dL)					
IFG	81	32.3	68	125	98.93 ± 10.32
Normal	170	67.7			
Age Group					
Early Adolescence	102	40.6	15	19	16,71 ± 0,87
Late Adolescence	149	59.4			
Gender					
Male	73	29.1	-	-	-
Female	178	70.9			
BMI Category					
Underweight	61	24.3	14,7	39,4	22,1 ± 4,96
Normal	109	43.4			
Overweight	24	9.6			
Obese	57	22.7			
Family History of Diabetes					
Yes	58	23.1	-	-	-
No	193	76.9			
Sugary Drink Consumption					
Normal	145	57.8	0	575	174,40 ± 118,51
Excessive	106	42.2			
Sleep Quality					
Good	49	20.0	2	17	7,77 ± 2,70
Poor	202	80.0			
Stress Level					
Normal	122	48.6	0	39	15,78 ± 8,95
Mild	43	17.1			
Moderate	44	17.5			
Severe	34	13.5			
Extremely Severe	8	3.2			

(59.4%), and most were female (70.9%). Based on BMI measurements, 43.4% of respondents fell within the normal range, while the remaining were classified as underweight (24.3%), overweight (9.6%), or obese (22.7%), indicating that the majority had abnormal BMI values. Most respondents (76.9%) reported having no family history of diabetes. In terms of dietary habits, 57.8% of adolescents consumed sugary beverages at normal levels, while 42.2% reported excessive consumption. A significant proportion of respondents (80.0%) experienced poor sleep quality. Meanwhile, less than half (48.6%) had normal stress levels, with the remainder experiencing varying degrees of psychological stress. To assess the relationship between the independent variables and the risk of prediabetes, a bivariate analysis was conducted using the chi-square test. The results were interpreted based on *p*-values and prevalence ratios (PR), as presented in the following table:

Based on Table 2, no significant associations were observed between age (p=0.057), gender (p=0.643), sleep quality (p=0.973), and stress level (p=0.635)

Table 2. Bivariate Analysis of Factors Associated with IFG

Variable	Fasting Capillary Glucose				Total		P	PR (CI 95%)
	IFG		Normal					
	n	%	n	%	n	%		
Age Group								
Early Adolescence	26	25.5	76	74.5	102	100.0	0.057*	1.447 (0.852-2.455)
Late Adolescence	55	36.9	94	63.1	149	100.0		
Gender								
Male	22	30.1	51	69.9	73	100.0	0.643	1.10 (0.286-1.927)
Female	59	33.1	119	66.9	178	100.0		
BMI Category								
Underweight	11	18.0	50	82.0	61	100.0	0.001*	0.89 (0.40-1.97)
Normal	22	20.2	87	79.8	109	100.0		*Ref.*
Overweight	14	58.3	10	41.7	24	100.0		2.89 (1.13-7.39)
Obese	34	59.6	23	40.4	57	100.0		2.95 (1.17-7.46)
Family History of Diabetes								
Yes	53	27.5	140	72.5	193	100.0	0.003*	1.76 (1.66 – 3.23)
No	28	48.3	30	51.7	58	100.0		
Sugary Drink Consumption								
Normal	34	23.4	111	76.6	145	100.0	0.001*	1.89 (1.10-3.26)
Excessive	47	44.3	59	55.7	106	100.0		
Sleep Quality								
Good	13	32.5	27	67.5	40	100.0	0.973	0.99 (0.611-1.604)
Poor	68	32.2	143	67.8	211	100.0		
Stress Level								
Normal	42	34.4	80	65.6	122	100.0	0.635	*Ref.*
Mild	13	30.2	30	69.8	43	100.0		0.88 (0.515-1.506)
Moderate	11	25.0	33	75.0	44	100.0		0.73 (0.426-1.25)
Severe	11	32.4	23	67.6	34	100.0		0.94 (0.536-1.648)
Extremely Severe	4	50.0	4	50.0	8	100.0		1.45 (0.495-4.254)

Abbreviations: PR = Prevalence Ratio; CI = Confidence Interval; *p < 0.05 indicates statistically significant association.

with the risk of prediabetes, as the p-values exceeded the threshold of 0.05. In contrast, a statistically significant relationship was identified between BMI and the risk of prediabetes (p=0.001). Adolescents classified as overweight were 2.89 times more likely to be at risk for prediabetes compared to those with a normal BMI (PR=2.89; 95% CI: 1.13–7.39), while those categorized as obese were 2.95 times more likely (PR=2.95; 95% CI: 1.17–7.46). A significant association was also found between family history of diabetes and prediabetes risk (p=0.003), with adolescents who had a family history being 1.76 times more likely to develop prediabetes compared to those without such a history (PR=1.76; 95% CI: 1.66–3.23). Furthermore,

Table 3. Multivariate Analysis

Variable	***p-Value***	**EXP (B) (CI 95% *Lower- Upper*)**
Age Group a. Early Adolescence (reference) b. Late Adolescence	0.019	2.205 (1.141 – 4.260)
Sugary Drink Consumption a. Normal (*reference*) b. Excessive	0.004	2.500 (1.333 – 4.687)
BMI Category a. Normal (reference)	<0.001	
b. Underweight		0.793 (0.336 – 1.871)
c. Overweight		6.339 (2.278 – 17.635)
d. Obese		7.276 (3.321 – 15.942)
Family History of Diabetes a. No (*reference*) b. Yes	<0.001	4.034 (1.947 – 8.360)

excessive consumption of sugary beverages was significantly associated with an increased risk of prediabetes (*p*=0.001). Adolescents who consumed sugary drinks excessively were 1.89 times more likely to be at risk compared to those with normal consumption levels (PR=1.89; 95% CI: 1.10–3.26). In this study, multivariate analysis was conducted with simple logistic regression testing using the Enter method, which aims to analyze the impact of independent variables on dependent variables and identify confounding variables. The independent variables tested were only those with a p-value < 0.25 in the chi-square test, which are age group, consumption of sweetened beverages, BMI, and family history of diabetes. The following results were obtained:

Based on Table 3, it was discovered that the variables of age group (0.019), consumption of sweetened beverages (0.004), BMI (<0.001), and family history of diabetes (<0.001) had a statistically significant impact on the incidence of IFG, as they had p-values <0.05. Therefore, no confounding variables were found among the variables tested. Obesity was the subvariable that most affected the incidence of IFG, with OR/EXP (B) of 7.276 (CI 95% 3.321 – 15.942), or adolescents with a BMI in the obese category were 7.276 times more likely to experience IFG than adolescents with a normal BMI. The second subvariable that most affected IFG incidence was overweight, with OR of 6.339 (95% CI 2.278–17.635), indicating that adolescents with an overweight BMI category were 6.339 times more likely to experience IFG than adolescents with a normal BMI. Meanwhile, underweight BMI has a protective OR of 0.793, but because the 95% confidence interval exceeds 1 (CI 95% 0.336 – 1.871), the OR is considered insignificant. Other than that, in the family history of diabetes variable, it was found that adolescents with a family history of diabetes were 4.034 times more likely to experience IFG than adolescents without a family history of diabetes (CI 95% 1.947 – 8.360). Consumption of sweetened beverages also affected the incidence of IFG with OR of 2.500 (95% CI 1.333–4.687), meaning that adolescents who consumed excessive amounts of sweetened beverages were 2.5 times more likely to develop IFG than adolescents who consumed sweetened beverages in normal amounts. Furthermore, although the bivariate analysis did not find a significant relationship between age group and IFG, the multivariate analysis found that age group had a significant effect on IFG, with an OR of 2.205 (95% CI 1.141–4.260) or the late adolescents are 2.205 times more likely to experience IFG than early adolescents.

Discussion

Prevalence of IFG

Capillary and plasma blood glucose measurements are appropriate for use as determinants of diabetes prevalence in a population, but cannot be used as diagnostic criteria (27). Therefore, in this study, blood glucose levels were used to identify IFG in adolescents by measuring fasting capillaryglucose levels, and we found that the prevalence of IFG in adolescents in Gresik Regency, with a range of 100-125 mg/dL, was 32.3%. Based on several studies in Western countries, it was found that the prevalence of IFG in adolescents between 2005 and 2020 ranged from 2.5% to 27.8% (9,28,29). In comparison, research in

East Asian countries from 2007 to 2024 found that the prevalence of IFG among children and adolescents also varied, ranging from 3.3% to 22%. (2,30–33). The prevalence of IFG among adolescents is higher overall in Western countries, which can be explained by dietary habits that involve consuming more foods high in carbohydrates, fats and sugar, leading to a risk of fatty liver , where IFG is caused by insulin resistance in the liver (34). Meanwhile, there have been studies conducted in Indonesia, including research by Soewondo, P. et al. (35) which found that 10% of adolescents in Surabaya had fasting blood sugar levels above 100mg/dL, and research by Putra, E.S. et al. (36) found a prevalence of prediabetes, with fasting blood glucose levels, in 15-19-year-olds of 17.9%, and the results of an analysis of IFG trend surveys in Indonesia by Muharram, F.R. et al. (37) found that in 2023, the prevalence in the > 15 age group was 13.2%. Nevertheless, the prevalence of IFG in the adolescent population found in this study can be considered quite high compared to previous studies. This difference is possible due to the method of measuring fasting blood glucose levels using capillary blood, where it was found that glucose levels using capillary blood were statistically higher than those using venous blood (mean difference 0.3 mmol/L). although the average difference did not reach the a priori established clinical significance value (1.0 mmol/L) (38). In general, there is variation in the accuracy of the glucometers used, which is also influenced by various factors, such as expiry date, heat, humidity, blood content, blood sample volume, blood collection site, and hand/finger hygiene of participants, which can interfere with glucose measurement using glucometers (39).

Relationship between age and IFG

The results of this study found that the early adolescent has a lower percentage of IFG incidence than the late adolescent. This is also supported by a study Huang, F., et al. (30) which found that increasing age is accompanied by an increase in fasting blood sugar levels (IFG).Although age did not reach statistical significance in the bivariate analysis (p = 0.057), it emerged as a significant variable in the multivariate logistic regression model (p = 0.019). This suggests that age may have an independent effect on the risk of IFG. No confounding factors were found, indicating that the multivariate model clarifies the relationship. Previous studies specifically related to the relationship between age and IFG were limited to adolescent populations. However, similar studies on samples aged 19–25 years also found a relationship between age and IFG (40,41). Furthermore, studies on obese children and adolescents in Germany and Sweden revealed that there is a relationship between age and IFG (42). Thus, the discovery of the influence of age groups in this study highlights the need for increased awareness as age increases.

The relationship between gender and IFG

Based on the univariate analysis, the incidence of IFG was found to be slightly higher among female respondents compared to males. This observation aligns with previous findings showing a higher prevalence of IFG in females (43). However, the results of the bivariate analysis did not demonstrate a statistically significant association between gender and IFG, suggesting that gender alone may not be a determining factor in this population. However, several other studies have reported a significant relationship between gender and impaired glucose regulation, such as IFG and IGT. As in the study by Denton, J., et al. (44), which found that gender had an effect on IFG. Furthermore, the results found in this study contradict the global trend showing a higher prevalence of IFG in men, which is consistent with the findings of Kautzky-Willer, A., et al. (45) rand Chen, C.M., et al. (33), that IGT is consistently more common in women and IFG is more common in men. This discrepancy may occur due to differences in blood sampling methods and the larger number of female participants compared to males. Therefore, further research using alternative methods is required.

The relationship between Body Mass Index and IFG

This study found that incidence of IFG increased with higher BMI. This finding is further supported by research that found the prevalence of IFG in participants with obesity was higher than in overweight participants and also higher than in normal weight participants (33). Previous research has also reported similar findings, indicating that the prevalence of prediabetes tends to increase in parallel with the progression of obesity status (46). Furthermore, the bivariate analysis in this study demonstrated a significant association between BMI and the, with obesity and overweight being the most influential variables on IFG occurrence. This is consistent with research finding that obesity increases the risk of IFG by 122% (47). Moreover, another study found that overweight individuals with IFG had a 9.9% lower probability of recovering to normoglycaemia than individuals with normal BMI, while obese individuals had a 16.9% lower probability of recovering to normoglycaemia (48). Obesity, especially when accompanied by increased abdominal fat distribution and abnormal triglyceride levels in the liver and muscles, is a major risk factor glucose intolerance because it causes insulin resistance and β-cell dysfunction. Accordingly, the global increase in obesity prevalence has led to a parallel increase in the prevalence of T2DM (49). However, the results of this study contrast with findings from other research which reported no significant association between BMI and fasting blood glucose levels. This discrepancy may be attributed to differences in sample characteristics, measurement methods, or population-specific factors (50). This discrepancy may be due to the limitations of the BMI measurement itself, as BMI is a simple indicator used to assess nutritional status and does not differentiate between muscle mass and fat mass. Therefore, it may not accurately reflect an individual's overall body composition, limiting its effectiveness as a sole predictor of metabolic risk such as prediabetes (51).

Relationship between family history of diabetes and IFG

The results of this study indicated that adolescents with IFG were more likely to have a family history of diabetes (FHD) compared to those without such a history. This observation was supported by the bivariate analysis, which revealed a statistically significant association between family history of diabetes and IFG, suggesting a potential genetic or familial predisposition to impaired glucose regulation. This finding is consistent with previous research showing that a family history of diabetes is a significant predictor of IFG, reinforcing the role of genetic and familial factors in the development of early disturbances in glucose metabolism (44). This association may be attributed to the inheritance of insulin-related genes from individuals with diabetes to their offspring particularly first-degree relatives which can lead to insulin resistance as a result of inherited metabolic traits (52). The impact of family history on type 2 diabetes mellitus (T2DM) also operates through obesity, insulin resistance (IR), and β-cell dysfunction (53). It is assumed that FHD has a stronger association with hepatic insulin resistance, a leading cause of IFG (54). The presence of FHD in first-degree relatives is important in predicting the risk of IFG, even without obesity, so it could be a priority criterion for diabetes screening in children and adolescents (55). Therefore, early detection and regular monitoring of IFG among individuals with a family history of diabetes are essential as preventive measures to reduce the risk of progression to type 2 diabetes.

The relationship between consumption of sweet drinks and IFG

The study found that adolescents with IFG were more prevalent among those who consumed excessive amounts of sugary drinks compared to those with normal consumption levels. This finding is consistent with previous research indicating that increased Artificially Sweetend Beverage (ASB) consumption is linked to higher fasting glucose levels and a lower β-cell function (56). The bivariate and multivariate analysis also found a significant impact of sugary drink consumption on the incedence of IFG. In line with this finding, it was also discovered that soft drink consumption >1 time per day is a risk factor for multiple metabolic syndromes, including IFG, with a risk 1.25 times greater than consumption < 1 time per day (57). In addition, previous research has shown that adolescents who consume more than 12 grams of sugar from sweetened beverages per day have a 4.333 times greater risk of developing impaired fasting glucose compared to those who consume less than 12 grams per day (36). This occurs because frequent consumption of sugary drinks leads to the accumulation of excess energy, which is stored as visceral fat contributing to central obesity. In addition, high sugar intake from these beverages has been shown to reduce insulin sensitivity, thereby increasing the risk of elevated blood glucose levels and the development of prediabetes (58).

The relationship between sleep quality and IFG

The study results showed no significant difference in the incidence of IFG between the poor and good sleep quality groups. Bivariate analysis also showed no significant association between sleep quality and IFG. This finding is consistent with previous research that also did not observe a significant association between global PSQI scores and fasting blood glucose levels (59,60). However, this finding contrasts with other studies that reported a significant association between sleep quality and OGTT and IGT as the measurement method. Therefore, it is possible that the impact of poor sleep quality on glucose metabolism becomes more apparent only after glucose administration, as measured by tests such as the OGTT, rather than through fasting blood glucose levels alone (59). Moreover, those studies found that only two of the seven components of the PSQI were significantly associated with prediabetes, suggesting that certain aspects of sleep quality may have a more direct influence on glucose metabolism than the global score alone (60,61). This is in line with findings of an increased risk of IFG associated with short sleep (less than 7 hours) behaviour along with insomnia (62,63). This happens because poor sleep quality in adolescents, especially on the aspect of sleep duration, may disrupt glucose regulation, with insulin sensitivity decreasing by up to 25%, equivalent to the level of adult diabetes patients (63). Thus, further research is warranted using alternative diagnostic methods, such as HbA1c, to gain a more comprehensive understanding of the relationship between sleep quality and glucose metabolism.

The relationship between stress levels and IFG

The results of the univariate analysis did not indicate an increased incidence of IFG with higher stress levels. Similarly, the bivariate analysis found no significant association between stress levels and IFG. These findings are consistent with previous research that also reported no significant relationship between stress levels and the occurrence of IFG (64,65). However, other research has identified a relationship between stress levels and blood glucose levels, particularly in final-year students, where the association was observed using laboratory-based testing methods (66). Additionally, an increase in glucose levels was found in residents living alongside military tension compared to civilian residents (67). This discrepancy may be attributed to differences in the duration and variety of stress exposure, as well as the methods used to measure blood glucose levels. Chronic stress can stimulate the endocrine system to release hormones such as epinephrine and cortisol, which in turn may lead to elevated blood glucose levels through increased gluconeogenesis and insulin resistance (66).

Limitation

We acknowledge that our study has several limitations that need to be considered in interpreting the results and in generalising the observations. The first limitation is that the population of our study consisted only of school students, and thus did not reflect the diversity of age, socioeconomic status, or lifestyle of the general population. This may limit the external validity and generalisability of the results to a broader population. Furthermore, nutritional status was measured using body mass index (BMI) without considering waist circumference or waist-to-hip ratio, which are more sensitive in detecting central obesity and related metabolic risks. Moreover, glucose testing was performed using capillary blood rather than venous blood, and was not accompanied by follow-up or repeated measurements, thus preventing the potential for glucose level fluctuations from being assessed longitudinally. And lastly, this study did not take ethnicity into account, even though genetic and cultural backgrounds can influence susceptibility to fasting glucose disorders and type 2 diabetes.

Conclusion

This study identified a relatively high estimated prevalence of IFG by using capillary blood among adolescents within the working area of the Alun-Alun Community Health Center (Puskesmas) in Gresik Regency, compared to the prevalence of IFG found in Southeast Asian countries. However, the capillary blood sample may have contributed to the high prevalence of IFG, so further research using venous blood is needed to obtain more accurate data. In addition, this study found that BMI, family history of diabetes, consumption of sweet drinks, and age group had a significant effect on the incidence of IFG. Therefore, it is hoped that adolescents can be more vigilant, especially regarding unhealthy lifestyles. Furthermore, increasing awareness of glucose intolerance is also necessary, so that early detection and treatment can be carried out properly. The role of the government in terms of glucose intolerance detection policies and easy data access is also very important in reducing the prevalence of IFG and preventing its development into T2DM.

Ethic Approval: This study received ethical approval from the Health Research Ethics Committee of the Faculty of Dentistry, Universitas Airlangga, on January 20, 2025. With approval number 0057/HRECC.FODM/I/2025.

Conflict of Interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

Author Contribution: ANZ: Data collection, manuscript writing, data analysis. LNY: Supervision, review, manuscript writing.

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