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Sweet Threshold and Fasting Blood Glucose Levels in Adolescents at Surabaya Indonesia

Ambang Rasa Manis dan Kadar Glukosa Darah Puasa Pada Remaja di Surabaya Indonesia

Silvia Rosalinda[1], Farapti Farapti[1]*, Afifah Nurma Sari[2], Dhandapani Shanthi[3]

[1]Department of Nutrition, Faculty of Public Health, Universitas Airlangga,, Surabaya 60115, Indonesia
[2]Plosoklaten Community Health Center, , Kediri 64175, Indonesia
[3]Department of Nutrition and Dietetic, School of Health Sciences, Kuala Lumpur 57000, Malaysia

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Correspondent:
Farapti Farapti
farapti@fkm.unair.ac.id

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ABSTRACT

Background: Diabetes mellitus (DM) is a degenerative disease characterized by elevated blood glucose levels (hyperglycemia). Based on Riskesdas 2018, the prevalence of diabetes mellitus diagnosed by doctors among the Indonesian population aged 15-24 years was 0.1%. The increase in blood glucose levels can be caused by high sugar consumption triggered by a high sweet taste threshold.
Objectives: This study was conducted to investigate a relationship between the sweet threshold and fasting blood glucose levels in adolescents at Surabaya Indonesia.
Methods: This cross-sectional study included 97 individuals selected through simple random sampling. The sweet taste threshold was carried out using three-alternative forced-choice (3-AFC) method. The sweet threshold was categorized as high if the sample could only answer <4 questions, while the normal category was defined as those who could answer >4 questions. Blood glucose measurements were performed by medical personnel using a glucometer, with a fasting blood glucose level of >100mg/dL considered high. Analysis was carried out using the Chi Square statistical test.
Results: The results indicated that 12.4% of the respondents had a high sweet taste threshold, while 10.3% of the respondents had high fasting blood sugar levels. The results showed that there was no relationship between the sweet taste threshold and fasting blood glucose levels (p-value = 0.210).
Conclusions: There is no relationship between the sweet taste threshold and fasting blood sugar levels in adolescents at Pondok Pesantren Subulussalam Surabaya. Respondents with high GDP levels should undergo further examination to facilitate early intervention and promote healthier lifestyles.

INTRODUCTION

Diabetes mellitus (DM) is a progressive condition characterized by elevated blood glucose levels (hyperglycemia), due to insufficient insulin production, insulin resistance, or a combination of both[1]. Individuals with DM frequently present with excessive hunger (polyphagia), excessive thirst (polydipsia), and frequent urination (polyuria)[2]. In adolescents, factors contributing to elevated blood glucose levels include genetic predisposition to DM, obesity, physical activity levels, stress, and dietary habits[4].

In 2019, Indonesia was ranked seventh worldwide for diabetes prevalence, with 10.7 million affected individuals, representing approximately 0.1% of the population aged 15-24 years[5]. Diabetes during adolescence has the potential to significantly impair productivity, decrease life expectancy by approximately five to ten years, and increase the risk of developing complications[6]. Type 2 diabetes mellitus is frequently associated with high sugar consumption habits, which lead to an elevated glycemic load. This, in turn, can trigger inflammation, glucose intolerance, and insulin resistance[7]. According to the 2013 Indonesia Basic Health Research, 53,1% of individuals aged 10 and older consumed sweet foods and beverages more than once a day[8]. By 2018, this number had risen to 61,3% for those who habitually consumed beverages with added sweeteners more than once a day[9]. Furthermore, 30,2% of respondents indicated an average consumption frequency of one to six times a week. The Indonesian Food Consumption Survey also indicated a slightly higher prevalence of sugar consumption exceeding 50 grams among adolescents compared to children, at 0,4%[10]. Biologically, adolescents tend to have a lower sweet taste sensitivity but a higher sweet taste preference compared to adults[11]. Consequently, they are identified as a

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population with a higher propensity to consume sugary foods and beverages.

The sweetness threshold is defined as the minimum concentration of sucrose that is capable of eliciting a taste response[12]. A heightened sweetness threshold indicates low sensitivity, which may result in an increased intake of sugar. Prolonged consumption of a diet with a high sugar content may have a detrimental impact on organ function, which in turn may lead to an increase in fasting blood glucose levels. Tsujimoto's study indicated that an elevated sweet taste threshold is associated with increased sugar consumption, which in turn is linked to an augmented susceptibility to disease[13]. Adolescents with obesity have been observed to exhibit reduced sweet taste sensitivity when compared to their non-obese counterparts[13] . Additionally, a significant association between sensitivity to sweet taste and nutritional status has been indicated by multiple studies[13]. A study conducted on adolescents in Poland has revealed that individuals with type 2 diabetes mellitus exhibited more pronounced taste bud impairments than their healthy peers[16]. These findings emphasize the need to comprehend the link between the sweetness threshold and general dietary patterns to enhance future disease prevention strategies.

The students at Pondok Pesantren Pelajar Mahasiswa (PPPM) Subulussalam, Surabaya, received meals with a standardized menu, where the side dishes were predetermined by the cook, and students were permitted to take rice according to their assigned portions. Furthermore, students have the option of purchasing food and beverages with pocket money provided by their parents at the canteen or from vendors in the boarding school area. Occasionally, students purchase food or beverages via online platforms using the gadgets provided to them by the college. Parents are permitted to visit their children every Sunday and consume food or drinks. Interviews with 20 students and two administrators revealed that students frequently purchased sweet beverages from local shops and cooperatives. The results indicated that 80% of the students consumed an average of one sachet drink per day. In light of these findings, further investigation is necessary to elucidate the relationship between the absolute threshold of sweet taste and fasting blood glucose levels in adolescents in Surabaya.

METHODS

This study employed observational and analytical approach, utilizing a cross-sectional design. The sample size was determined through a simple random sampling method. The study sample consisted of students from Pondok Pesantren Subulussalam, Surabaya, aged 11-19 years, who consented to fast for a minimum of eight hours and were willing to participate in the study. Students with comorbidities were excluded from the study, resulting in a final sample size of 97 students.

The study was conducted at PPPM Subulussalam, Surabaya, over four-month period, from May to August 2022. The dependent variable in this study was the fasting blood glucose (FBG) level, while the independent variable was the sweet taste threshold. The data set included information on the subjects' characteristics, such as sex, age, nutritional status, and family history of diabetes mellitus.

Prior to the commencement of the study, the respondents were instructed to fast for a period of 10 hours. The FBG levels were measured using a glucometer with a test strip method, which is considered easier to use, safe, and non-invasive approach for adolescents. Blood samples were obtained by capillary blood collection from the fingertip by a trained nurse The glucometer monitor then displayed the FBG levels, which were categorized as normal if FBG was < 100 mg/dL and high if FBG was ≥ 100 mg/dL[17]. Subsequently, anthropometric measurements were performed to obtain data regarding the respondents' nutritional status. Nutritional status data were obtained through weight measurements using a digital scale, and height measurements using a stadiometer. Nutritional status was classified as underweight (< -2 SD), normal (-2 SD to +1 SD), overweight (+1 SD to +2 SD), or obese (> +2 SD))[18]. Following the completion of these measurements, the respondents were provided with breakfast and instructed to consume it. After breakfast, structured interviews were conducted to gather key data and relevant variables. During this period, the participants were advised to refrain from consuming any food or drink other than water.

After breakfast and the interview, which lasted approximately 2 hours, subjects underwent a sweet taste threshold test. Sweet taste threshold was measured using the three-alternative forced-choice (3-AFC) method with a strip test technique[19,20]. This method involved providing a set of samples, consisting of two blank samples containing distilled water and one test sample containing a sucrose solution. In this study, eight sample sets were prepared with sucrose concentrations in the test samples as follows: 400 g/L, 224.8 g/L, 126.2 g/L, 71 g/L, 39.8 g/L, 22.4 g/L, 12.6 g/L, and 7.1 g/L, as adapted from a previous study[21]. Each sample was placed in a 10 mL plastic cup and stored at room temperature. The sucrose solution at each concentration was then applied using a cotton swab to the respondent's tongue, starting from the lowest to the highest concentration. Each respondent was given a few minutes to identify each sample set, and neutralization between the samples was achieved by rinsing with water. Responses were designated as "+" for correct answers and "0" for incorrect answers. Sweet taste threshold was categorized based on response scores ranging from 1 to 8, where a score < 4 indicated a high threshold, and a score ≥ 4 indicated a normal threshold[21]. The collected data were then categorized. The chi-squared test was employed for statistical analysis with a significance level of $p < 0.05$ to determine whether an association existed between the two variables under investigation.

This study met all ethical standards required. The study was conducted in accordance with the ethical standards set forth by the Health Research Ethics Committee of the Faculty of Public Health, Universitas Airlangga, which granted approval on July 11, 2022, under the reference number 143/EA/KEPK/2022. Prior to the study, written consent was obtained from the head of PPPM Subulussalam, Surabaya, and from each respondent. Only those who had provided informed

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consent were permitted to proceed with the study procedures.

RESULTS AND DISCUSSIONS

The respondents of this study were students enrolled at an Islamic boarding school in Surabaya. The demographic and health characteristics examined included sex, age, family history of DM, and nutritional status. The characteristics of the respondents are presented in the following table:

Table 1. Distribution of Respondent Characteristics

Respondent Characteristics	n	%
Sex		
Male	48	49.5
Female	49	50.5
Total	**97**	**100**
Age		
11-13 years	20	20.8
14-16 years	61	63.5
17-19 years	15	15.6
Total	**97**	**100**
Family history of DM		
Yes	14	14.4
None	83	85.6
Total	**97**	**100**
Nutritional status		
Underweight	2	2.1
Normal	72	74.2
Overweight	11	11.3
Obese	12	12.4
Total	**97**	**100**

Table 1 indicates that the respondents were nearly evenly distributed between females (49.5%) and males (50.5%). Nonetheless, prior study has demonstrated that adolescent females exhibit a higher risk of elevated FBG levels and T2DM compared to their male counterparts[22.23]. A study conducted in Mexico corroborated this finding, revealing that 71% of adolescent females exhibited hyperinsulinemia[23], whereas insulin resistance was identified in 63% of adolescents in Indonesia[22]. The presence of higher body fat reserves in females, coupled with hormonal fluctuations associated with the menstrual cycle, has been demonstrated to influence blood glucose levels[24]. Furthermore, the heightened secretion of sex hormones during puberty may contribute to the development of insulin resistance, increased adiposity, and altered levels of Insulin-like growth factor-1 (IGF-1), particularly among adolescent females[25].

In this study, respondents' ages were classified into three categories: early adolescence (ages 11-13), middle adolescence (ages 14-16), and late adolescence (ages 17-19) [26]. The majority of the respondents were fell within the middle-adolescent category, with a mean age of 14 years. Adolescence is characterized by profound psychological, mental, emotional, and physical transformations. It is noteworthy that physiological changes, including increased adiposity and elevated serum IGF-1 levels during puberty, have been implicated in approximately 3% of insulin resistance development, which may subsequently lead to hyperglycemia[27]. Type 1 diabetes, which frequently manifests during adolescence, typically peaks at puberty[28]. Adolescents at this developmental stage frequently seek autonomy in decision-making, which is indicative of their aspirations to be regarded as adults rather than children[29]. It is crucial for adolescents to understand the importance of maintaining good health and a balanced diet. They are often prone to consuming foods and beverages that are lacking in essential nutrients, which can have a detrimental impact on their well-being[30.31]. This recent study indicates that adolescents exhibit a heightened propensity to consume sugary foods on weekends, which may contribute to the prevalence of obesity and diabetes[32]. This highlights the necessity of adopting a healthy diet and healthy eating habits as a component of controlled diabetes management[33].

A family history of DM represents a significant risk factor for elevated blood glucose levels in individuals. Interviews revealed that 14 participants (14.4%) reported a family history of DM. The same etiopathogenetic mechanisms have been identified as risk factors for both type 1 and type 2 DM, with both forms exhibiting genetic heterogeneity[34]. This familial predisposition is frequently correlated with an earlier onset of type 2 DM, inadequate insulin secretion, and a higher prevalence of the HLA-DBQB1*03.02/X genotype, which is associated with susceptibility to type 1 DM[35].

Nutritional status is a vital indicator for evaluating an individual's health. In this study, 11 participants (11.3%) were identified as overweight, while 12 (12.4%) were classified as obese. Excessive body weight has been linked to adverse health outcomes, including elevated blood glucose levels. As body fat increases, so too does leptin production, which can have a detrimental impact on insulin function. Leptin, a hormone that regulates body fat mass, plays a pivotal role in appetite control by signaling satiety and facilitating fat oxidation for energy utilization[36]. These findings are consistent with those of a

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study investigating leptin concentrations and cardiometabolic risk among adolescents in Iran reported significantly elevated leptin levels in adolescents with obesity (p-value < 0.001) [36]. Furthermore, hyperleptinemia has been positively correlated with insulin levels, particularly in the context of obesity, among adolescents[37].

Table 2. Respondents' Sweetness Threshold Distribution

Variable	n	%
Set 1 (7.1 g/L)		
Correct	4	4.1
False	93	95.9
Set 2 (12.6 g/L)		
Correct	45	46.4
False	52	53.6
Set 3 (22.4 g/L)		
Correct	72	74.2
False	25	25.8
Set 4 (39.8 g/L)		
Correct	85	87.6
False	12	12.4
Set 5 (71 g/L)		
Correct	85	87.6
False	12	12.4
Set 6 (126.2 g/L)		
Correct	97	100
False	0	0
Set 7 (224.8 g/L)		
Correct	97	100
False	0	0
Set 8 (400g/L)		
Correct	97	100
False	0	0
Sweet taste threshold		
Normal	85	87.6
High	12	12.4
Total	**97**	**100**

The sweet taste threshold serves as a metric of an individual's ability to perceive gustatory stimuli. As indicated by the data presented in Table 2, only four respondents (4.1%) accurately identified 128 samples that contained the lowest concentration of sucrose. In contrast, all respondents successfully detected the sweet taste starting from the sixth sample, labeled 124. This finding suggests that a considerable proportion of respondents were unable to recognize taste at the normative threshold, as those who provided incorrect responses beyond the fourth sample were classified as having a high taste threshold. In addition, 12 respondents (12.4%) had a high sweet taste threshold. Collectively, these results imply that the majority of the respondents demonstrated a normal sweet taste threshold.

Gustatory perception in adolescents is typically effective. Existing literature indicates that taste sensitivity generally declines with advancing age, which is attributed to a reduction in the number of taste buds, which subsequently influences taste thresholds[38]. This decline typically commences around the age of 60, when a noticeable decrease in taste sensitivity is observed. Furthermore, factors such as individual taste thresholds, smoking behaviors, dietary habits, and specific health conditions may significantly affect taste sensitivity.

Table 3. Distribution of FBG

Variable	n	%
Fasting Blood Glucose		
Normal (<100 mg/dl)	87	89.7
High (≥100 mg/dl)	10	10.3
Total	**97**	**100**

FBG refers to the concentration of glucose in the blood following a fasting period of more than eight hours. According to the data presented in Table 3, the distribution of FBG levels among respondents revealed that 10 individuals (10.3%) were categorized as having elevated fasting blood glucose, defined as levels equal to or exceeding 100 mg/dL. These findings indicate that the majority of respondents maintained well-regulated

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fasting blood glucose levels. Elevated FBG levels may serve as a potential indicator of diabetes mellitus; however, additional diagnostic testing is necessary to confirm this condition. A study conducted in Korea indicated that 11.66% of adolescents exhibited high FBG levels[39], implying that, while a subset of adolescents may experience challenges in glucose regulation, the prevalence remains relatively low. A number of factors, including genetic predisposition, environmental influences, and immune system health, can affect FBG levels.

Table 4. Relationship between Sweetness Threshold and FBG

Sweet Taste Threshold	FBG						Chi-Squared Test
	Normal		High		Total		
	n	%	n	%	n	%	
Normal	75	77.3	10	10.3	85	87.6	0.210
High	12	12.4	0	0	12	12.4	
Total	**87**	**89.7**	**10**	**10.3**	**97**	**100**	

Table 3 demonstrate no significant association between sweet taste threshold and FBG levels (p-value = 0.210). This finding implies that a heightened sweet taste threshold does not inherently correspond to elevated FBG levels. Notably, respondents with elevated FBG levels had normal sweet taste thresholds. This finding differs from previous research suggesting that a high sweet taste threshold may contribute to increased sugar intake, resulting in elevated blood glucose levels[12]. Elevations in fasting blood glucose levels may arise from endogenous factors, such as hormonal influences, as well as exogenous factors not addressed in this study, or possibly other unidentified variables. Furthermore, adolescence is not typically considered a risk factor for elevated blood glucose levels, as individuals at this developmental stage generally have well-functioning physiological systems that metabolize carbohydrates effectively[40]. Moreover, a high taste threshold does not directly dictate an individual's sugar consumption; rather, it is influenced by a confluence of factors including cultural norms, financial resources, and personal preferences. This recent study indicates that taste sensitivity and preference among adolescents are significant determinants of dietary behavior[15]. Consequently, managing sweet taste thresholds by providing nutritious food options may represent a critical strategy for mitigating the risk of obesity and diabetes within this demographic.

Limitations of this study include the lack of data regarding sugar and carbohydrate consumption patterns, nutritional status, stress levels, preferences, and sociocultural factors, all of which may influence DM. In addition, smoking habits and health conditions were not included in the exclusion criteria despite their established impact on taste thresholds, which may have influenced the study results. Future studies should include these variables to facilitate a more comprehensive analysis. In addition to sugar intake, future studies should investigate the overall carbohydrate consumption patterns, as these significantly influence blood glucose levels. Inclusion of this would enhance understanding of the relationship between dietary habits and DM. Another limitation pertains to the utilization of capillary blood sampling to measure FBG. This method was chosen because of it is minimally invasive nature and higher acceptance among respondents, particularly in light of the restrictions imposed by schools and the reluctance of most individuals to undergo venous blood sampling. This study was conducted on a small and relatively homogeneous sample consisting exclusively of students from an Islamic boarding school with a uniform diet provided by the institution. These characteristics constrain the generalizability of the findings to the broader adolescent population as the results may not accurately reflect dietary diversity and lifestyle factors in other demographic groups.

CONCLUSIONS

This study indicated a lack of association between sweet taste threshold and FBG levels among adolescents in Surabaya. The majority of respondents exhibited results within the normal range for both sweet taste thresholds and fasting blood glucose levels. A more thorough investigation of dietary patterns, particularly carbohydrate consumption, along with environmental and lifestyle factors such as physical activity, sleep habits, and stress levels may provide valuable insights into the risk factors for DM. This merits further investigation, and a larger and more representative sample size, coupled with comprehensive evaluations of familial diabetes history and longitudinal studies, would significantly improve the understanding of risk factors and the progression of diabetes among adolescents. For participants exhibiting elevated fasting blood glucose levels, it is advisable to conduct follow-up examinations to promote early prevention and encourage adoption of healthier lifestyle practices.

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CONFLICT OF INTEREST AND FUNDING DISCLOSURE

The authors declare no conflict of interest related to this study, writing, and the publication of this article. In addition, this study was conducted without any financial support. All the study costs were borne by the

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AUTHOR CONTRIBUTIONS

FF: conceptualization. methodology. supervision; SRA: conceptualization. methodology. formal analysis. investigation. writing-original draft; ANS: writing-review & editing. visualization; DS: supervision.

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