Jurnal Gizi Indonesia
(The Indonesian Journal of Nutrition)

Jurnal Gizi Indonesia (The Indonesian Journal of Nutrition)
Vol. 14, No. 2, June 2026 (165-172)
Received: 6 August 2025, Revised: 25 March 2026,
Accepted: 9 April 2026, Published: 30 June 2026
https://ejournal.undip.ac.id/index.php/jgi, DOI:10.14710/jgi.14.2.165-172

Association of Sugar-Sweetened Beverages (SSBs) consumption and sedentary behavior with prediabetes among adolescents

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ABSTRACT

Background: Prediabetes is a borderline glycemic condition that indicates an increased risk of progression to type 2 diabetes mellitus. Prediabetes in adolescent is increasing along with economic development, nutritional transition, and sedentary behavior. Nutritional transition characterized by frequent intake of sugar-sweetened beverages (SSBs) and increased sedentary behavior has contributed to the rising risk of prediabetes among Indonesian adolescents. Without appropriate intervention, prediabetes is likely to develop into diabetes mellitus.

Objectives: To examine the association between SSBs consumption and sedentary behavior with adolescents' prediabetes, as a basis for early detection and timely intervention.

Materials and Methods: This study is an analytical observational study with a cross-sectional design involving 146 adolescents from 9 senior high schools in the service areas of the Jember Kidul Community Health Center and the Lojejer Community Health Center. The variables studied included the frequency and consumption of SSBs measured using SQ-FFQ, sedentary behavior measured using ASAQ, and fasting blood glucose levels measured with Easy-touch GCU glucometer after an-8 hour fast. The data were analyzed using Spearman correlation with statistical software.

Results: Milk-flavored drinks were the most frequently consumed SSBs type (90.4%), while energy drinks were the least (10.2%). The most common sedentary behavior was using computer for fun (4.3 hours/day), while the least was worship-related activities (0.8 hours/day). The results showed a significant association between adolescent prediabetes and the frequency of SSBs consumption ($p < 0.001$), sugar intake from SSBs ($p < 0.001$) and sedentary behavior ($p < 0.001$).

Conclusion: Consumption of SSBs and sedentary behavior are associated with prediabetes in adolescents. Therefore, early screening and education on prediabetes are needed in the healthcare sector and in schools.

Keywords: *Adolescent; prediabetes; sedentary behavior; sugar sweetened beverages*

BACKGROUND

Prediabetes is a condition in which blood glucose levels are above normal but do not yet meet the criteria for diabetes mellitus (DM), including impaired glucose tolerance (140–199 mg/dL) and impaired fasting glucose (100–125 mg/dL) according to the American Diabetes Association. Prediabetes is a transitional stage that may either revert to normal (reversible) or progress to DM (irreversible).[1] Prediabetes does not show signs of symptoms, so most individuals are unaware of their prediabetes condition.[2] In fact, prediabetes contributes to the rise in DM cases, with approximately 37% of those with prediabetes at risk of developing type 2 DM.[3] The number of people with type 2 DM continues to rise globally according to International Diabetes Federation (IDF).

The Health Ministry of Indonesia reported that the number of people with type 2 diabetes in Indonesia in 2024 reached 19.5 million people and is estimated to reach 28.5 million people in 2045.[4] Prediabetes is increasingly occurring in the child and adolescent population with a prevalence of 10.8% in the 15–24 age group in Indonesia.[5] The rise in prediabetes cases among adolescents is linked to economic development, nutritional transition, and sedentary behavior.[6]

A nutritional transition, characterized by the consumption of SSBs, is a risk factor for prediabetes. Consumption of 1-2 servings of SSBs per day has a 26% higher risk of developing prediabetes.[7] In Indonesia, SSBs are consumed at least once a week by 62% of children, 72% of adolescents, and 61% of adults[8]. Research shows the level of consumption of sugary drinks in adolescents aged 15-18 years is high at 60%.[9] In addition to the SSBs consumption, a sedentary lifestyle is also a risk factor for prediabetes.

Sedentary behavior refers to activities with very low energy expenditure outside of sleep.[10] The 2023 Indonesian Health Survey found that 50.4% of adolescents aged 15–19 is physically inactive, which is higher than the national prevalence of 37.4%. Lack of physical activity can lead to a 6.2 times greater risk of developing DM.[9] High consumption of SSBs and sedentary behavior is in line with the increasing number of

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adolescents at risk of prediabetes.[11] Prediabetes without proper management has the potential to develop into DM, which contributes to increasing the prevalence of DM in in high-risk areas.[12]

East Java, where Jember Regency is located, is the province with the fifth-highest prevalence of DM in Indonesia. The number of DM cases in this regency continues to rise significantly from 2020 to 2023. According to the Health Ministry of Indonesia, Jember Regency consists of urban and rural areas. The highest incidence of diabetes was found in the service areas of the Jember Kidul Community Health Center (urban) and the Lojejer Community Health Center (rural).[4] Therefore, early detection and intervention during the prediabetes phase are crucial, as this condition is still reversible and progression to diabetes can be prevented.[13]

MATERIALS AND METHODS

This study is an analytical observational study with a cross-sectional design conducted in March–April 2025 among 146 adolescents from 9 senior high schools in the service areas of the Jember Kidul Community Health Center and the Lojejer Community Health Center, selected through simple cluster sampling. The respondents were students aged 15–18 years who were willing to participate in the study. The variables studied included the frequency and consumption of SSBs, sedentary behavior, and fasting blood glucose levels. The frequency and consumption of SSBs were measured using the SQ-FFQ, covering carbonated beverages, fruit-flavored beverages, sports drinks, energy drinks, milk-flavored drinks, sweetened tea, and sweetened coffee. Sedentary behavior was measured using the ASAQ questionnaire, while fasting blood glucose levels were measured with an Easy-touch GCU glucometer after an 8-hour fast. Bivariate analysis used the Spearman test because the data were not normally distributed. This study received ethical approval under number 2966/UN25.8/KEPK/DL/2025.

RESULTS

According to Table 1, the majority of respondents was male (54.8%), 17 years old (32.2%), had normal nutritional status (39.7%), had no family history of diabetes mellitus (67.1%), and lived in urban areas (76.03%).

Table 1. Respondent Characteristics

Characteristics	Total (n)	Frequency (%)
Gender		
Male	80	54.8
Female	66	45.2
Age (years)		
15	12	8.2
16	44	30.1
17	47	32.2
18	43	29.5
Body Mass Index (kg/m^2)		
Underweight (<18,5)	40	27.4
Normal (18,5 – 22,9)	58	39.7
Overweight (23 – 24,9)	20	13.7
Obese (>25)	28	19.2
Family History of Diabetes		
Yes	48	32.9
No	98	67.1
Geographic Location		
Rural	35	23.97
Urban	111	76.03
Total	**146**	**100**

As presented in Table 2, milk-flavored beverages were the type of SSBs most frequently consumed by respondents (90.4%), while energy drinks were the least frequently consumed (10.2%).

Table 2. Types of SSBs

Variable	Total (n)	Frequency (%)
Types of SSBs		
Milk-flavored drinks	132	90.4
Coffee	117	80.1
Tea	115	78.7
Fruit flavoured drinks	110	75.3
Soft drinks	87	59.5
Sport drinks	74	50.6
Energy drinks	15	10.2

Based on Table 3, the most prevalent sedentary behavior among respondents was the use of smartphones, computers, or laptops for entertainment purposes (such as playing online games and using social media), with an average duration of 4.3 hours per day. Meanwhile, the least common sedentary activity was religious worship, with an average duration of 0.8 hours per day.

Table 3. Types of Sedentary Behavior

Variable	Average hours/day (n)
Sedentary behavior	
Using computer for fun	4.3
Sitting around (chatting with friends/on the phone/chilling)	3.4
Using computer for doing homework	2.1
Being tutored	2.5
Doing crafts or hobbies	2.2
Doing homework not on the computer	2,1
Travel (car/bus/train/bike/motorcycle)	2.0
Reading for fun	1.9
Watching videos/DVDs	1.7
Watching TV	1.2
Playing/practicing a musical instrument	1.1
Worship-related activities	0,8

Table 4. Statistical Test of Frequency of SSBs Consumption, Added Sugar Consumption from SSBs, Sedentary Behavior dan Prediabetes Incident

	Min.	Max.	Median	Prediabetes Incident				Total		*p-value*	*R*
				Normal		Prediabetes					
				n	%	n	%	n	%		
Frequency of SSBs Consumption											
Low (< 3 x/week)	1	8	3	96	65.8	5	3.4	101	69.2	<0.001*	0.424
High (≥ 3 x/week)				28	19.1	17	11.7	45	30.8		
Added Sugar Consumption from SSBs											
Sufficient (< 50 g/day)	10.32	72.39	37.20	96	65.8	9	6.2	105	72	<0.001*	0.291
Excessive (≥ 50 g/day)				28	19.1	13	8.9	41	28		
Sedentary Behavior											
Low (< 2 hours/day)	1.09	8.15	4.57	10	6.8	0	0	10	6.8	<0.001*	0.467
Moderate (2-5 hours/day)				82	56.2	2	1.4	84	57.6		
High (≥ 5 hours/day)				32	21.9	20	13.7	52	35.6		

As illustrated in Table 4, 15.1% of respondents had prediabetes, 30.8% frequently consumed SSBs, 28.1% had excessive sugar intake from SSBs, and 35.6% exhibited high levels of sedentary behavior. The median frequency of SSB consumption was 3 times per week (range: 1–8 times), the median sugar intake from

SSBs was 37.29 g per day (range: 10.32–72.39 g per day), and the median duration of sedentary behavior was 4.57 hours per day (range: 1.09–8.15 hours per day).

The results of the study show that 11.7% of respondents with a high frequency of sugar-sweetened beverage (SSB) consumption fell into the prediabetes category based on their fasting blood glucose levels. Spearman's test revealed a significant association between the frequency of SSB consumption and prediabetes in adolescents ($p < 0.001$). A correlation coefficient of 0.424 indicates a positive association of moderate strength, suggesting that the more frequently SSBs are consumed, the higher the fasting blood glucose levels. A total of 8.9% of respondents with excessive sugar intake from SSBs were also classified as prediabetic. The results of the Spearman's test showed a significant association between sugar intake from SSBs and prediabetes in adolescents ($p < 0.001$). A correlation coefficient of 0.291 indicates a weak positive association, meaning that an increase in sugar intake from SSBs tends to be followed by an increase in fasting blood glucose levels. In addition, 13.7% of respondents with high levels of sedentary behavior fell into the prediabetes category. The Spearman's test revealed a significant association between sedentary behavior and prediabetes in adolescents ($p < 0.001$). A correlation coefficient of 0.467 indicates a positive association of moderate strength, suggesting that the higher the level of sedentary behavior, the greater the risk of elevated fasting blood glucose levels.

Based on table 5, the incidence of prediabetes is more common in urban areas (12.3%) compared to in rural areas (2.8%).

Table 5. Statistical Test of Geographic Location with Prediabetes Incident

Geographic Location	Prediabetes Incident				Total		*p-value*
	Normal		Prediabetes				
	n	%	n	%	n	%	
Rural	31	21.2	4	2.8	35	23.9	0.531
Urban	93	63.7	18	12.3	111	76.1	
Total	**124**	**84.9**	**22**	**15.1**	**146**	**100**	

A Mann-Whitney U test was conducted to determine differences in the prevalence of prediabetes among adolescents in rural and urban areas. A p-value of 0.531 was obtained, indicating no significant difference in the prevalence of prediabetes between rural and urban areas.

DISCUSSION

Respondent Characteristics

This study involved high school students from the service areas of the Jember Kidul Community Health Center and the Lojejer Community Health Center. The results showed that the majority of respondents were male (54.8%). This finding is consistent with a UNICEF report (2024) stating that adolescent males in Indonesia are a group vulnerable to various health problems, particularly noncommunicable diseases, whose prevalence continues to rise.

This study involved respondents aged 15–18 years. This age range represents a critical phase in the development of adolescents' metabolic health, as it is marked by various changes in lifestyle and dietary patterns that can influence the risk of cardiometabolic diseases in adulthood.[14] According to the study results, the majority of participants were 17 years old (32.2%). Among adolescents, the prevalence of prediabetes is reported to range from 6% to 14%, influenced by dietary patterns and physical activity levels.[15] These findings underscore the importance of early intervention and health education to prevent the development of more serious metabolic disorders in adulthood.[16]

Nutritional status based on BMI is classified into four categories: underweight, normal weight, overweight, and obese. The results of this study show that 39.7% of respondents had a normal nutritional status. This finding is consistent with a study of high school students in Karawang, which reported a normal nutritional status of 43.2%.[17] Maintaining a normal nutritional status during adolescence is crucial because this period is characterized by rapid growth and optimal development of the brain and central nervous system.[17]

Genetic factors are one of the key factors associated with prediabetes. According to the American Diabetes Association (ADA), family history, particularly among first-degree relatives such as parents or siblings, is a significant risk factor for type 2 DM. Based on this study, the majority of respondents (67.1%)

had no family history of diabetes mellitus. This finding is consistent with a study of high school students in Palangkaraya, which showed that the majority of respondents (69.5%) also had no family history of DM.[6]

Most of the respondents in this study reside in urban areas. This finding is supported by 2024 data from the Central Statistics Agency of Jember, which shows that population density in urban areas (3,850 km²) is higher than in rural areas (1,433 km²). In addition, the number of residents aged 15–19 was also higher in urban areas (9,542 people) than in rural areas (8,663 people). On the other hand, there have been dynamic changes in the prevalence of impaired glucose tolerance in urban areas, rising from 10.2% in 2007 to 29.9% in 2013, then declining slightly to 28.8% in 2018.[18]

Sugar Sweetened Beverages Consumption

SSBs consumption was assessed based on the frequency and sugar intake from the beverages consumed by the respondents. The study results showed that the majority of respondents (69.2%) had a low frequency of SSB consumption, while the remaining 30.8% fell into the high-frequency category. This finding is consistent with a previous study of adolescents in Jayapura City, which reported that 63% of respondents also fell into the low-consumption category.[19] The median frequency of SSBs consumption in this study was 3 times per week, lower than that reported in a previous study, which found an average consumption of 5–6 times per week.[19] Among adolescents, high frequency of SSBs consumption is known to be associated with an increased risk of metabolic disorders such as obesity, insulin resistance, and prediabetes.[20]

Sugar intake from SSBs in this study showed that 105 respondents (71.9%) fell into the moderate category, while 41 respondents (28.1%) fell into the excessive category. These findings are consistent with a previous study that reported 55% of respondents in the moderate category and 45% in the excessive category.[21] The median sugar intake from SSBs in this study was 37.29 g/day. This result is also consistent with another study showing an average sugar intake from SSBs among adolescents of 36.80 g/ day,[22] although other studies have reported higher values, ranging from 41 to 50 g/ day.[23]

The most consumed SSBs types by respondents was milk-flavored drinks, while the least frequently consumed was energy drinks. These findings are consistent with other studies showing that milk-flavored drinks are the type of SSBs most frequently consumed by adolescents, while energy drinks are the least frequently consumed.[24] Another study also reported that milk-flavored drinks are the most commonly consumed type of SSB among adolescents in Malaysia.[24]

The type of added sugar commonly found in SSBs is high fructose corn syrup (HFCS). The effect of increased consumption of HFCS is increased blood glucose levels. Fructose can trigger an increase in blood sugar levels through several mechanisms, one of which is by stimulating the process of de novo lipogenesis (DNL), which is the process of converting excess fructose into fatty acids.[25]

Sedentary Behavior

Most respondents (57.5%, or 84 people) exhibited moderate sedentary behavior, while 35.6% (52 people) fell into the high category. These findings are consistent with a study in Jombang, which showed that the majority of respondents fell into the moderate (54.55%) and high (39.34%) categories.[26] The average duration of sedentary behavior among respondents was 4.57 hours per day. This result is consistent with other studies reporting that the average duration of sedentary behavior among adolescents is less than 5 hours per day.[27]

The most common sedentary behavior among respondents was the use of smartphones, computers, or laptops for entertainment, such as playing online games and accessing social media, while the least common was activities related to religious worship. Social media use is known to be one of the factors that increase the tendency toward sedentary behavior among adolescents, particularly through activities such as playing games and watching engaging content, which can reduce motivation to engage in physical activity.[28] Sedentary behavior among adolescents is also influenced by various factors, including individual, environmental, and social aspects.

Association between Sugar Sweetened Beverages (SSBs) Consumption and Sedentary Behavior with Adolescent Prediabetes

The study results indicate a significant association between the frequency of SSBs consumption and prediabetes in adolescents. These findings are consistent with previous studies indicating that consuming sweetened beverages ≥3 times per week is associated with an increased risk of insulin resistance and metabolic disorders in adolescents.[29] Repeated sugar intake can cause spikes in blood glucose levels and chronic metabolic stress on the pancreas, which in turn triggers impaired glucose tolerance as an early stage of prediabetes.[30]

The results of this study show a significant association between sugar intake from SSBs and prediabetes in adolescents. Frequent consumption, even in small amounts, can still increase metabolic risk due to repeated fluctuations in glucose and insulin levels.[31] Consumption in large quantities can also cause spikes in blood glucose levels, triggering high insulin secretion. If this condition persists, insulin sensitivity may decrease, thereby increasing the risk of prediabetes.[32]

The results of this study reveal a significant association between sedentary behavior and prediabetes in adolescents. These findings are consistent with other studies reporting a significant association between sedentary behavior and prediabetes in adolescents at the Johor Baru Health Center (p=0.0270).[33] Sedentary behavior is defined as an activity with very low energy expenditure, specifically <1.5 metabolic equivalents of task (METs).[34] This condition can increase blood glucose levels by reducing the activity of the enzyme lipoprotein lipase (LPL).[35]

Lipoprotein Lipase (LPL) activity is highly dependent on physical activity and muscle contraction. When muscle contraction is reduced, it can inhibit the process of converting sugar in the muscles into energy, affecting the decrease in blood sugar levels. This leads to decreased insulin effectiveness and poor utilization of glucose and fat in the cells.[35] The lack of muscle movement can lead to excess energy in the body and will then be converted into fat and this can cause inflammation which can trigger insulin resistance which is the main cause of DM.[35]

Identification of Prediabetes Incidence in Adolescents in Rural and Urban Areas

The prevalence of prediabetes was reported to be higher in urban areas (12.3%) than in rural areas (2.8%). The WHO found a similar pattern, with a prevalence of 7.3% in urban communities and 3.1% in rural communities. These findings indicate that adolescents in urban areas face a higher risk of prediabetes, which is associated with high levels of sedentary behavior, consumption of fast food, and exposure to sugar-sweetened beverages.[36]

The Mann–Whitney U test showed no significant difference in the incidence of prediabetes between adolescents living in rural and urban areas (p = 0.531). This suggests that differences in regional characteristics do not significantly affect the respondents' fasting blood glucose levels. Geographic factors are not the primary determinants of adolescents' metabolic status; rather, it is more influenced by lifestyle factors such as diet, physical activity, and sleep quality.[37]

CONCLUSIONS

SSBs consumption and sedentary behavior are significantly associated with prediabetes in adolescents, whereas differences in geographic characteristics do not show a significant effect on fasting blood glucose levels. Based on these findings, early screening for prediabetes among adolescents by the health sector and schools is recommended, with a focus on monitoring SSBs consumption and sedentary behavior. Prevention efforts can be implemented through nutrition education, restricting access to high-sugar beverages, and increasing physical activity.

ACKNOWLEDGMENT

We would like to express our gratitude to the high school teachers and students in the service areas of the Jember Kidul Community Health Center and the Lojejer Community Health Center for their support and participation in this study.

CONFLICT OF INTEREST

The author declarate that there is no conflict of interest regrading the publication.

DECLARATION USE AI

The author declarate that no Artifical Intelligence (AI) tools were used.

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