

THE RELATIONSHIP BETWEEN ULTRA-PROCESSED FOOD AND BEVERAGE CONSUMPTION PATTERNS, BLOOD GLUCOSE LEVELS, AND NUTRITIONAL STATUS AMONG ADOLESCENTS

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Abstract

Background: The consumption of ultra-processed foods (UPFs) among adolescents has increased significantly, raising concerns about long-term metabolic health. **Objective:** This study aimed to analyze the relationship between ultra-processed food and beverage consumption patterns, blood glucose levels, and nutritional status among adolescents in public and private high schools. **Methods:** A cross-sectional study was conducted with 72 respondents aged 16–18 years in East Jakarta and Bekasi. Data were collected using a Semi-Quantitative Food Frequency Questionnaire (SQ-FFQ), glucometer for random blood glucose measurements (non-fasting), and BMI-for-age (BMI/A). **Results:** A significant environmental inequality was observed, with high UPF consumption found in 75% of public school students compared to 52.8% of private school students ($p=0.020$). Despite this high intake, most respondents maintained normal blood glucose levels (97.2%–100%; $p=0.951$) and normal nutritional status (72.2%–75%; $p=0.955$). No significant relationship was found between UPF consumption and random blood glucose levels or nutritional status ($p>0.05$). **Conclusion:** Structural disparities in school food environments likely drive the higher UPF consumption in public schools. While immediate metabolic correlations were not found possibly due to the limited sensitivity of random glucose testing and high adolescent metabolic rates high UPF intake remains a latent risk.



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Introduction

The consumption of ultra-processed foods (UPFs) among adolescents has increased markedly in recent decades, with significant implications for their health and dietary patterns. UPFs are characterized by industrial formulations, high caloric density, and

excessive content of added sugars, fats, and sodium, often replacing traditional diets rich in minimally processed whole foods. Adolescents are particularly vulnerable due to greater autonomy in food choices, exposure to aggressive marketing, and easy access to these foods in schools and social settings.

Research shows that high UPF intake in adolescents is associated with adverse health outcomes including poor quality of life, increased incidence of insomnia, and pro-inflammatory states. For example, adolescent girls with the highest UPF consumption had an almost twofold likelihood of reduced quality of life and fourfold increased odds of insomnia (1). Additionally, adolescents consuming more UPFs show elevated serum inflammatory markers, such as leptin, C-reactive protein (CRP), and interleukin-8 (IL-8), indicating systemic inflammation linked to poor diet quality (2). This early inflammatory response may predispose to chronic diseases later in life.

UPF consumption also correlates with obesity and related metabolic complications in youth. Narrative reviews highlight that UPF-rich diets drive excessive caloric intake, disrupt hunger regulation, and contribute to obesity, dyslipidemia, hypertension, and insulin resistance among children and adolescents (3). Further, in adolescents with type 1 diabetes, higher UPF consumption is associated with poorer glycemic control, as indicated by elevated glycated hemoglobin (HbA1c) levels (4). At a physiological level, UPFs negatively affect the gut microbiome and gut barrier function, reducing microbial diversity and increasing pro-inflammatory microorganisms. This gut dysbiosis contributes to persistent inflammation that exacerbates chronic diseases including metabolic disorders and may impact mental health via the gut-brain axis (5).

In Indonesia, particularly in urban areas, the prevalence of obesity and type 2 diabetes among adolescents continues to rise, with Jakarta and Bekasi being the areas with the highest incidence. However, the school food environment in these cities often lacks adequate nutritional regulation. Public school canteens are frequently surrounded by unregulated street vendors offering low-cost, nutrient-poor ultra-processed foods, whereas private schools often enforce stricter canteen management policies. This situation raises concerns about adolescents' long-term health (6). Therefore, this study was conducted to analyze the relationship between consumption of UPF and packaged beverages with blood glucose levels and nutritional status of adolescents in public and private schools.

Materials and Methods

This study employed a cross-sectional design conducted in public and private high schools in East Jakarta and Bekasi City from December 2024 to June 2025. A total of 72 adolescents aged 16–18 years were selected using a purposive sampling technique, with 36 participants representing each school type. The selected schools were regular full-day schools (non-boarding) to ensure comparability in students' daily food access outside of

school hours. Dietary data regarding Ultra-Processed Food and beverage (UPF) consumption patterns were collected through a Semi-Quantitative Food Frequency Questionnaire (SQ-FFQ). Blood glucose levels were measured using a glucometer and Easy Touch glucose test strips, while nutritional status was assessed based on Body Mass Index-for-age (BMI/A) through direct measurements of weight and height. Measurements were taken in a non-fasting state during school hours (between 09:00 and 11:00 AM). It is acknowledged that random blood glucose screening using a glucometer has lower sensitivity compared to HbA1c for detecting early metabolic dysregulation, serving primarily as a preliminary screening tool in this study. All participants provided written informed consent prior to data collection, and the study underwent an ethical review process. Data analysis was performed using univariate analysis for descriptive statistics and Spearman correlation for bivariate analysis to examine the relationships between variables, with a significance level set at $p < 0.05$. Additionally, Mann-Whitney tests and multiple linear regression were utilized to compare data and analyze differences between school categories.

Results

Table 1. Distribution of Respondents

Characteristic	Public High School		Private High School		N	
	n	%	n	%	n	%
Age (years)						
16 - 17	4	11.1	12	33.3	16	22.2
≥17 – 18	32	88.9	24	66.7	56	77.8
Gender						
Male	15	41.7	11	30.6	26	36.1
Female	21	58.3	25	69.4	46	63.9
Monthly Pocket Money						
<500.000	14	38.9	10	27.8	24	33.3
500.000 – 1.000.000	18	50	25	69.4	46	63.9
1.000.000 – 2.000.000	4	11.1	7	19.4	11	15.3
>2.000.000	0	0	0	0	0	0

Source: Processed Primary Data (2025)

Table 1 presents the demographic and economic profiles of the 72 respondents involved in the study. The majority of participants in both public (88.9%) and private (66.7%) high schools were aged between 17 and 18 years, falling into the middle adolescent developmental stage. In terms of gender distribution, female students predominated the sample, accounting for 58.3% in public schools and 69.4% in private schools. Regarding economic characteristics, the most common monthly pocket money range for respondents

was between IDR 500,000 and IDR 1,000,000, representing 50% of students in public schools and 52.8% in private schools. Notably, none of the respondents reported receiving pocket money exceeding IDR 2,000,000 per month⁶. These findings suggest that the adolescent participants generally come from similar economic backgrounds, which can significantly influence their dietary and consumption patterns

Table 2. Distribution of UPF Consumption, Blood Glucose Levels, and Nutritional Status

Characteristic	Public High School		Private High School		P - value
	n	%	n	%	
UPF Consumption Pattern					
High	27	75	19	52.8	0.020*
Moderate	8	22.2	14	38.9	
Low	1	2.8	3	8.3	
Blood Glucose Levels					
Normal	35	97.2	36	100	0.951
Low	1	2.8	0	0	
Nutritional Status (BMI)					
Normal	26	72.2	27	75	0.955
Underweight	3	8.3	1	2.8	
Overweight	3	8.3	4	11.1	
Obese	4	11.1	4	11.1	

Note: Significance level $p < 0.05$.

The results indicate a significant difference in Ultra-Processed Food and Beverage (UPF) consumption patterns between the two school categories ($p=0.020$). Adolescents in public schools exhibited a higher prevalence of "High" UPF intake (75%) compared to those in private schools (52.8%). This condition suggests that a normal BMI does not guarantee metabolic health, aligning with the "Thin Outside, Fat Inside" (TOFI) phenomenon, as visceral fat accumulation and metabolic inflammation may occur silently due to high UPF consumption before manifesting in weight changes. In contrast, there were no significant differences observed in physiological markers. The majority of respondents in both groups maintained normal random blood glucose levels ($p=0.951$), with 97.2% in public schools and 100% in private schools falling within the normal range. Similarly, nutritional status was predominantly "Normal" across both institutions ($p=0.955$), involving 72.2% of public school students and 75% of private school students. Although UPF consumption was high, particularly in public schools, it did not immediately translate into abnormal glucose levels or nutritional status in this adolescent sample

DISCUSSION

Based on the research results in Table 2, it was found that there was a significant difference in the consumption patterns of Ultra-Processed Food and Beverages (UPF) between adolescents in public and private schools ($p=0.020$). The high consumption of UPF among adolescents in public schools (75%) compared to private schools (52.8%) is largely driven by disparities in the school food environment and policy. Public schools in this region tend to have an 'open' food environment where students have unrestricted access to unregulated external vendors selling high-calorie snacks (7). In contrast, private schools often implement stricter control over food availability, typically relying on managed canteens with better nutritional oversight (8). The availability of cheap and practical processed foods around schools significantly contributes to increased consumption of unhealthy foods among adolescents. Food environments close to schools are often dominated by outlets selling fast food and processed convenience items, which adolescents access frequently due to their affordability and convenience (9). Adolescents tend to choose these foods as they are affordable and readily available, particularly in urban settings where school food environments do not support healthy food choices (10). Research shows that the cheap prices of processed and fast foods encourage adolescents to buy more unhealthy items rather than healthier options, which can often be more expensive or less accessible (9). Adolescents also report that healthy foods like fruits are often inaccessible or unaffordable in school environments dominated by processed snacks (10). This economic factor not only drives the frequency of unhealthy food consumption but also shapes social behaviors, as adolescents seek foods that provide social acceptability and convenience (10).

The lack of a significant relationship between ultraprocessed food (UPF) consumption and immediate metabolic disturbances must be interpreted with caution due to the limited variation in blood glucose data, which reduces the statistical power of the Spearman correlation. Furthermore, the use of random capillary glucose testing may not be sensitive enough to detect subtle early-stage insulin resistance compared to HbA1c markers. Despite these methodological limitations, physiological factors may also play a role. During this age range, adolescents experience active growth characterized by a very high basal metabolic rate (BMR), which enables the body to effectively compensate for excess calorie intake from UPFs. This high BMR supports energy expenditure and growth demands, mitigating the acute metabolic effects of excess calorie consumption during this critical developmental window. Moreover, metabolic disturbances such as increased blood glucose levels, insulin resistance, or drastic changes in nutritional status due to UPF intake typically develop as chronic conditions requiring prolonged exposure. Evidence from studies in children and adolescents shows a positive association between UPF consumption and metabolic disorders like insulin resistance and metabolic-associated steatotic liver disease (MASLD), but these associations become more pronounced over longer durations and with

sustained high intake of UPFs (11). This supports the understanding that metabolic impairments linked to diets rich in processed foods may not be immediately evident during adolescence but rather tend to manifest in early adulthood or after years of chronic exposure.

Longitudinal and simulation studies emphasize that reducing UPF consumption can significantly reduce obesity and associated metabolic risks over time in young populations, which further underscores the chronic nature of such metabolic disturbances (12). Additionally, some impacts of UPF are observed in developmental aspects like bone quality, which may suffer from long-term consumption due to impaired growth plate function, revealing how damage extends beyond overt metabolic parameters and may not be immediately clinically apparent (13).

Conclusion

This study concludes that there is a significant disparity in ultra-processed food and beverage (UPF) consumption between public and private high school students, with public school students exhibiting higher intake levels. This difference is largely driven by the school food environment. The absence of a significant immediate correlation... suggests that the high basal metabolic rate, may temporarily mask the effects of excessive caloric intake. However, since UPF poses cumulative health risks, these findings serve as an early warning. Future research should utilize more sensitive metabolic biomarkers such as HbA1c or lipid profiles rather than random blood glucose to better detect early metabolic shifts. Practically, there is an urgent need for policy interventions to regulate street vendors around public schools and upgrade public school canteen management to ensure equitable access to healthy food for all adolescents.

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