July – September, 2026
Original Article
DOI: http://dx.doi.org/10.30867/action.v11i3.3254

Pages: 904 – 911

AcTion:
Aceh Nutrition Journal
p-issn 2527-3310; e-issn 2548-5741

Analysis of sugar, salt, and fat intake and physical activity in relation to metabolic syndrome risk among adolescents in Depok City, Indonesia

Analisis konsumsi gula, garam, lemak, dan aktivitas fisik dengan risiko sindrom metabolik pada remaja di Kota Depok, Indonesia

Rhizka Nurul Aenu[1*], Ikeu Ekayanti[2], Hadi Riyadi[3]

[1] Department of Nutrition, Faculty of Medicine and Nutrition, Institut Pertanian Bogor, West Java, Indonesia.
E-mail: rhizkanurul1234@gmail.com
[2] Department of Nutrition, Faculty of Medicine and Nutrition, Institut Pertanian Bogor, West Java, Indonesia.
E-mail: i.ekayanti.1966@gmail.com
[3] Department of Nutrition, Faculty of Medicine and Nutrition, Institut Pertanian Bogor, West Java, Indonesia.
E-mail: hadiri@apps.ipb.ac.id

***Corresponding Author:**
Department of Nutrition, Faculty of Medicine and Nutrition, Institut Pertanian Bogor, Jl. Raya Dramaga, Kampus IPB Dramaga Bogor, 16680 West Java, Indonesia.
E-mail: rhizkanurul1234@gmail.com

Article History:
Received: May 12, 2026; Revised: June 05, 2026; Accepted: June 12, 2026; Published: September 03, 2026.

Publisher:
Politeknik Kesehatan Aceh
Kementerian Kesehatan RI

© The Author(s). 2026 **Open Access**
This article has been distributed under the terms of the *License Internasional Creative Commons Attribution 4.0*

Abstract

Several studies have shown that schoolchildren in Indonesia frequently consume foods high in sugar, salt, and fat (SSF), and low physical activity may also contribute to an increased risk of metabolic syndrome from an early age. This study aimed to analyze the association between SSF intake and physical activity and the risk of metabolic syndrome among adolescents in Depok City. A cross-sectional study was conducted among 119 high school adolescents selected purposively. SSF intake was assessed using a Semi-Quantitative Food Frequency Questionnaire (SQ-FFQ), physical activity using a structured questionnaire, and metabolic syndrome risk using the Metabolic Syndrome Risk Score for Adolescents, which has been validated in a similar population. Data were analyzed using univariate, bivariate (chi-square), and multivariate (logistic regression) analyses at a significance level of $p < 0.05$. Most respondents had low physical activity (68.9%) and excessive sodium (86.6%) and transfat (97.5%) intakes. Physical activity was a significant protective factor against metabolic syndrome risk ($p < 0.001$; Exp(B) = 0.02), whereas sugar intake showed a tendency toward increased metabolic syndrome risk ($p = 0.06$; Exp(B) = 7.24). In conclusion, adequate physical activity may play an important role in reducing the risk of metabolic syndrome, whereas excessive sugar intake may increase the risk. Therefore, health promotion and preventive efforts focusing on increasing physical activity and controlling the intake of SSF should be prioritized during adolescence.

Keywords: Metabolic syndrome, physical activity, sugar intake

Abstrak

Beberapa penelitian menunjukkan bahwa anak-anak sekolah di Indonesia sering mengonsumsi makanan tinggi gula, garam, dan lemak (GGL), sementara rendahnya aktivitas fisik berkontribusi terhadap peningkatan risiko sindrom metabolik sejak usia dini. Penelitian ini bertujuan menganalisis konsumsi GGL dan aktivitas fisik serta hubungannya dengan risiko sindrom metabolik pada remaja di Kota Depok. Penelitian menggunakan desain cross-sectional pada 119 remaja SMA yang dipilih secara purposive. Data konsumsi GGL dikumpulkan menggunakan Semi-Quantitative Food Frequency Questionnaire (SQ-FFQ), aktivitas fisik diukur menggunakan kuesioner terstruktur, dan risiko sindrom metabolik dinilai menggunakan Metabolic Syndrome Risk Score for Adolescents yang telah divalidasi pada populasi serupa. Analisis dilakukan secara univariat, bivariat (chi-square), dan multivariat (regresi logistik) dengan tingkat signifikansi $p < 0,05$. Sebagian besar responden memiliki aktivitas fisik rendah (68,9%) serta konsumsi natrium (86,6%) dan lemak trans (97,5%) yang melebihi anjuran. Aktivitas fisik merupakan faktor protektif yang signifikan terhadap risiko sindrom metabolik ($p < 0,001$; Exp(B) = 0,02), sedangkan konsumsi gula menunjukkan kecenderungan meningkatkan risiko sindrom metabolik (p = 0,06; Exp(B) = 7,24). Kesimpulannya, aktivitas fisik yang memadai berperan penting dalam menurunkan risiko sindrom metabolik pada remaja, sedangkan konsumsi gula berlebih berpotensi meningkatkan risiko meskipun belum signifikan secara statistik. Upaya promotif dan preventif melalui peningkatan aktivitas fisik serta pengendalian konsumsi GGL perlu diprioritaskan sejak remaja.

Kata Kunci: Aktivitas fisik, asupan gula, sindrom metabolik

Introduction

Fast food and artificially sweetened beverages are widely available and may be more readily accessible than healthier food options for children. Technological advances are increasingly associated with lower levels of physical activity and exercise among adolescents. Consequently, reduced physical activity may have contributed to weight gain. According to the 2023 data from the Ministry of Health (Kemenkes), 28.7% of the Indonesian population consumed sugar, salt, and fat (SSF) above the recommended limits. In addition, 53.5% of the Indonesian population consumes salt above the recommended limit of 2,000 mg/day (Kemenkes, 2023). A study conducted in South Jakarta reported added sugar intakes ranging from 34.9 to 45.9 g per capita per day, with the highest intake among school-age boys (Andarwulan et al., 2021). Previous research has also found that Indonesian schoolchildren frequently consume foods high in sugar (68.5%), fat (67.1%), and salt (56.2%) (Zaizafia et al., 2024).

High SSF intake and low physical activity levels are closely associated with the prevalence of noncommunicable diseases. A high sugar intake may contribute to insulin resistance and increase the risk of type 2 diabetes mellitus, particularly among adolescents with obesity (Sinha et al., 2022). Excessive salt intake is associated with increased blood pressure and hypertension risk, whereas excessive fat intake may contribute to dyslipidemia, body fat accumulation and obesity (Murni et al., 2022). These conditions may be further exacerbated by sedentary behavior and high screen time, which are associated with an increased risk of metabolic syndrome in adolescents (Christofaro et al., 2019). Obesity is a key characteristic of metabolic syndrome and contributes to the development of coronary heart disease, heart failure, stroke, arrhythmia, and sudden cardiac death. Therefore, maintaining a healthy nutritional status through healthy lifestyle behaviors and reduced SSF intake is important during adolescence (Powell et al., 2021).

Globally, the prevalence of metabolic syndrome among adolescents is < 10%. In high-income countries, the prevalence estimates range from 4.1% to 8.4%. A meta-analysis reported that among adolescents with obesity, the prevalence ranged from 2.1% to 74.4%, with a mean of 29.4% (Wentzel et al., 2026). In developing Asian countries, its prevalence is increasing alongside rising rates of adolescent obesity (Wilson & Shah, 2025). In Indonesia, 13.36% of adolescents and young adults have diseases related to metabolic syndrome (Ningsih et al., 2026).

Questionnaire-based research on metabolic syndrome is limited in Indonesia. Most previous studies have relied primarily on clinical and laboratory examinations for diagnosis and have focused on adult populations only. In addition, available metabolic syndrome screening instruments have generally been developed for adults and may be less appropriate for adolescents. A distinctive feature of this study is the use of the Metabolic Syndrome Risk Score for Adolescents, a questionnaire designed specifically to assess metabolic syndrome risk in adolescents using a simpler and more practical approach tailored to their characteristics. Unlike previous studies that focused primarily on clinical diagnosis or adult screening instruments, this study used an adolescent-specific screening instrument.

This study aimed to analyze sugar sweetened beverage (SSB) consumption and physical activity among adolescents in Depok City. This study also aimed to examine the relationship between SSF consumption and physical activity with metabolic syndrome risk among adolescents in Depok City using the Metabolic Syndrome Risk Questionnaire for Adolescents (METS). The findings are expected to contribute to the evidence base and serve as a reference for future studies.

Methods

This study employed a cross-sectional design and was conducted from April to October 2025 at the IPB Dramaga Campus in Bogor and Depok City, West Java. The study population consisted of adolescents registered in senior high schools in Depok City. The sample consisted of adolescents from several sub-districts in Depok City. The sampling process is illustrated in Figure 1. The minimum sample size, calculated using Lemeshow's (1997) formula, was 119 participants. The inclusion criteria were as follows: adolescents who appeared healthy (as indicated by their attendance at the time of data collection) and were aged 15–18 years; adolescents who were willing to be interviewed and assessed with parental consent; and adolescents who provided their consent. Adolescents were excluded if they had poor nutritional status with or without edema (BMI-for-age z score < 3 SD), a chronic disease (as indicated by a physician's diagnosis), or an eating disorder. The sampling was conducted in stages. Of the 11 subdistricts in Depok City, five were randomly selected using simple random sampling. Five schools within these sub-districts were selected as the study sites. Among the adolescents aged 15–18 years in the target population, 225 individuals were identified. After applying the inclusion and exclusion criteria, 119 respondents were randomly selected as the final study sample. The sampling stages are illustrated in Figure 1.

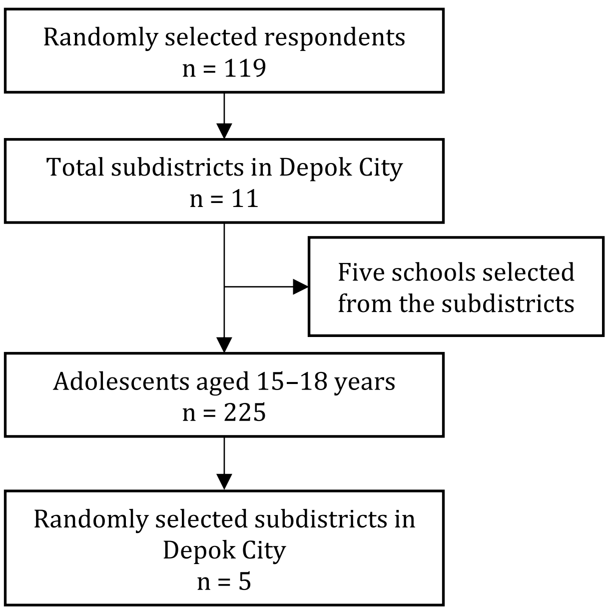

Figure 1. Sampling stages

This study used primary and secondary data. Secondary data were obtained from the study "Food Security, Physical and Mental Health among Adolescents in Depok, Indonesia" and included adolescent characteristics, parental /family characteristics, anthropometric measurements, physical activity, and SSF intake assessed using the Semi-Quantitative Food Frequency Questionnaire (SQ-FFQ). Primary data included family medical history and metabolic syndrome risk, assessed using the Metabolic Syndrome Risk Score for Adolescents questionnaire, which underwent validity and reliability testing. Data were collected through interviews, observations, and direct measurements. Information on adolescent characteristics, parental/ family characteristics, physical activity, SSF intake, family medical history, history of hypertension, history of elevated blood glucose, dietary habits, and light exercise habits were collected using questionnaires and interviews with the adolescents.

Anthropometric measurements, including waist circumference, were obtained directly with a precision of 0.1 cm.

After data collection, data on adolescent characteristics, family characteristics, anthropometric measurements, SSF intake, and responses to the Metabolic Syndrome Risk Score for Adolescents questionnaire were entered into Excel as a master dataset and processed using SPSS version 27.0. Univariate, bivariate (chi-square), and multivariate (logistic regression) analyses were performed using a significance level of $p < 0.05$. In the multivariate analysis, potential confounders, including age, sex, obesity status, and parental characteristics, were controlled for, as they could theoretically influence the risk of metabolic syndrome. Before logistic regression, multicollinearity was assessed using the variance inflation factor (VIF) and tolerance values to ensure that the independent variables were not highly correlated. The model was considered free of multicollinearity when VIF < 10 and tolerance > was > 0.10.

Result and Discussion

The respondents were 119 adolescents attending five high schools in Depok. Based on their scores on the metabolic syndrome risk questionnaire, respondents were classified into two groups: at risk and not at risk of developing metabolic syndrome.

Table 1. Characteristics of respondents

Characteristic	Risk of Metabolic Syndrome		p-value
	At risk, n (%)	Not at risk, n (%)	
Age			0.322
15–16 years	8 (38.1)	49 (50.0)	
17–18 years	13 (61.9)	49 (50.0)	
Gender			0.088
Male	11 (52.4)	32 (32.7)	
Female	10 (47.6)	66 (67.3)	
Father's Education			0.708
did not complete high school	2 (9.5)	7 (7.1)	
graduated high school	19 (90.5)	91 (92.9)	
Father's Income			0.480
<IDR 1 million	4 (19.0)	8 (8.2)	
IDR 1 million – IDR 5 million	8 (38.1)	38 (38.8)	
IDR 5 million – IDR 10 million	6 (28.6)	32 (32.7)	
>IDR 10 million	3 (14.3)	20 (20.4)	
Mother's Education			0.590
did not complete high school	1 (4.8)	8 (8.2)	
graduated high school	20 (95.2)	90 (91.8)	
Mother's Income			0.990
<IDR 1 million	10 (47.6)	45 (45.9)	
IDR 1 million – IDR 5 million	6 (28.6)	29 (29.6)	
IDR 5 million – IDR 10 million	3 (14.3)	14 (14.3)	
>IDR 10 million	2 (9.5)	10 (10.2)	

As shown in Table 1, none of the socioeconomic variables were significantly associated with metabolic syndrome risk ($p > 0.05$). The 17–18-year age group had a higher proportion of respondents at risk (61.9%) than the 15–16-year age group (38.1%), although the difference was not significant ($p = 0.322$). Males also had a higher proportion at risk than females (52.4% vs. 47.6%), although the difference was not significant ($p = 0.088$). Neither the father's ($p = 0.708$) nor the mother's education ($p = 0.590$) was significantly associated with the risk of metabolic syndrome. Most respondents in both groups had parents who completed high school, resulting in relatively limited variation in parental education.

Similarly, neither the father's income ($p = 0.480$) nor the mother's income ($p = 0.990$) was significantly associated with the risk of metabolic syndrome. The uneven distribution of respondents across income categories may partly explain the lack of a significant association. Father's occupation and income indicated that most respondents were in the middle socioeconomic category. This socioeconomic position may provide some protection against metabolic syndrome risk, as previous research has shown that a higher socioeconomic status is associated with healthier lifestyles and a lower prevalence of metabolic syndrome. Conversely, a lower socioeconomic status may confer a greater risk because of limited access to nutritious foods and environments that support physical activity.

Parental occupation may also shape adolescents' health behaviors through family supervision and household habits. Therefore, family socioeconomic status remains an important factor to consider when examining the risk of metabolic syndrome in adolescents. Socioeconomic factors may have a relatively small influence, despite their association with metabolic syndrome (Dos Santos et al., 2018). Metabolic syndrome in adolescents may be more strongly influenced by behavioral and biological factors, including obesity, high sugar/high-fat dietary patterns, and insufficient physical activity (Wang et al., 2018).

Table 2. Bivariate analysis of SSF intake, physical activity, and obesity status in relation to metabolic syndrome risk

Characteristic	Risk of Metabolic Syndrome		p-value
	At risk, n (%)	Not at risk, n (%)	
Obesity status			
Normal	13 (61.9)	81 (82.6)	0.034
Obesity	8 (39.1)	17 (17.4)	
Physical Activity			
Low	16 (76.2)	66 (67.5)	0.081
Moderate/high	5 (23.8)	32 (32.7)	
Sugar Intake			
Good	19 (90.5)	71 (72.4)	
Excessive	2 (9.5)	27 (27.6)	
Sodium Intake			0.562
Good	2 (9.5)	14 (14.3)	
Excessive	19 (90.5)	84 (85.7)	
Total Fat Intake			0.426
Good	11 (52.4)	42 (42.9)	
Excessive	10 (47.6)	56 (57.1)	
Saturated Fat Intake			0.195
Good	16 (76.2)	60 (61.2)	
Excessive	5 (23.8)	38 (38.8)	
Trans Fat Intake			0.470
Good	1 (4.8)	2 (2.0)	
Excessive	20 (95.2)	96 (98.0)	
Cholesterol Intake			0.513
Good	13 (55.5)	53 (54.1)	
Excessive	8 (38.1)	45 (45.9)	

Based on the bivariate analysis (Table 2), there was no significant association between obesity status, physical activity, or glycemic index consumption and metabolic syndrome risk ($p > 0.05$). However, low physical activity was associated with a metabolic syndrome risk at p = 0.08. This finding is consistent with Werneck et al. (2020), who reported that physical activity may reduce the risk of metabolic syndrome in adolescents, including its relationship with obesity. Other studies have also shown that exercise can improve the metabolic profiles of adolescents, including lipid profiles and body composition (Cayres-Santos et al., 2020).

Based on the logistic regression analysis (Table 3), physical activity was the only factor with a significant effect on the risk of metabolic syndrome (p = 0.000; Exp(B) = 0.02). The negative coefficient for physical activity indicated that individuals with sufficient physical activity had a 98% lower likelihood of developing metabolic syndrome. Sugar intake was also associated with the risk of developing hypertension (p = 0.06; Exp(B) = 7.24). This finding is consistent with that of Codazzi et al. (2023), who reported that low physical activity was significantly associated with a higher prevalence of metabolic syndrome among adolescents. Adolescents with low physical activity levels may be more likely to exhibit clusters of metabolic syndrome risk factors, particularly abdominal obesity and insulin resistance (Codazzi et al., 2023). Wang et al. (2024) reported that low physical activity was associated with higher blood pressure, fasting blood glucose, total cholesterol, and LDL cholesterol levels, as well as lower HDL cholesterol levels.

The regression model indicated a weak association between sugar intake and the risk of metabolic syndrome. Excessive sugar intake was associated with an Exp(B) of 7.24 (B = 1.98; P = 0.06), suggesting a tendency toward a higher risk of metabolic syndrome. Pan et al. (2022) explained that added sugars from sugary beverages, processed foods, juices, and syrups may contribute to the risk of metabolic syndrome through excess energy intake, increased visceral adiposity, insulin resistance, and dyslipidemia.

Biologically, a high intake of simple sugars, such as fructose, can increase de novo lipogenesis in the liver, raise triglyceride levels, lower HDL cholesterol levels, and worsen insulin sensitivity. Malik et al. (2019) and Stanhope (2016) emphasized that liquid sugars from sugar-sweetened beverages may have more adverse metabolic effects than solid energy sources because of their lower satiety effect and higher glycemic response.

Table 3. Multivariate analysis

Variable	B	S.E.	Wald	p-value	Exp(B)
Physical Activity	-3.89	1.1	10.74	0.00	0.02
Obesity status	-1.54	0.24	41.0	0.00	0.21
Sugar Intake	1.98	1.08	3.342	0.06	7.24
Sodium Intake	-0.71	1.18	0.36	0.54	0.49
Total Fat Intake	0.2	0.7	0.08	0.77	1.22
Saturated Fat Intake	0.73	0.7	1.08	0.29	2.09
Trans Fat Intake	2.78	1.8	2.3	0.13	2.09
Cholesterol Intake	0.27	0.56	0.24	0.62	1.3

Although sugar intake showed a strong association in terms of the effect estimate, several other variables, including sodium, total fat, and cholesterol intakes, were not significantly associated with the risk of metabolic syndrome in this model (Table 3). These findings suggest that excessive sugar intake may act as an early marker of metabolic syndrome risk before other dietary changes or clinical development of obesity. The findings also suggest that metabolic disturbances may be present even in adolescents who are not anthropometrically obese.

Among adolescents, the risk of metabolic syndrome may be more strongly influenced by adiposity and physical activity (Table 3). Obesity status was significantly associated with metabolic syndrome risk ($B = -1.54$; $p < 0.001$; Exp(B) = 0.21), indicating that adolescents with normal nutritional status had a substantially lower likelihood of developing metabolic syndrome than those with obesity. This finding implies that adolescents with obesity were at a markedly higher risk, consistent with previous studies identifying obesity as a major determinant of metabolic syndrome in youth. Excess adiposity, particularly central fat accumulation, contributes to insulin resistance, dyslipidemia, elevated blood pressure, and chronic low-grade inflammation, which collectively constitute the core components of metabolic syndrome (Gepstein & Weiss, 2019).

Physical activity was also significantly associated with the risk of metabolic syndrome ($B = -3.89$; $p < 0.001$; Exp(B) = 0.02), indicating a strong protective association. Adolescents with higher physical activity levels were substantially less likely to develop metabolic syndrome than those with low physical activity levels. This finding is consistent with previous research showing that regular moderate-to-vigorous physical activity improves insulin sensitivity, enhances lipid metabolism, reduces adiposity, and lowers blood pressure, thereby reducing the cardiometabolic risk (Dimitriadis et al., 2025). In this study, obesity was treated as an independent determinant and potential confounder because it was directly related to metabolic syndrome risk and was also related to physical activity and dietary intake patterns. Therefore, obesity status was controlled for in the logistic regression analysis to minimize confounding factors.

In contrast, sugar, sodium, total fat, saturated fat, trans fat, and cholesterol intakes were not statistically significant in the multivariate model. Although sugar intake approached statistical significance, it did not show an independent statistically significant association after considering the other variables. This may reflect the stronger influence of obesity and physical activity and their potential roles in the relationship between diet and metabolic syndrome. Recent research suggests that overall dietary patterns may provide a clearer picture of the relationship between diet and metabolic syndrome than individual nutrients. For example, adherence to healthy dietary patterns, such as the Mediterranean diet, has repeatedly been associated with a lower risk of metabolic syndrome, whereas studies on individual nutrients have produced mixed findings (Fabiani et al., 2019; Kastorini et al., 2011).

Mirmiran et al. (2019) found that overall diet quality was a better indicator of metabolic syndrome risk than that of individual nutrients. Accordingly, the absence of strong associations in this study may partly reflect the analysis of individual nutrients rather than the combined effects of foods and nutrients within the overall dietary patterns.

Conclusion

The results of this study indicate that some adolescents in Depok City have factors that may increase their risk of metabolic syndrome, including low physical activity, excessive intake of sugar, sodium, and fat, and abdominal obesity (AO). Based on the analysis, adolescents with adequate physical activity had a lower likelihood of developing metabolic syndrome, although this association was not statistically significant. Excessive sugar intake, particularly that of simple sugars, may increase the risk of metabolic syndrome. These findings highlight the importance of physical activity and sugar intake control in the early prevention of metabolic syndrome among adolescents.

Health promotion and preventive efforts should focus on increasing adolescents' physical activity through school- and community-based programs, including optimizing physical education, encouraging regular physical activity, and reducing sedentary behavior. Further research using longitudinal designs and biomarker measurements is recommended to strengthen the evidence regarding the factors associated with metabolic syndrome.

Acknowledgements

The authors thank all the institutions and participants involved in this study. This study was funded by the IPB University Research Grant (No. 1648/IT3.KEPMSM-IPB/SK/2025, ratified on March 6, 2025.

References

Andarwulan, N., Madanijah, S., Briawan, D., Anwar, K., Bararah, A., Saraswati, & Średnicka-Tober, D. (2021). Food consumption pattern and the intake of sugar, salt, and fat in the South Jakarta City—Indonesia. *Nutrients, 13*(4), 1289. https://doi.org/10.3390/nu13041289

Badan Kebijakan Pembangunan Kesehatan. (2024). *Survei Kesehatan Indonesia (SKI) dalam angka*. https://www.badankebijakan.kemkes.go.id/repositori/id/eprint/5539/

Codazzi, V., Frontino, G., Galimberti, L., Giustina, A., & Petrelli, A. (2024). Mechanisms and risk factors of metabolic syndrome in children and adolescents. *Endocrine, 84*(1), 16–28. https://doi.org/10.1007/s12020-023-03642-x

Dimitriadis, G. D., Chryssanthopoulos, C., Philippou, A., & Koutsilieris, M. (2025). The significant role of physical activity and exercise in health and metabolic diseases. *Physiologia, 5*(4), 57. https://doi.org/10.3390/physiologia5040057

Fabiani, R., Naldini, G., & Chiavarini, M. (2019). Dietary patterns and metabolic syndrome in adult subjects: A systematic review and meta-analysis. *Nutrients, 11*(9), 2056. https://doi.org/10.3390/nu11092056

Gepstein, V., & Weiss, R. (2019). Obesity as the main risk factor for metabolic syndrome in children. *Frontiers in Endocrinology, 10*, 568. https://doi.org/10.3389/fendo.2019.00568

Gupta, R., & Xavier, D. (2018). Hypertension: The most important non communicable disease risk factor in India. *Indian Heart Journal, 70*(4), 565–572. https://doi.org/10.1016/j.ihj.2018.02.003

Malik, S. U. F., Mahmud, Z., Alam, J., Islam, M. S., & Azad, A. K. (2019). Relationship among obesity, blood lipids and insulin resistance in Bangladeshi adults. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews, 13*(1), 444–449. https://doi.org/10.1016/j.dsx.2018.10.015

Mirmiran, P., Ziadlou, M., Karimi, S., Hosseini-Esfahani, F., & Azizi, F. (2019). The association of dietary patterns and adherence to WHO healthy diet with metabolic syndrome in children and adolescents: Tehran lipid and glucose study. *BMC Public Health, 19*(1), 1457. https://doi.org/10.1186/s12889-019-7779-9

Ningsih, O. S., Efendi, F., Dewi, Y. S., Murti, F. A. K., & Chan, C. M. (2026). Prevalence and factors associated with metabolic syndrome risk in Indonesian adolescents and young adults: A cross-sectional study. *Journal of Pediatric Nursing, 87*, 227–235. https://doi.org/10.1016/j.pedn.2026.01.017

Pan, F., Wang, Z., Wang, H., Su, C., Zhang, J., Du, W., Jia, X., Wang, L., Jiang, H., Li, W., Zhang, B., & Ding, G. (2022). Association between free sugars intake and risk of metabolic syndrome in Chinese adults: Results from the China Health and Nutrition Survey, 2000–2018. *Nutrients, 14*(24), 5385. https://doi.org/10.3390/nu14245385

Powell, P. A., Rowen, D., Rivero-Arias, O., Tsuchiya, A., & Brazier, J. E. (2021). Valuing child and adolescent health: A qualitative study on different perspectives and priorities taken by the adult general public. *Health and Quality of Life Outcomes, 19*(1), 222. https://doi.org/10.1186/s12955-021-01858-x

Sinha, S., & Haque, M. (2022). Obesity, diabetes mellitus, and vascular impediment as consequences of excess processed food consumption. *Cureus, 14*(9), e28762. https://doi.org/10.7759/cureus.28762

Stanhope, K. L. (2016). Sugar consumption, metabolic disease and obesity: The state of the controversy. *Critical Reviews in Clinical Laboratory Sciences, 53*(1), 52–67. https://doi.org/10.3109/10408363.2015.1084990

Wang, L. X., Gurka, M. J., & DeBoer, M. D. (2018). Metabolic syndrome severity and lifestyle factors among adolescents. *Minerva Pediatrica, 70*(5), 467–475. https://doi.org/10.23736/S0026-4946.18.05290-8

Wang, W., Zhou, H., Qi, S., Yang, H., & Hong, X. (2024). The association between physical activities combined with dietary habits and cardiovascular risk factors. *Heliyon, 10*(7), e28845. https://doi.org/10.1016/j.heliyon.2024.e28845

Wentzel, A., Nguyen, K. A., von Philipsborn, P., Levitt, N., & Mchiza, Z. J. R. (2026). Prevalence of metabolic syndrome among adolescents in Cape Town, South Africa: A cross-sectional analysis comparing five diagnostic criteria to explore suitability. *Diabetes Research and Clinical Practice, 231*, 113053. https://doi.org/10.1016/j.diabres.2025.113053

Wilson, D. P., & Shah, A. S. (2025). Metabolic syndrome in youth—A fresh look at an old problem. *Journal of Clinical Lipidology, 19*(4S), 4–14. https://doi.org/10.1016/j.jacl.2025.03.005

Zaizafia, A., Aristi, D., Ciptaningtyas, R., & Angkasa, D. (2024). Analysis of sugar, salt and fat in snack foods sold at elementary school food stalls. *Journal of Nutrition College, 13*(1), 1–8. https://doi.org/10.14710/jnc.v13i1.38444

Zhang, B., Shi, H., Cai, W., Yang, B., & Xiu, W. (2025). Metabolic syndrome in children and adolescents: Definitions, epidemiology, pathophysiology, interventions, and challenges. *Frontiers in Endocrinology, 16*, 1512642. https://doi.org/10.3389/fendo.2025.1512642