

ORIGINAL ARTICLE

Factors Associated with Obesity Classification among Senior High School Adolescents in Tomohon City, Indonesia

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ABSTRACT

OBJECTIVE: To analyze obesity-related behaviors among adolescents at senior high school residing in Tomohon City, Indonesia.

METHODOLOGY: This analytical cross-sectional study used purposively selected samples of 468 young adolescents aged 15–18 years with obesity, defined as a BMI of 30.0–39.9 kg/m². Obesity class (Class I: 30.0–34.9 kg/m²; Class II: 35.0–39.9 kg/m²) was the dependent variable. Data were collected using valid questionnaires and anthropometric measurements of participants. Chi-Square tests based on Odds Ratios were conducted; bivariate analysis and binary logistic regression were used for multivariate analysis. Notably, 69.7% of those surveyed had class I and 30.3% had class II obesity. In the bivariate analysis, all four independent variables were significantly associated with obesity class ($p < 0.05$).

RESULTS: Class II obesity was associated with highly sedentary behavior (OR=1.74, 95% CI: 1.12–2.69, $p=0.013$), poor dietary patterns (OR: 1.67(1.09–2.56); $P=0.019$), light physical activity 1.61 (95% CI: 1.05–2.49, $p=0.031$), and short sleep duration of ≤ 6 h per night (OR = 1.56(95 % CI 01–2.42) $p=0.047$). The most common cause was lack of exercise. The fit of the model was adequate (Hosmer-Lemeshow $p=0.733$; AUC = 0.68).

CONCLUSION: In adolescents, the degree of obesity was significantly associated with sedentary behavior, diet, physical activity, and sleep duration, with sedentary behavior as the strongest predictor.

KEYWORDS: Adolescent Obesity, Physical Activity, Sedentary Behavior, Sleep Duration, Obesity Classification

INTRODUCTION

The NCD Risk Factor Collaboration reported that age-standardized obesity prevalence among children and adolescents aged 5–19 years increased from 0.7% in 1975 to 5.6% in 2016 globally; however, trajectories vary by region over the last two decades ¹. Global statistics indicate that the prevalence of adolescent obesity has increased significantly throughout the early 21st century, and the rise in youth obesity prevalence is expected to continue. This phenomenon suggests a complex epidemic trajectory driven by changing lifestyle patterns in everyday life.

A meta-analysis showed that globally, adolescents with obesity are at a heightened risk of hypertension progression and other metabolic disorders compared to those with normal weight. These findings align with adult observational data confirming the persistence of childhood obesity and increased disease risk later in life ³. In addition, longitudinal studies reveal that most obese adolescents will carry on as adults and that adolescent obesity is harder to tackle ⁴.

The major modifiable risk factors for obesity in adolescents are the unhealthy behaviour patterns linked to eating, physical activity & sedentary behavior and sleeping habits ⁵. In adolescents, poor dietary practices, low levels of physical activity, and long hours of sedentary behavior are projected to be significant associated risk factors for obesity in multicountry analyses ⁶. There are also high chances of obesity in many countries due to the high consumption of sweetened beverages, ultra-processed foods, and long hours on screens. These complex interrelations between these lifestyle behaviours make it important to investigate the relationship of dietary approaches with obesity risk ⁷.

Still, while the majority of earlier studies in this field have looked at these lifestyle factors separately or at the offspring's obesity risk status in broad terms without particular consideration for objectively measured patterns and levels of obesity (e.g. whether the combined contributions of diet, physical activity, sedentary behavior, and sleep duration to obesity differ), this has been investigated infrequently in studies among high-risk adolescents who are already overweight or have high adiposity, especially in resource-limited populations such as smaller Indonesian cities. This is a limitation because, rather than distinguishing which behavioral factors better predict obesity severity, the studies only predicted the presence of obesity.

Despite this evidence, most previous studies have examined these lifestyle factors in isolation or focused broadly on obesity prevalence without differentiating obesity severity. Few studies have simultaneously assessed the combined influence of diet, physical activity, sedentary behavior, and sleep duration among already obese adolescents, particularly in underrepresented populations such as those in smaller Indonesian cities. This gap limits understanding of which behavioral factors most strongly contribute to obesity severity, not just its presence.

This study aimed to evaluate the factors associated with changes in obesity status among high school adolescents in Tomohon City, with the target age range of adolescents aged 15–18 years attending public high schools, related to diet, physical activity, sedentary behavior, and sleep duration, as well as to determine the most common contributing factors that affect obesity severity. The novelty of this study lay in the use of the multivariate approach, which included four health behavior variables in a population of obese adolescents, an underrepresented population in previous studies. Because this study used categories, respondents were classified by degree of obesity (classes I and II). However, previous studies generally focused on obesity prevalence or a single factor.

METHODOLOGY

Design and Setting

This study employed a cross-sectional observational design conducted in Tomohon City, North Sulawesi, Indonesia, a small urban municipality with a population of approximately 104,000. Local health authorities reported rising adolescent obesity prevalence, and the study selected Tomohon because it was feasible of access public senior high schools within a geographically compact urban setting. Public and private high schools in the city were included to enhance sample diversity.

Sample

The study population comprised senior high school adolescents (grades X–XII, aged 15–18 years) enrolled during the 2025–2026 academic year. Data collection occurred between November 2025 and April 2026.

Sampling was conducted purposively. A total of 12 senior high schools (8 public, 4 private) in Tomohon City were approached, but only 10 agreed to participate. We anthropometrically screened all students in grades X–XII ($N = 3,214$). Of these, 527 met the obesity z-score threshold ($> +2$ SD). Exclusion criteria included diagnosed endocrine conditions affecting body weight (e.g., hypothyroidism, Cushing's syndrome; $n = 4$), pregnancy ($n = 2$), school absence during data collection ($n = 31$), and incomplete questionnaire responses ($n = 22$). The final analytic sample comprised 468 adolescents with obesity. The purposive, non-probability design limits generalizability to the broader Indonesian adolescent population, and findings should be interpreted within this context.

Variables

The dependent variable was obesity severity: Class I obesity (BMI-for-age z-score $+2$ to $+3$ SD) versus Class II obesity (BMI-for-age z-score $> +3$ SD).

Independent variables were operationalized as follows:

Dietary intake: Assessed via a validated food frequency and dietary habits questionnaire. Scores at or above the median were classified as "Good"; below the median as "Poor."

Respondent characteristics (grade, age, sex) were collected for descriptive purposes. Trained enumerators obtained anthropometric measurements (weight and height) using a calibrated digital scale (precision: 0.1 kg) and portable stadiometer (precision: 0.1 cm), following WHO-standardized procedures.

A pilot test was conducted among 30 adolescents outside the study sample. Item-total correlation analysis retained items with r -calculated exceeding r -table. Cronbach's alpha coefficients were as follows: dietary habits questionnaire ($\alpha = 0.74$), PAQ-A ($\alpha = 0.78$), sedentary behavior questionnaire ($\alpha = 0.72$), and sleep duration questionnaire ($\alpha = 0.73$), all exceeding the 0.70 acceptability threshold.

Data Collection

The investigation proceeded in four phases: (1) **preparation**—obtaining permits from local government and school authorities, training enumerators on anthropometric protocols and questionnaire administration; (2) **screening**—measuring BMI-for-age z-scores of all enrolled students to identify eligible participants; (3) **data collection**—supervised self-administration of questionnaires and anthropometric measurements; and (4) **verification**—checking data completeness and consistency. Data processing included editing, coding, double-entry, and cleaning.

Data Analysis

Analyses were conducted at $\alpha = 0.05$. Univariate analysis calculated frequency distributions and percentages. Bivariate analysis employed chi-square tests with Odds Ratios (OR) and 95% Confidence Intervals (CI). Multivariate binary logistic regression (Enter method) identified determinants of Class II obesity. Model fit was assessed using the Omnibus Test, Hosmer-Lemeshow Goodness-of-Fit Test (adequate fit if $p > 0.05$), and Nagelkerke R^2 .

Discriminatory ability was evaluated by the Area Under the ROC Curve (AUC). Regression coefficients, standard errors, Wald statistics, adjusted ORs, 95% CIs, and p-values were reported; statistical significance required $p < 0.05$ and 95% CI excluding 1.

Ethical Considerations

The Health Polytechnic of the Ministry of Health Manado granted ethical approval (Reference No. IRB-2025-0283). Written informed consent was obtained from parents/guardians of participants under 18 years of age, and written assent was obtained from all participating adolescents. Participants aged 18 provided their own informed consent. Participation was voluntary, and respondents could withdraw at any time without consequence. All data were anonymized using coded identifiers, stored in password-protected databases accessible only to the research team, and handled in accordance with applicable data protection regulations.

RESULTS

Table I presents the demographic and behavioral characteristics of the participants. The largest group was in Class XI (49.4%), was 15 years old (43.1%), and was female (70.3%). The majority of respondents had Class I Obesity (69.7%), had adequate dietary habits (65.4%), were physically active (66.5%), had low sedentary behavior (67.1%), and had adequate sleep duration (68.4%).

Table I: Respondent Characteristics

Variables	Category	n	%
Class	X	207	44.2
	XI	231	49.4
	XII	30	6.4
Age (year)	15	202	43.1
	16	145	31.0
	17	86	18.4
	18	35	7.5
Gender	Male	139	29.7
	Female	329	70.3
Adolescent Obesity	Class I	326	69.7
	Class II	142	30.3
Dietary Habit	Adequate	306	65.4
	Inadequate	162	34.6
Physical Activity	Active	311	66.5
	Inactive	157	33.5
Sedentary Behavior	Low	314	67.1
	High	154	32.9
Sleep Duration	Adequate	320	68.4
	Inadequate	148	31.6

Table II shows bivariate associations between the independent variables and obesity class. All variables were significantly associated with Class II obesity ($p < 0.01$). Higher odds ratios (1.88-1.97) for Class II obesity were found with inadequate diet, physical inactivity, high sedentary behavior, and inadequate sleep duration.

Table II: Cross-tabulation of Independent Variables with Obesity in Adolescents

Independent Variables	Category	Class I Obesity n (%)	Class II Obesity n (%)	Total n (%)	p-value	OR (95% CI)
Dietary habit	Adequate	228 (74.5)	78 (25.5)	306 (100)	0.001	1.91 (1.28-2.85)
	Inadequate	98 (60.5)	64 (39.5)	162 (100)		
Physical Activity	Active	231 (74.3)	80 (25.7)	311 (100)	0.001	1.88 (1.26-2.82)
	Inactive	95 (60.5)	62 (39.5)	157 (100)		
Sedentary Behavior	Low	234 (74.5)	80 (25.5)	314 (100)	0.001	1.97 (1.31-2.96)
	High	92 (59.7)	62 (40.3)	154 (100)		
Sleep Duration	Adequate	237 (74.1)	83 (25.9)	320 (100)	0.002	1.89 (1.26-2.85)
	Inadequate	89 (60.1)	59 (39.9)	148 (100)		

Table III shows that all four variables remained significantly associated with Class II obesity. Sedentary behavior had the strongest association with Class II Obesity (OR=1.74, p=0.013), followed by diet (OR=1.67, p=0.019), physical activity (OR=1.61, p=0.031), and sleep duration (OR=1.56, p=0.047). The model showed an acceptable fit (Hosmer-Lemeshow p=0.733), moderate discrimination (AUC=0.68), and an overall accuracy of 71.2%.

Table III: Factors Associated with Class II Obesity in Adolescents

Independent Variables	Coefficient (B)	SE	Wald (χ^2)	df	OR (Exp B)	95% CI OR (Lower – Upper)	p-value
Diet	0.512	0.218	5.52	1	1.67	1.09-2.56	0.019
Physical Activity	0.478	0.221	4.68	1	1.61	1.05-2.49	0.031
Sedentary Behavior	0.553	0.223	6.15	1	1.74	1.12-2.69	0.013
Sleep Duration	0.445	0.224	3.95	1	1.56	1.01-2.42	0.047
Constant	-1.847	0.198	86.98	1	0.16	-	<0.001
Model Evaluation							
Omnibus Test (χ^2)	28.74			4			<0.001
Hosmer–Lemeshow Test (χ^2)	5.23			8			0.733
Nagelkerke R ²	0.12						
AUC (95% CI)	0.68 (0.62- 0.74)						<0.001
Sensitivity	33.1%						
Specificity	87.4%						
Overall Accuracy	71.2%						

DISCUSSION

Compared with a healthy diet, a poor nutritional diet was associated with an increased risk of Class II obesity (OR = 1.67; $p = 0.019$). This result is consistent with other studies showing that low fruit, vegetable, and fish consumption, along with higher fast-food and soft drink consumption, are related to poorer health outcomes⁸. Diet and obesity are interconnected through multiple direct and indirect pathways, including energy balance, physical activity and association with other lifestyle behaviours^{8,9}.

Adolescent eating patterns are known to be associated with other obesogenic behaviours¹⁰. This was corroborated in a study of lifestyle patterns among Chinese adolescents, which reported that low awareness of a healthy diet, combined with low physical activity, resulted in a 1.432-fold increased risk of overweight and obesity compared with a healthy lifestyle pattern¹¹. Unique lifestyle clusters, defined by dietary patterns, physical activity, sedentary behaviours and sleep time, showed that poorer dietary patterns were related to higher obesity risk¹².

The pathways underlying the association between diet and obesity during adolescence are complex. Poor nutrition is related both to positive energy balance and cognitive dysfunction, which have serious negative consequences such as poor academic performance¹³, both of which are associated with higher risk for adult obesity. Furthermore, dietary trends from adolescence carry over into adulthood, making this developmental period critical for establishing healthy eating habits¹⁴.

Light physical activity compared with heavy physical activity was associated with Class II obesity (OR = 1.61; $p = 0.031$). This finding is consistent with extensive literature showing that physical activity protects against obesity among adolescents^{15,16}. For example, the level of physical activity is inversely associated with fatness markers in adolescents¹⁷.

Physical inactivity mediates obesity through direct and indirect pathways. The direct and indirect effects of physical exercise, in conjunction with diet, on energy expenditure, body composition, appetite control, metabolic function and sleep quality have been demonstrated¹⁸. Structured physical activity also supports other healthy adolescent lifestyles, creating a chain of positive effects on nutrition and overall health¹⁹. Conversely, lower physical activity has emerged as a key predictor of both the development and sustained presence of obesity, relative to other detrimental lifestyle habits²⁰.

Lower physical activity may cluster with other obesity-promoting behaviours²¹. Previous research has shown that older adolescents and females are more likely to belong to the low physical activity cluster²⁰. The current sample was predominantly female (70.3%). Therefore, its relatively high proportion of light physical activity (33.5%) underscores the importance of targeted physical activity interventions for this population.

The strongest association was between high sedentary behaviour and Class II obesity (OR = 1.74; $p = 0.013$). Our findings corroborate ample evidence that sedentary behaviours, especially screen-based activities, are independently associated with obesogenic factors in children and adolescents^{22,23}.

Sedentary behaviour contributes to obesity through multiple pathways. Screen time, in particular, has been associated with increased food consumption, exposure to food advertising and dietary changes²⁴. Research highlights a link between later sleep schedules, often associated with high screen time, and higher caloric intake independent of total sleep hours²⁵. Sedentary behaviour has also been linked to metabolic alterations, including impaired insulin sensitivity, which may precede weight gain and obesity¹⁸.

Among sedentary Chinese adolescents, overweight prevalence was higher among those with high screen-based activity (≥ 2 hours/day) than those with low screen-based activity²³. Moreover, insufficient sleep combined with prolonged screen time was associated with the highest obesity risk (OR = 1.552, 95% CI: 1.162–1.911), indicating that effects of multiple

unhealthy habits contribute to obesity²³. Similarly, obese Turkish adolescents engaged in nearly two additional hours of daily sedentary behaviour compared to normal-weight counterparts¹⁵.

Insufficient sleep duration was also associated with a 56% increased risk of Class II obesity (OR = 1.56; p = 0.047). This is consistent with the well-documented relationship between short sleep duration and increased risk of overweight in childhood and adolescence^{15,26}. Previous results indicated that less than 8 hours of sleep per day was positively associated with BMI, fat mass density, and waist and hip circumference, with this association being more pronounced in females²⁷.

Multiple physiological and behavioural pathways mediate the relationship between insufficient sleep and obesity. Restricted sleep increases hunger, appetite, and food intake, disrupting energy homeostasis²⁸. Leptin, a hormone that regulates food intake, is modulated by sleep duration and represents an important link between sleep insufficiency, altered energy expenditure, and obesity onset²⁹.

Our modelling revealed that sleep duration was the strongest predictor of obesity risk among adolescents (Exp(B) = 0.103), consistent with findings that emphasise sleep in obesity prevention²⁶. This accords with recommendations that sleep, alongside nutrition and physical activity, should form part of obesity prevention public health policy³⁰.

Analyses of tracking changes in clustering of health behaviours show that 'healthy' and 'unhealthy' clusters persist over time²⁰. This implies that behavioural patterns become habitual and resistant to change, and that establishing healthy behaviours in adolescence may lead to behavioural persistence later in life²⁰.

This is vital for intervention timing. The model evaluation metrics (Nagelkerke R^2 = 0.12, AUC = 0.68) suggest that although the assessed lifestyle attributes significantly contribute to obesity classification, other influencing factors are also likely important contributors. Previous studies have identified genetic factors, socioeconomic status, psychological factors and environmental factors as additional risk factors for adolescent obesity^{11,26}.

CONCLUSION

This study showed that dietary habits, physical activity, sedentary behavior, and sleep duration were all significantly associated with Class II obesity among adolescents. Among these factors, sedentary behavior was the strongest predictor, followed by inadequate dietary habits, physical inactivity, and insufficient sleep duration. These findings suggest that multiple modifiable behavioral factors, rather than a single determinant, influence the severity of obesity in adolescents. Multivariate analysis confirmed that all four variables independently contributed to higher obesity classifications, even after controlling for potential confounding effects. These results underscore the importance of comprehensive intervention strategies that simultaneously address multiple lifestyle behaviors, including promoting healthy eating, increasing physical activity, reducing sedentary time, and ensuring adequate sleep, to reduce the development of obesity among adolescents.

Ethical Permission: Health Polytechnic of the Ministry of Health, Manado, Indonesia, ERC approval letter No. IRB-2025-0283.

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Data Sharing Statement: The corresponding author can provide the data proving the findings of this study on request. Privacy or ethical restrictions bound us from sharing the data publicly.

AUTHOR CONTRIBUTION

Lariwu CK: The work's design, critical revision, final approval, and accountability for accuracy and integrity, agreeing to investigate and resolve any questions related to the work's accuracy or integrity.

Susanti R: The work's design, critical revision, final approval, and accountability for accuracy and integrity, agreeing to investigate and resolve any questions related to the work's accuracy or integrity.

Cahyati WH: Agreeing to investigate and resolve any questions related to the work's accuracy or integrity.

Rahayu SR RR: Accountability for accuracy and integrity, agreeing to investigate and resolve any questions related to the work's accuracy or integrity.

REFERENCES

1. Ahmed SK, Mohammed RA. Obesity : Prevalence, causes, consequences, management, preventive strategies and future research directions. *Metabol Open*. 2025; 27(June): 100375. doi: 10.1016/j.metop.2025.100375.
2. Bocharova OV, Teplyakova ED. Children and adolescents' obesity is the 21st-century health problem. *Kazan Med J*. 2020; 101(3): 1–7. doi: 10.17816/KMJ2020-381.
3. Zaen NA, Tamtomo D, Ichsan B. Effects of Overweight and Obesity on Hypertension in Adolescents : A Meta-Analysis. *Journal of Epidemiology and Public Health*. 2023; 08(01): 109–20. doi: 10.26911/jepublichealth.2023.08.01.10.
4. Oluwasanu AO, Akinyemi JO, Oluwasanu MM, Oseghe OB, Oladoyinbo OL, Bello J et al. Temporal trends in overweight and obesity and chronic disease risks among adolescents and young adults : A ten-year review at a tertiary institution in Nigeria. *PLoS One*. 2023; 18(4): e0283210. doi: 10.1371/journal.pone.0283210.
5. Sriwijaya MK, Handayani D, Adinda HR. Factors of Sedentary Lifestyle Impact on Adolescent Health in Palembang City. *Majalah Kedokteran Sriwijaya*. 2023; 55(3): 1–8.
6. Ummah F, Indanah, Purnomo M. The Relationship Between Eating Junk Food and a Sedentary Lifestyle with Obesity in Elementary School Children. *Adv Healthcare Res*. 2025; 3(2): 332–49. doi: 10.60079/ahr.v3i2.557.
7. Sultana S, Rahman M, Sigel B, Hashizume M. Associations of lifestyle risk factors with overweight or obesity among adolescents : a multicountry analysis. *Am J Clin Nutr*. 2021; 113(3): 742–50. doi: 10.1093/ajcn/nqab022.
8. Naveed S, Lakka TA, Haapala EA. An Overview on the Associations Between Health Behaviors and Brain Health in Children and Adolescents With Special Reference to Diet Quality. *Int J Environ Res Public Health*. 2020; 17(3): 953. doi: 10.3390/ijerph17030953.
9. Hall KD, Farooqi IS, Friedman JM, Klein S, Loos RJ, Mangelsdorf DJ et al. The energy balance model of obesity: beyond calories in, calories out. *Am J Clin Nutr*. 2022 May; 115(5): 1243–54. doi: 10.1093/ajcn/nqac031.
10. Kunset P, Punsawad C, Petsirasan R, Suwanbamrung C, Shohaimi S, Narkkul U et al. Unhealthy Dietary Patterns and Their Associations with Sociodemographic Factors as Predictors among Underweight and Overweight Adolescents in Southern Thailand. *Int J Environ Res Public Health*. 2023 Sep 1; 20(17): 1–15. doi: 10.3390/ijerph20176703.
11. Ma Y, Wu H, Shen J, Wang J, Wang J, Hou Y. Correlation Between Lifestyle Patterns and Overweight and Obesity Among Chinese Adolescents. *Front Public Health*. 2022; 10: 1027565. doi: 10.3389/fpubh.2022.1027565.
12. Kebbe M, Damanhoury S, Browne NE, Dyson MP, McHugh TL, Ball GD. Barriers to and Enablers of Healthy Lifestyle Behaviours in Adolescents With Obesity: A Scoping Review and Stakeholder Consultation. *Obesity Reviews*. 2017; 18(12): 1439–53. doi: 10.1111/obr.12602.
13. Tafuri MG, Tafuri D, Latino F. Relationship Between Obesity and Impairment of Cognitive Functions: An Investigation into the Integrated Role of Nutritional Education and Physical Activity in Lower Secondary School. *Nutrients*. 2025 Jul 31; 17(15): 1–23. doi: 10.3390/nu17152531.
14. Sinai T, Axelrod R, Shimony T, Boaz M, Kaufman-Shriqui V. Dietary Patterns among Adolescents Are Associated with Growth, Socioeconomic Features, and Health-Related Behaviors. *Foods*. 2021 Dec 8; 10(12): 1–11. doi: 10.3390/foods10123054.
15. Turhan B. The Association of Sleep Duration, Wake-Up Time, and Lifestyle Habits With Obesity in Adolescents. *Int J Adolesc Med Health*. 2026. doi: 10.1515/ijamh-2025-0236.

16. Alam S, Syahrir S, Adha AS, Achmad PM. Incidence of Obesity in Students at Alauddin State Islamic University Makassar : A Cross-Sectional Study. *Comm Res Epidemiol (Core)*. 2022; 31–44. doi: 10.24252/corejournal.vi.33869.
17. Ntumi S. Validating high-fidelity simulation for assessing procedural skills in nursing education: a kane framework approach in Ghana. *BMC Med Educ*. 2025 Aug 18; 25(1): 1–18. doi: 10.1186/s12909-025-07724-4.
18. Simon SL, Higgins J, Melanson EL, Wright KP, Nadeau KJ. A Model of Adolescent Sleep Health and Risk for Type 2 Diabetes. *Curr Diab Rep*. 2021; 21(2): 4. doi: 10.1007/s11892-020-01373-1.
19. San Martín González P, Moral García JE, Amatria Jiménez M, Arroyo del Bosque R. Promotion of Healthy Habits in Adolescents: An Interdisciplinary Study on Motivation Towards Physical Education, Mediterranean Diet and Physical Activity. *Behavioral Sciences*. 2025 Jun 4; 15(6): 1–17. doi: 10.3390/bs15060778.
20. Blyth F, Haycraft E, Peral-Suárez Á, Pearson N. Tracking and Changes in the Clustering of Physical Activity, Sedentary Behavior, Diet, and Sleep Across Childhood and Adolescence: A Systematic Review. *Obesity Reviews*. 2025; 26(7): e13909. doi: 10.1111/obr.13909.
21. Barbosa BCR, de Deus Mendonça R, Machado EL, Meireles AL. Co-occurrence of obesogenic behaviors and their implications for mental health during the COVID-19 pandemic: a study with university students. *BMC Public Health*. 2024 Jun 14; 24(1): 1–12. doi: 10.1186/s12889-024-19031-6.
22. Lu T, Li M, Zhang R, Li R, Shen S, Chen Q et al. Associations of Academic Study- and Non-Study-Related Sedentary Behaviors with Incident Obesity in Children and Adolescents. *Nutrients*. 2025 May 9; 17(10): 1–16. doi: 10.3390/nu17101633.
23. Zhang M. Association Between Sleep Duration, Screen-Based Sedentary Time, and Weight Status Among Chinese Adolescents. *Healthcare*. 2025; 13(24): 3237. doi: 10.3390/healthcare13243237.
24. Trigueros R, Aguilar-Parra JM. Dietary and Sedentary Behavior in Children and Adolescents. *Nutrients*. 2025 Mar 28; 17(7): 1–5. doi: 10.3390/nu17071178.
25. Skjåkødegård HF, Danielsen YS, Frisk B, Hystad SW, Roelants M, Pallesen S et al. Beyond sleep duration: Sleep timing as a risk factor for childhood obesity. *Pediatr Obes*. 2021 Jan 29; 16(1): 1–20. doi: 10.1111/ijpo.12698.
26. Hiola RN. Association Between Determinant Factors and Obesity Among Adolescents. *Indonesian Journal of Global Health Research*. 2025; 7(6): 1059–64. doi: 10.37287/ijghr.v7i6.785.
27. Garaulet M, Ortega FB, Ruiz JR, Rey-López JP, Béghin L, Manios Y et al. Short Sleep Duration Is Associated With Increased Obesity Markers in European Adolescents: Effect of Physical Activity and Dietary Habits. The HELENA Study. *Int J Obes*. 2011; 35(10): 1308–17. doi: 10.1038/ijo.2011.149.
28. Liu S, Wang X, Zheng Q, Gao L, Sun Q. Sleep Deprivation and Central Appetite Regulation. *Nutrients*. 2022 Dec 7; 14(24): 1–12. doi: 10.3390/nu14245196.
29. Mosavat M, Mirsanjari M, Arabiat D, Smyth A, Whitehead L. The Role of Sleep Curtailment on Leptin Levels in Obesity and Diabetes Mellitus. *Obes Facts*. 2021; 14(2): 214–21. doi: 10.1159/000514095.
30. Chaput J, Dutil C. Lack of Sleep as a Contributor to Obesity in Adolescents: Impacts on Eating and Activity Behaviors. *Int J Behav Nutr Phys Activity*. 2016; 13(1): 103. doi: 10.1186/s12966-016-0428-0.