

Overweight and obesity among school-going adolescents in South India: Findings from a cross-sectional study

S. Kamalika¹, Sandeep Kaur^{1,2}, Akashdeep Singh Chauhan¹

¹Public Health Foundation of India, Indian Institute of Public Health-Delhi, New Delhi, India, ²Department of Surgery and Cancer, Faculty of Medicine, Imperial College London, Hammersmith Campus, London, UK

ABSTRACT

Background: Adolescent obesity represents an escalating public health challenge in India, with limited evidence on its multifactorial determinants. This study was undertaken to assess the prevalence and determinants of overweight and obesity among school-going adolescents in South India. This study employed the waist-to-hip ratio and body mass index to assess central obesity.

Materials and Methods: Four schools were selected using stratified random sampling. Preexisting validated questionnaires were adapted. Dietary intake patterns were assessed using the World Health Organization Oral Health Assessment Proforma and the NOVA food classification system. Physical activity (PA) was assessed using the Physical Activity Questionnaire for Adolescents. Anthropometric measurements were recorded using regularly calibrated standardized equipment.

Results: Among the 372 sampled adolescents, the prevalence of overweight or obesity was 17.2% while 14% of participants had central obesity based on waist-to-hip ratio. Female participants (adjusted odds ratio [AOR]: 3.68; 95% confidence interval [CI]: 1.78–7.62), participants from upper (AOR: 4.85; 95% CI: 1.00–23.46) or middle (AOR: 6.07; 95% CI: 1.63–22.57) socioeconomic class, and those of older age (AOR: 2.00; 95% CI: 1.24–3.21) showed significantly higher odds of being overweight or obese. Consumption of three or more meals per day (AOR: 7.16; 95% CI: 1.43–35.61), moderate consumption of ultra-processed foods (UPFs; AOR: 2.94; 95% CI: 1.23–7.01), and higher consumption of culinary ingredients (AOR: 3.75; 95% CI: 1.08–12.98) were significantly associated with increased odds of central obesity.

Conclusion: Higher UPF intake was significantly associated with central obesity, and adequate sleep and PA were associated with lower odds of overweight or obesity. There is a need for multilevel intervention, implementing school-based regulations to restrict the availability of UPFs and incorporating health education into school curricula.

Keywords: BMI, central obesity, physical activity, ultra-processed foods, waist-to-hip ratio

Introduction

Adolescence is a transitional phase between childhood and adulthood and is often considered one of the healthiest stages of human life.^[1] However, this period is also associated with a significant burden of mortality, morbidity, and injury, much of which is preventable or treatable.^[1] Over the past few decades, a concerning trend has emerged: the prevalence of overweight and

obesity among adolescents has increased dramatically across both high- and low-income countries.^[2] This is a major public health concern, as excess weight during

Address for correspondence: Dr. Sandeep Kaur, Public Health Foundation of India, Indian Institute of Public Health-Delhi, Mohan Estate - 110044, New Delhi, India. E-mail: sandeep.kaur109@gmail.com

This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 License (CC BY-NC-ND), where it is permissible to download and share the work provided it is properly cited. The work cannot be changed in any way or used commercially without permission from the journal.

For reprints contact: WKHLRPMedknow_reprints@wolterskluwer.com

How to cite this article: Kamalika S, Kaur S, Chauhan AS. Overweight and obesity among school-going adolescents in South India: Findings from a cross-sectional study. *Int J Non-Commun Dis* 2026;11:376-86.

Submitted: 22-Dec-2025,

Revised: 19-May-2026,

Accepted: 29-May-2026,

Published: 26-Jun-2026.

Access this article online	
Website: https://www.ovid.com/jnls/IJNC	Quick Response Code 
DOI: 10.4103/jncd.jncd_226_25	

adolescence is a known proximal risk factor for various noncommunicable diseases (NCDs) in adulthood, including cardiovascular disease, diabetes, and certain types of cancer.^[3]

According to the World Health Organization (WHO), globally, more than 390 million children and adolescents aged 5–19 years were overweight in 2022, of whom 160 million were obese. This number is projected to increase to approximately 464 million by 2030, representing an additional 143 million cases since 2015.^[4] India, home to one of the world's largest adolescent populations of approximately 243 million, also faces an increasing risk of overweight and obesity. As per the World Obesity Atlas, there were 33 million children and adolescents in India who were living with overweight and obesity in the year 2020, with projections suggesting a sharp rise to 83 million by 2035.^[5]

Urbanization has substantially influenced lifestyle behaviours, with increased consumption of ultra-processed foods (UPFs) and reduced physical activity (PA). Beyond these factors, socioeconomic status, parental education, and prevailing cultural norms also play a significant role in shaping children's dietary practices and lifestyle behaviors. In India, approximately 23% of the country's 243 million adolescents reside in urban areas, where most are enrolled in secondary (13–15 years) and higher secondary (16–18 years) schools. This makes schools a critical setting for investigating and addressing overweight and obesity and their associated determinants.^[6] Despite increasing recognition of adolescent obesity, the complex interactions among dietary factors, PA, and school environment remain incompletely understood.

Local evidence on adolescent overweight and obesity, particularly from urban regions of South India, remains limited.^[7] Surveys like the National Family Health Survey (NFHS) provides data relevant to adolescent nutrition, but it does not comprehensively report overweight and obesity rates among adolescents.^[8] The Comprehensive National Nutrition Survey does offer detailed anthropometric data for adolescents, but it was conducted only once, nearly a decade ago.^[9] This absence of up-to-date data leaves a gap in the understanding of the nutritional status of this age group.

With this background, this study was undertaken to estimate the prevalence and determinants of overweight and obesity among school-going adolescents in urban settings of South India. Although a few studies from South India have reported the burden of obesity, most have not comprehensively examined its predictors.^[10] Most previous studies have primarily relied on body mass index (BMI) for classification; this study additionally employed

waist-to-hip ratio (WHR) to categorize adolescents at higher risk of central obesity. The inclusion of WHR adds to the novelty of the study, as emerging evidence suggests that central obesity, characterized by excess abdominal or visceral fat, is a stronger predictor of NCDs than general obesity measured solely using BMI.

Materials and Methods

Study design and setting

This was a school-based cross-sectional study carried out in Chennai. Chennai is a rapidly urbanizing metropolitan city in South India with diverse school management systems, including government, aided, and private schools, allowing assessment of adolescents from different socioeconomic strata. The study participants were school-going adolescents enrolled in four types of schools that differed in management type based on administrative and financial control, namely central government (fully aided), state government (fully aided), state government (partially aided), and private (unaided). The inclusion of schools across these categories was intended to capture variability in the socio-demographic characteristics of school-going adolescents and the school environment that may influence adolescent behaviour and physical health.

Inclusion and exclusion criteria

Adolescents aged 15–17 years (senior high school), proficient in either English or Tamil language, and who have been residing in Chennai district for at least 6 months before the study were eligible for inclusion in the study. Out of all eligible participants, those who provided assent to participate and whose parents/guardians provided written informed consent were enrolled. Students with known medical conditions affecting growth and weight, such as, endocrine disorders and genetic syndromes or physical disabilities affecting growth and mobility were excluded.

Sample size and sampling strategy

The sample size was estimated using the formula $n = Z^2pq/d^2$. Based on the reported prevalence (p) of adolescent overweight/obesity of 40.6% from a previous South Indian study,^[10] a 5% margin of error (d), and at a 95% confidence level, the sample size was calculated to be 372 adolescents. A multi-stage sampling approach was employed, integrating probability and nonprobability techniques across successive stages [Figure 1]. In Stage 1, one administrative block was selected from the 10 blocks in Chennai district using convenience sampling, based on feasibility, administrative accessibility, and permissions from educational authorities. In Stage 2, four higher

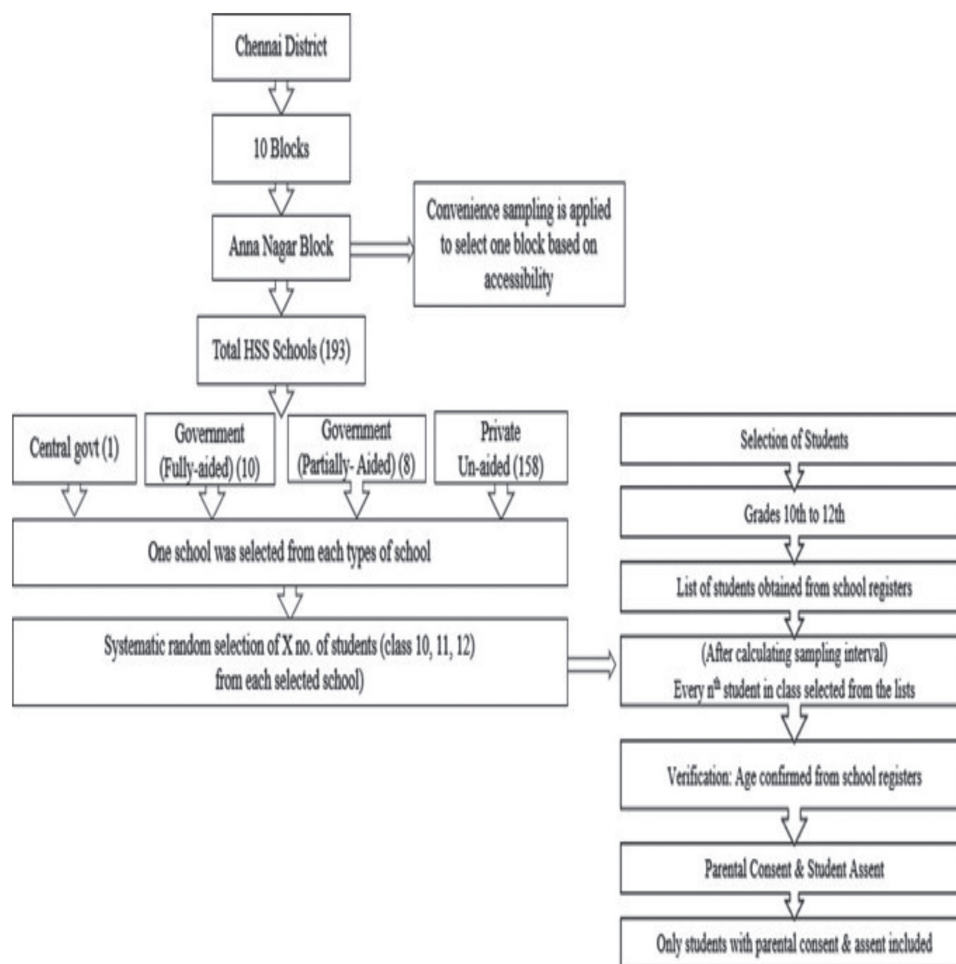


Figure 1: Study flow diagram

secondary schools were purposively selected from those approved by the Chief Educational Officer, representing diverse management categories (central government fully aided, state government fully aided, state government partially aided, and private unaided) to capture variation in socio-demographic profiles and school environments. In Stage 3, students from Classes 10–12 in the selected schools were recruited via systematic random sampling: every sixth student was selected from class registers until the target sample size was reached.

Data collection

Data was collected from January to March 2025. Data was collected using a structured questionnaire developed using existing validated tools and adapted to the study context to capture a wide range of variables, including socio-demographic characteristics, cultural and dietary practices, PA, sedentary behaviour, anthropometric measurement, media exposure, and school environment. It was pre-tested among 20 adolescents in a private school (excluded from the final sample) to ensure clarity and contextual relevance.

PA was assessed using the Physical Activity Questionnaire for Adolescents, a validated 7-day recall instrument for high-school students.^[11] Dietary intake was captured using the diet history section of the WHO Oral Health Assessment Proforma, which includes standardized questions on the frequency of consumption of various food items such as fruits, vegetables, biscuits, bakery products, soft drinks, and processed foods relevant to dietary behaviours associated with obesity.^[12] To further assess obesity-related dietary exposures, the collected dietary information was additionally categorized using the NOVA food classification system.^[13] Screen time and media exposure were measured in terms of gadget use, total screen time, and eating during screen time. Sedentary behaviours included sleep duration, skipping meals, and snacking habits. The school environment section covered the availability of canteen services and facilities promoting health, such as information about the frequency of physical education classes per week.

Anthropometric measurements were collected using standardized equipment. Height was measured using a United Nations Children's Fund portable stadiometer

(nearest 0.1 cm) with participants standing barefoot, heels together, and head positioned in the Frankfort horizontal plane to ensure accurate and consistent posture.^[14] Weight was measured in kilograms (kg; nearest 0.1 kg) using a digital weighing scale, which was checked for “zero” before every reading. Anthropometric measurements were taken in a separate private space within the school premises, such as vacant classrooms or counseling rooms, to maintain privacy and minimize discomfort. Hip circumference (HC) and waist circumference (WC) were measured to the nearest 0.1 cm by using a fiberglass measuring tape. Fiberglass tape was used, as it is resilient to any wear and tear and does not expand in warm weather conditions like an ordinary measuring tape.

Data analysis

Statistical analyses were conducted using Stata version 15.0. Socioeconomic status was summarized using the Kuppaswamy Scale (2024), which incorporates family monthly income along with the education and occupation of the head of the household.^[15] WHR was calculated by dividing the WC by the HC. Sex-specific WHR cutoffs of 0.90 for males and 0.85 for females, recommended by the WHO, were applied to classify adolescents as high risk or low risk for central obesity.^[16] In the absence of validated adolescent-specific WHR cutoffs, these WHO thresholds were used as reference values.

In addition, BMI was also calculated, as weight (kg)/height (m²), to classify adolescents as overweight, obese, or underweight using Center for Disease Control and Prevention BMI-for-age growth reference percentiles.^[17] Dietary intake was classified as low, moderate, or high consumption based on the diet frequency information. In addition, NOVA food classification was applied to diet frequency data used to classify the food intake into: (i) unprocessed or minimally processed foods, (ii) processed culinary ingredients, (iii) processed foods, and (iv) UPF.^[13] Further details on food classification are available in Appendix S1 of the Supplementary Material.

Associations between obesity outcomes, defined according to BMI categories and WHR risk status, and a range of independent variables, including socio-demographic characteristics, dietary patterns, PA, screen time, and sleep duration, were assessed using multivariate logistic regression analysis. Variables with a *P* value < 0.20 in the bivariate analysis were considered for inclusion in the multivariable logistic regression models. Final variable selection was guided by conceptual relevance and existing literature. Unadjusted odds ratios (ORs) and adjusted ORs, along with 95% confidence intervals (CIs), were reported. A *P* value of < 0.05 was considered statistically significant.

Ethical considerations

Permission was obtained from the Chief Education Officer, Chennai district, Tamil Nadu, and the study protocol was approved by the Institutional Ethics Committee of the Indian Institute of Public Health, Delhi (IIPHD_IEC_S-14-2025) to conduct the study.

Results

Sociodemographic characteristics

From each of the four school types, 93 participants were enrolled. Of all the participants, half were females. Most of the participants were Hindu (85%). Parental education levels varied, with approximately one-fifth of both mothers and fathers being graduates [Table 1]. Most mothers (64%) were unemployed, whereas employed

Table 1: Sociodemographic characteristics of study participants

Socio-demographic characteristics	<i>n</i> (%)
Sex	
Male	187 (50)
Female	185 (50)
Religion	
Hindu	316 (85)
Christian	34 (9)
Muslim	22 (6)
Father education	
No formal education	44 (12)
Primary, middle school	111 (30)
High school, intermediate/diploma	74 (20)
Graduate, professional degree	143 (38)
Mother education	
No formal education	54 (14)
Primary, middle school	100 (27)
High school, intermediate/diploma	77 (21)
Graduate and above	141 (38)
Mother occupation	
Unemployed	238 (64)
Employed	134 (36)
Socioeconomic class	
Upper	160 (43)
Middle	62 (17)
Lower	150 (40)
Type of family	
Nuclear	282 (76)
Joint	90 (24)
Family history of obesity	
Yes	46 (12)
No	326 (88)

Socioeconomic status was assessed by the Kuppaswamy Scale (2024). The Kuppaswamy Socioeconomic Status (SES) scale includes family monthly income, education, and occupation of the head of the household, which is typically the father in Indian homes. Family history of obesity refers to self-reported obesity in first-degree relatives. For analysis, categories were regrouped as follows: “Upper (I)” and “Upper Middle (II)” combined into “Upper”; “Lower Middle (III)” retained as a separate category as “Middle”; and “Upper Lower (IV)”, and “Lower (V)” combined into “Lower”.

mothers predominantly worked in elementary (21%) or professional (10%) roles. Fathers were mainly engaged as skilled/sales workers (29%) [Table S1]. A majority of adolescents (76%) lived in nuclear families, and the data further revealed that 12% of the adolescents had a family history of obesity (Table S2)

Dietary intake

Approximately 81% of the participants had a moderate consumption of “unprocessed or minimally processed foods” [Table 2]. A large proportion of participants (87%) consumed high levels of “processed culinary ingredients.” In contrast, the intake of UPF was predominantly low (56%) or moderate (44%), with no respondents reporting high consumption. The consumption pattern was similar

across genders. Meal frequency was sub optimal, with 42% consuming two or fewer meals per day. Breakfast consumption was notably irregular, with 45% of the participants having breakfast at home 1–3 times per week.

Physical activity

A majority of the participants (63%) reported low levels of PA. When disaggregated by sex, 67% of females and 59% of males were classified as having low PA levels [Table 2].

Screen time and sleep patterns

The results showed that around 54% of the participants had >3 h of screen time every day. Only 13% had a limited screen time of less than an hour. A slightly higher

Table 2: Dietary habits, physical activity, screen time, sleep duration, and anthropometric measurements of the sampled adolescents

Predictors	Categories	Total (n = 372)	Male (n = 187)	Female (n = 185)
Number of meals consumed per day	2 or <2	158 (42)	81 (43)	77 (42)
	3	133 (36)	65 (35)	68 (37)
	>3	81 (22)	41 (22)	40 (22)
Frequency of consuming breakfast at home	4–5 times a week	108 (29)	61 (33)	47 (25)
	1–3 times a week	168 (45)	77 (41)	91 (49)
	Rarely	96 (26)	49 (26)	47 (25)
Dietary intake based on NOVA food classification				
Group 1: Unprocessed or minimally processed foods	Moderate	302 (81)	149 (80)	153 (83)
	High	70 (19)	38 (20)	32 (17)
Group 2: Processed culinary ingredients (oils, fats, salt, and sugar)	Moderate	48 (13)	24 (13)	24 (13)
	High	324 (87)	163 (87)	161 (87)
Group 3: Processed foods	Moderate	207 (56)	104 (56)	103 (56)
	High	165 (44)	83 (44)	82 (44)
Group 4: Ultra-processed foods	Low	208 (56)	104 (56)	104 (56)
	Moderate	164 (44)	83 (44)	81 (44)
Physical activity (PA) level	Low PA	235 (63)	111 (59)	124 (67)
	Moderate PA	97 (26)	51 (27)	46 (25)
	High PA	40 (11)	25 (13)	15 (8)
Daily screen time	<1 h	49 (13)	24 (13)	25 (14)
	1–2 h	123 (33)	57 (31)	66 (36)
	3–4 h	141 (38)	73 (39)	68 (37)
	>4 h	59 (16)	33 (18)	26 (14)
Sleep duration	<6 h	191 (51)	92 (49)	99 (54)
	6–10 h	168 (45)	88 (47)	80 (43)
	>10 h	13 (4)	7 (4)	6 (3)
Frequency of snacking between meals	Daily	158 (42)	79 (42)	79 (43)
	2–3 times a week	159 (43)	80 (43)	80 (43)
	Occasionally	55 (15)	28 (15)	27 (15)
Body mass index	Underweight (<5th percentile)	105 (28)	43 (23)	62 (34)
	Healthy weight (5th to <85th percentile)	203 (55)	122 (65)	81 (44)
	Overweight (85th to <95th percentile)	42 (11)	14 (8)	28 (15)
	Obesity (95th percentile or greater)	22 (6)	8 (4)	14 (8)
Waist-to-hip ratio	Low risk (<0.90 for men and <0.85 for female)	320 (86)	164 (88)	156 (84)
	High risk (≥0.90 for men and ≥0.85 for female)	52 (14)	23 (12)	29 (16)

Table 3: Multivariate analysis of overweight/obesity versus normal-weight adolescents

Variable	Overweight and obese (<i>n</i> = 64)			
	Crude OR (95% CI)	<i>P</i> value	AOR (95% CI)	<i>P</i> value
Sex				
Male	Ref		Ref	
Female	2.87 (1.59, 5.17)	<0.001**	3.68 (1.78, 7.62)	<0.001**
Age	1.43 (1.00, 2.05)	0.049*	2.00 (1.24, 3.21)	0.004**
Mother education				
No formal education	Ref		Ref	
Primary, middle school	1.03 (0.32, 3.31)	0.9	1.03 (0.24, 4.36)	0.9
High school, intermediate/diploma	1.27 (0.40, 4.00)	0.7	1.32 (0.24, 7.09)	0.7
Graduate, professional degree	1.91 (0.67, 5.44)	0.2	1.35 (0.21, 8.63)	0.7
Mother occupation				
Unemployed	Ref		Ref	
Employed	1.35 (0.76, 2.42)	0.3	1.76 (0.83, 3.75)	0.1
Socioeconomic class*				
Lower	Ref	*	Ref	*
Middle	3.01 (1.24, 7.28)	0.01*	6.07 (1.63, 22.57)	0.007**
Upper	2.39 (1.17, 4.90)	0.02	4.85 (1.00, 23.46)	0.05
Type of family				
Nuclear	Ref		Ref	
Joint	0.54 (0.26, 1.11)	0.1	0.42 (0.17, 1.03)	0.06
Family history of obesity				
No	Ref		Ref	
Yes	1.66 (0.79, 3.45)	0.2	1.01 (0.41, 2.50)	0.9
Number of meals consumed per day				
<2 or 2	Ref		Ref	
3	1.14 (0.57, 2.27)	0.7	0.76 (0.21, 2.63)	0.6
>3	1.94 (0.95, 3.93)	0.07	0.64 (0.12, 3.26)	0.6
Frequency of consuming breakfast at home				
Rarely	Ref		Ref	
1–3 times a week	1.54 (0.74, 3.19)	0.2	0.83 (0.32, 2.13)	0.7
4–5 times a week	0.93 (0.41, 2.11)	0.9	0.32 (0.09, 1.04)	0.06
The NOVA food classification system—consumption				
Group 1: Unprocessed or minimally processed foods				
Moderate	Ref		Ref	
High	0.59 (0.27, 1.28)	0.2	0.66 (0.23, 1.83)	0.4
Group 2: Oils, fats, salt, and sugar				
Moderate	Ref		Ref	
High	1.35 (0.56, 3.26)	0.5	2.05 (0.67, 6.19)	0.2
Group 3: Processed foods				
Moderate	Ref		Ref	
High	0.49 (0.26, 0.90)	0.02*	0.39 (0.16, 0.93)	0.03*
Group 4: Ultra-processed foods				
Low	Ref		Ref	
Moderate	1.72 (0.97, 3.05)	0.06	1.25 (0.52, 2.98)	0.6
Canteen availability				
No	Ref		Ref	
Yes	1.50 (0.83, 2.74)	0.2	0.27 (0.07, 1.07)	0.06
Physical activity (PA) level				
Low PA	Ref		Ref	
Moderate PA	0.43 (0.21, 0.89)	0.02*	0.43 (0.17, 1.09)	0.08
High PA	0.07 (0.01, 0.58)	0.01*	0.08 (0.00, 0.79)	0.03*
Daily screen time				
<1 h	Ref		Ref	
1–2 h	2.17 (0.75, 6.29)	0.2	1.41 (0.40, 4.92)	0.6
3–4 h	1.55 (0.53, 4.48)	0.4	1.11 (0.30, 4.05)	0.9
>4 h	1.74 (0.54, 5.63)	0.4	1.10 (0.25, 4.80)	0.9

Table 3. Continued

Variable	Overweight and obese (<i>n</i> = 64)			
	Crude OR (95% CI)	<i>P</i> value	AOR (95% CI)	<i>P</i> value
Sleep duration				
<6 h	Ref		Ref	
6–10 h	0.42 (0.23, 0.79)	0.007**	0.46 (0.20, 1.04)	0.06
>10 h	0.28 (0.03, 2.31)	0.2	0.10 (0.00, 1.27)	0.08
Frequency of snacking between meals				
Occasionally	Ref		Ref	
2–3 times a week	1.35 (0.72, 2.53)	0.3	1.35 (0.55, 3.27)	0.5
Daily	1.22 (0.53, 2.78)	0.6	0.64 (0.18, 2.22)	0.5

OR - Odds ratio, AOR - Adjusted odds ratio, CI - Confidence interval, Ref - Reference category.

**P* < 0.05;

***P* < 0.01. Model diagnostics indicated an acceptable fit for the multivariable logistic regression model (Hosmer–Lemeshow goodness-of-fit test: $\chi^2 = 8.75$, *P* = 0.364). No significant multicollinearity was observed among the included variables

proportion of males (18%) than females (14%) reported screen use exceeding 4 h daily. Over half of the participants (51.3%) reported sleeping <6 h per day, whereas 4% reported sleeping for >10 h [Tables 2 and Supplementary Table S3].

Anthropometric profile

The anthropometric profile of the sampled participants showed a mean height of 162 cm and a weight of 55 kg with an average BMI of 20.6 kg/m². Based on BMI classification, the majority of adolescents were of healthy weight (55%), whereas 28% were underweight, and 17% were either overweight (11%) or obese (6%). The mean WHR was 0.82, with 14% of participants in the high-risk category for central adiposity [Table 2].

When disaggregated by school type, the burden of overweight and obesity was particularly higher in central government (17% and 8%) and private unaided schools (14% and 10.8%), whereas underweight was more prevalent among students from government partially aided (43%) and government fully aided (39%) schools. Likewise, the risk of central obesity was higher among those children in the central government (18%) and private unaided schools (25%), as shown in Table S4 of the Supplementary Material.

Determinants of overweight and obesity

The adjusted estimates showed that girls had significantly higher odds of being overweight or obese compared with boys (adjusted odds ratio [AOR]: 3.68; 95% CI: 1.78–7.62; *P* < 0.001), as shown in Table 3. Age was also significantly associated with overweight or obesity, with higher age exhibiting higher odds (AOR: 2.00; 95% CI: 1.24–3.21; *P* = 0.004). Those belonging to the upper (AOR: 4.85; 95% CI: 1.00–23.46; *P* = 0.050) or middle socioeconomic class (AOR: 6.07; 95% CI: 1.63–22.57; *P* = 0.007) showed higher odds of being overweight or obese. Higher PA levels were associated with lower odds of overweight or obesity

(AOR: 0.08; 95% CI: 0.00–0.79; *P* = 0.031). Interestingly, higher consumption of processed foods was significantly associated with reduced odds of overweight or obesity (AOR: 0.39; 95% CI: 0.16–0.93; *P* = 0.034). Although the frequency of having breakfast at home 4–5 times a week and sleep duration of 6–10 h were linked to lower odds, the association was not statistically significant in adjusted estimates.

Determinants of higher risk of central obesity

Participants consuming three meals or more each day had higher odds of central obesity compared with those consuming two or fewer meals [Table 4]. Dietary composition showed that moderate consumption of UPF was associated with nearly three times higher odds of central obesity compared to low consumption. Similarly, the high consumption of culinary ingredients increased the odds of central obesity by 3.75 times. Conversely, greater consumption of processed foods was linked to reduced odds of central obesity (AOR: 0.37; 95% CI: 0.13–0.98; *P* = 0.046). Moderate PA (AOR: 0.31; 95% CI: 0.11–0.86; *P* = 0.024) and daily snacking between meals also showed lower odds of central obesity (AOR: 0.18; 95% CI: 0.04–0.71; *P* = 0.015).

Discussion

This study found that approximately 64 (17.2%) of adolescents were overweight, and 52 (14%) were at a higher risk of central obesity, underscoring the prevalence of obesity among this population. Notably, our findings distinguish between general obesity, characterized by excess body fat, and central obesity, marked by abdominal or visceral fat accumulation. This distinction is critical because it necessitates different assessment criteria, particularly important for adolescents whose nutritional requirements differ significantly from those of adults.

Table 4: Multivariate analysis of high-risk waist-to-hip ratio in adolescents

Variable	High-risk waist-to-hip ratio (<i>n</i> = 52)			
	Crude OR (95% CI)	<i>P</i> value	AOR (95% CI)	<i>P</i> value
Sex				
Male	Ref		Ref	
Female	1.32 (0.73, 2.39)	0.3	1.36 (0.68, 2.71)	0.4
Age	1.06 (0.74, 1.53)	0.7	1.12 (0.71, 1.77)	0.6
Mother education				
No formal education	Ref		Ref	
Primary, middle school	0.30 (0.09, 0.97)	0.046*	0.21 (0.05, 0.80)	0.02*
High school, intermediate/diploma	0.57 (0.19, 1.69)	0.3	0.25 (0.03, 1.81)	0.2
Graduate, professional degree	1.68 (0.72, 3.94)	0.2	1.53 (0.06, 4.45)	0.6
Mother occupation				
Unemployed	Ref		Ref	
Employed	0.84 (0.45, 1.57)	0.6	0.96 (0.44, 2.09)	0.9
Socioeconomic class				
Lower	Ref	**	Ref	
Middle	1.70 (0.66, 4.39)	0.3	1.23 (0.21, 7.03)	0.8
Upper	2.87 (1.41, 5.82)	0.003	0.89 (0.12, 6.27)	0.9
Type of family				
Nuclear	Ref		Ref	
Joint	0.71 (0.34, 1.48)	0.4	0.67 (0.27, 1.66)	0.4
Family history of obesity				
No	Ref		Ref	
Yes	2.18 (1.02, 4.63)	0.04	1.83 (0.72, 4.64)	0.2
Number of meals consumed per day				
<2 or 2	Ref		Ref	
3	2.61 (1.17, 5.81)	0.02*	3.77 (1.04, 13.69)	0.04*
>3	5.51 (2.46, 12.35)	0.001**	7.16 (1.43, 35.61)	0.02*
Frequency of consuming breakfast at home				
Rarely	Ref		Ref	
1-3 times a week	1.39 (0.68, 2.84)	0.4	0.56 (0.21, 1.36)	0.2
4-5 times a week	1.04 (0.45, 2.41)	0.9	0.38 (0.10, 1.43)	0.1
The NOVA food classification system—consumption				
Group 1: Unprocessed or minimally processed foods				
Moderate	Ref		Ref	
High	0.63 (0.27, 1.47)	0.3	1.07 (0.37, 3.03)	0.9
Group 2: Oils, fats, salt, and sugar				
Moderate	Ref		Ref	
High	1.91 (0.65, 5.56)	0.2	3.75 (1.08, 12.98)	0.04*
Group 3: Processed foods				
Moderate	Ref		Ref	
High	0.28 (0.14, 0.58)	0.001**	0.37 (0.13, 0.98)	0.05*
Group 4: Ultra-processed foods				
Low	Ref		Ref	
Moderate	4.17 (2.17, 8.02)	<0.001**	2.94 (1.23, 7.01)	0.02*
Canteen availability				
Yes	2.83 (1.54, 5.20)	0.001**	0.62 (0.16, 2.43)	0.5
No	Ref		Ref	
Physical activity (PA) level				
Low PA	Ref		Ref	
Moderate PA	0.34 (0.15, 0.80)	0.01*	0.31 (0.11, 0.86)	0.02*
High PA	0.23 (0.05, 1.01)	0.05	0.28 (0.05, 1.54)	0.1
Daily screen time				
<1 h	Ref		Ref	
1–2 h	0.77 (0.27, 2.19)	0.6	0.35 (0.10, 1.22)	0.1
3–4 h	1.69 (0.65, 4.39)	0.3	0.86 (0.26, 2.87)	0.8
>4 h	0.96 (0.30, 3.08)	0.9	0.48 (0.11, 2.00)	0.3

Table 4. Continued

Variable	High-risk waist-to-hip ratio (<i>n</i> = 52)			
	Crude OR (95% CI)	<i>P</i> value	AOR (95% CI)	<i>P</i> value
Sleep duration				
<6 h	Ref		Ref	
6–10 h	0.87 (0.48, 1.60)	0.7	1.82 (0.79, 4.20)	0.2
>10 h	1.05 (0.22, 5.03)	0.9	0.63 (0.08, 4.74)	0.7
Frequency of snacking between meals				
Occasionally	Ref		Ref	*
2–3 times a week	1.77 (0.92, 3.38)	0.08	0.77 (0.32, 1.83)	0.6
Daily	1.20 (0.47, 3.09)	0.7	0.18 (0.04, 0.71)	0.02

OR - Odds ratio, AOR - Adjusted odds ratio, CI - Confidence interval, Ref - Reference category, WHR - Waist-to-hip ratio.

**P* < 0.05;

***P* < 0.01; Model diagnostics indicated acceptable fit for the multivariable logistic regression model (Hosmer–Lemeshow goodness-of-fit test: $\chi^2 = 3.44$, *P* = 0.903). No significant multicollinearity was observed among the included variables

Recent evidence indicates that central obesity is a stronger predictor of NCDs than general obesity. The present study reveals that frequent consumption of UPFs, along with high intake of oils, fats, sugar, and salt, was significantly associated with a higher risk of developing central obesity. Adolescent dietary practices, including frequent consumption of UPFs high in calories and low in nutritional value, may contribute to excess weight gain. These findings align with previous systematic reviews, which conclude that high UPF intake is consistently linked to increased obesity risk and WC.^[18,19] The overweight/obesity prevalence of 17% observed in present study also aligns with the recent scoping review by Panda *et al.*,^[6] which documents that overweight rates range from 1.25% to 35.8%, with higher prevalence consistently reported in urban settings.

The finding of the present study that there is an inverse association between processed food consumption and obesity rates requires nuanced interpretation, particularly in light of the cultural context. In India, traditionally processed foods, such as fermented products, dried fruits, and home-baked goods, may have different nutritional profiles compared with the processed or UPF in Western diets. This distinction is supported by a recent review by Lane *et al.*,^[19] which underscores the heterogeneity in the health effects of processed foods and UPF and emphasizes the need for context-specific definitions when examining these associations. Therefore, results highlight the importance of considering the local dietary context when assessing the relationship between processed food consumption and health outcomes.^[19]

Present findings also suggest that frequent meal consumption, shorter sleep duration, and lower PA levels were associated with higher odds of obesity among adolescents. While meal frequency in itself is not necessarily harmful, this association likely reflects excess calorie-dense food products

consumed between regular meals. The study by Yıldız *et al.*,^[20] demonstrated that poor sleep quality and social jet lag were correlated with higher rates of obesity in adolescents. The systematic review by Porri *et al.*, also emphasized sleep hygiene as a critical modifiable factor in childhood obesity prevention.^[21] Present findings align with a dose–response study by Sriram *et al.*,^[22] which found that adolescents engaging in 90–150 min per week of moderate-to-vigorous PA had significant reductions in BMI percentile. The significant association between inadequate physical education (PE) hours (<2 h/week) and increased obesity risk underscores the critical role of school-based PA programs, particularly relevant given our finding that only 50.81% of students received adequate PE time.

One of the important findings from this study is that girls are at higher odds of both being overweight/obese and underweight [Table S5]. This finding aligns with data from the NFHS-5 and other recent studies.^[23] This dual burden may be influenced by sociocultural factors that restrict PA among girls after puberty, as well as gender-specific differences in dietary habits prevalent in India. Socioeconomic class was also significantly associated with overweight and obesity, with upper and middle classes showing 3–4 times the odds of being overweight or obese. This finding resonates with recent literature highlighting that India's ongoing nutrition transition disproportionately affects higher socioeconomic groups, who have greater access to UPFs and also tend to engage in lower levels of PA. A related observation from this study is that participants enrolled in private schools, who are predominantly from the higher socioeconomic classes [Table S2 of the Supplementary Material], exhibited higher rates of being overweight and obese. This association is consistent with evidence from other Indian states.^[24]

While genetic predisposition contributes to obesity risk, our study highlights that behavioral factors also play a more

prominent role. Traditionally, many low- and middle-income countries (LMICs) were viewed as battling only undernutrition; however, they now face a double burden of malnutrition. Although initiatives such as the National Nutrition Mission (Poshan Abhiyan) sought to eliminate malnutrition by 2022, the progress has not been as expected.^[25] Nevertheless, other schemes like the Mid-Day Meal and Integrated Child Development Services have helped mitigate malnutrition to some extent.^[26]

Schools may serve as important settings for shaping health behaviors and implementing preventive interventions. Policies such as the Central Board of Secondary Education's "Sugar Boards" aim to raise awareness about the harms of excess sugar consumption, whereas broader school-based health education and supportive environments have been shown to promote healthier lifestyles.^[27] Evidence suggests that up to 80% of heart disease, 12% of strokes, most cases of type 2 diabetes, and one-third of cancers could be prevented through effective health education and early preventive interventions.^[28] By promoting well-being from an early age, schools can not only reduce future disease risk but also equip students with essential life skills, including emotional regulation, goal-setting, and responsible decision-making.

Another important finding of this study is the substantial prevalence of underweight among adolescents, highlighting the coexistence of undernutrition and overnutrition within the same population. This reflects the dual burden of malnutrition commonly observed in LMICs such as India, where rapid nutritional transition, socioeconomic disparities, and changing lifestyle patterns contribute to both forms of malnutrition simultaneously.

The present study had a few limitations. First, the self-reported dietary data may be subject to recall bias, although we tried to overcompensate for these potential limitations by using objective measures such as WHR and BMI. Second, the study's cross-sectional design limits the ability to establish temporal or causal relationships between exposures and obesity outcomes. A limitation of this study is that the WHO Oral Health Assessment Proforma, although useful for assessing obesity-related dietary behaviors and categorized using the NOVA classification system, was originally designed for oral health surveys and may not comprehensively capture detailed dietary intake, portion sizes, caloric intake, or overall nutrient consumption. Additionally, the use of convenience sampling for administrative block selection and purposive sampling for school selection may have introduced selection bias and limited representativeness. However, since a large proportion of the Indian population belongs to lower

socioeconomic strata, to which most of our study participants also belonged, the findings may be generalizable to similar Indian settings.

Recommendations

Present study highlights the need for multilevel intervention, including implementing school-based regulations to restrict the availability of UPFs and developing gender-sensitive PA programs that address cultural and social barriers limiting female participation.^[29] We further recommend incorporating health education into school curricula, covering topics such as sleep hygiene, physical health, and the differences between healthy and unhealthy dietary patterns. Implementing policies like "Sugar Boards" also represents an effective initiative to reduce excessive sugar consumption among school-children.

Conclusion

This study identified a prevalence of 28% underweight, 17% overweight or obesity, and 14% of central obesity among adolescents, with girls exhibiting a higher risk across all categories. The consumption of UPF and higher consumption of oils, fats, salt, and sugar were significantly associated with increased odds of central obesity. Adequate sleep and moderate-to-vigorous PA were associated with lower odds of overweight or obesity among adolescents.

Author contributions

ASC and KS conceptualized the study. KS carried out the data collection, data curation, and formal analysis and wrote the first draft of the manuscript. ASC and SK provided their supervision for the study, contributed to the data presentation, and validated the data and results carried out in this study. All authors were involved in reviewing and editing and gave their final approval for the version to be published.

Data availability statement

The data presented in this study are available on request due to privacy and ethical restrictions.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. World Health Organization. Adolescent Health; 2025. Available from: <https://www.who.int/health-topics/adolescent-health>. [Last accessed on 11 Aug 2025].

2. Zhang X, Liu J, Ni Y, Yi C, Fang Y, Ning Q, *et al.* Global prevalence of overweight and obesity in children and adolescents. *JAMA Pediatr* 2024;178:800-13.
3. World Health Organization. Noncommunicable Diseases: Childhood Overweight and Obesity; 2025. Available from: <https://www.who.int/news-room/questions-and-answers/item/noncommunicable-diseases-childhood-overweight-and-obesity>. [Last accessed on 11 Aug 2025]
4. World Health Organization. Obesity and Overweight; 2025. Available from: <https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight>. [Last accessed on 11 Aug 2025]
5. World Obesity Federation. Prevalence of Obesity; 2025. Available from: <https://www.worldobesity.org/about/about-obesity/prevalence-of-obesity>. [Last accessed on 11 Aug 2025]
6. Panda A, Parida J, Jena S, Behera SS, Pradhan A, Patra PK, *et al.* Prevalence and associated risk factors of overweight and obesity among adolescent population of India: A scoping review. *BMC Nutr* 2025;11:110.
7. Kaur S, Kumar R, Kaur M. Nutritional assessment of adolescents: A cross-sectional study from public schools of North India. *PLoS One* 2025;20:e0316435.
8. Verma M, Esht V, Alshehri MM, Aljahni M, Chauhan K, Morsy WE, *et al.* Factors contributing to the change in overweight/obesity prevalence among Indian adults: A multivariate decomposition analysis of data from the National Family Health Surveys. *Adv Ther* 2023;40:5222-42.
9. Ministry of Health and Family Welfare; 2025. Available from: <https://dhsprogram.com/pubs/pdf/FR375/FR375.pdf>. [Last accessed on 11 Aug 2025]
10. Kosuri S, Chithapuram S, Kumar IJ. Age and sex-specific waist circumference percentiles among school children in Chennai. *Int J Contemp Pediatr* 2023;10:1359-65.
11. Kowalski KC, Crocker PR, Donen RM. The physical activity questionnaire for older children (PAQ-C) and adolescents (PAQ-A) manual. College of Kinesiology, University of Saskatchewan. 2004;87:1-38. Available from: https://www.prismssports.org/UserFiles/file/PAQ_manual_ScoringandPDF.pdf.
12. World Health Organization. Oral Health Surveys: Basic Methods. 5th ed; 2025. Available from: <https://www.who.int/publications/item/9789241548649>. [Last accessed on 11 Aug 2025]
13. Petrus RR, do Amaral Sobral PJ, Tadini CC, Gonçalves CB. The NOVA classification system: A critical perspective in food science. *Trends Food Sci Technol* 2021;116:603-8.
14. World Health Organization & United Nations Children's Fund. The UNICEF-WHO-World Bank Joint Child Malnutrition Estimates (JME) standard methodology: tracking progress on SDG Indicators 2.2. 1 on stunting, 2.2. 2 (1) on overweight and 2.2. 2 (2) on wasting; 2025. Available from: <https://mics.unicef.org/tools>. [Last accessed on 11 Aug 2025]
15. Mandal I, Hossain SR. Update of modified Kuppuswamy scale for the year 2024. *Int J Community Med Public Health* 2024;11:2945-6.
16. World Health Organization. Waist Circumference and Waist-Hip Ratio: Report of a WHO Expert Consultation, Geneva, 8–11 December 2008. <https://apps.who.int/iris/bitstream/handle/10665/44583?sequence=1>. [Last accessed on 11 Aug 2025]
17. Centers for Disease Control and Prevention. Child and Teen BMI Categories; 2024. Available from: <https://www.cdc.gov/bmi/child-teen-calculator/bmi-categories.html>. [Last accessed on 11 Aug 2025]
18. Martini D, Godos J, Bonaccio M, Vitaglione P, Grosso G. Ultra-processed foods and nutritional dietary profile: A meta-analysis of nationally representative samples. *Nutrients* 2021;13:3390.
19. Lane MM, Gamage E, Du S, Ashtree DN, McGuinness AJ, Gauci S, *et al.* Ultra-processed food exposure and adverse health outcomes: Umbrella review of epidemiological meta-analyses. *BMJ* 2024;384:e077310.
20. Yıldız F, Aksakal MZT, Yıldız R, Baş F. The relationship between sleep quality, sleep duration, social jet lag and obesity in adolescents. *J Clin Res Pediatr Endocrinol* 2024;16:419-25.
21. Porri D, Luppino G, Aversa T, Corica D, Valenzise M, Messina MF, *et al.* Preventing and treating childhood obesity by sleeping better: A systematic review. *Front Endocrinol* 2024;15:1426021.
22. Sriram K, Mulder HS, Frank HR, Santanam TS, Skinner AC, Perrin EM, *et al.* The dose-response relationship between physical activity and cardiometabolic health in adolescents. *Am J Prev Med* 2021;60:95-103.
23. Jaleel A, Chilumula M, Satya SGC, Singnale P, Telikicherla UR, Pandurangi R. The assessment of nutritional status of adolescents aged 15-18 years using BMI cutoffs and BMI Z scores: A secondary analysis of National Family Health Survey-5 (2019-21) data. *Cureus* 2024;16:e59800.
24. Bhosale TS, Potdar NJ, Choudhari SK. Prevalence of obesity among adolescents: a study from Western Maharashtra. Assessment of knowledge, attitudes, and practices of adolescents regarding obesity in private schools in Western Maharashtra. *J Neonatal Surg* 2025;14:472-6.
25. Niti Ayog. Poshan-Abhiyaan; 2025. Available from: <https://www.niti.gov.in/sites/default/files/2022-09/Poshan-Abhiyaan-Monitoring.pdf>. [Last accessed on 11 Aug 2025]
26. Raveenthiranathan L, Ramanarayanan V, Thankappan K. Impact of free school lunch program on nutritional status and academic outcomes among school children in India: A systematic review. *BMJ Open* 2024;14:e080100.
27. Paul VK, Singh A, Palit S. POSHAN Abhiyaan: Making nutrition a jan andolan. *Proc Indian Natl Sci Acad* 2018;84:835-41.
28. World Health Organization. Noncommunicable Diseases; 2025. Available from: <https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases>. [Last accessed on 11 Aug 2025]
29. Kaur S, Kumar R, Kaur M. School-based behaviour change intervention to reduce ultra-processed food consumption among adolescents: Evidence from a cluster-randomised controlled trial in India. *BMJ Global Health* 2026;11:e020799.

Supplementary Material

Overweight and Obesity Among School Going Children in South India: Findings from a Cross-Sectional Study

Contents:

- Supplementary Appendix S1: Dietary intake assessment and NOVA food classification procedure.....3
- Table S1: Socio-demographic characteristics of study participants.....4
- Table S2: Socio-demographic characteristics of school-children by type of school.....6
- Table S3: Distribution of dietary behaviours, physical activity, screen time, sleep and snacking patterns by sex and socio-economic status among study participants (n=372) 7
- Table S4: Nutritional status of adolescents by school type 9
- Table S5: Multivariate analysis of under-weight in adolescents (Underweight versus Normal weight).....10

Supplementary Appendix S1: Dietary intake assessment and NOVA food classification procedure

Dietary intake was classified as low, moderate or high consumption based on the diet frequency information. In addition, NOVA food classification was applied to diet frequency data used to classify the food intake into: (i) unprocessed or minimally processed foods, (ii) processed culinary ingredients, (iii) processed foods, and (iv) ultra-processed foods (UPF; 1). Dietary intake was assessed using diet history section of the WHO oral health assessment performa. In this system, a six-point scale was used to quantify the frequency of food consumption. The scale ranged from one to six, where a score of one corresponded to the lowest frequency of consumption, meaning “never,” while a score of six represented the highest frequency, defined as “several times a day.” In between these two extremes, a score of two indicated consumption several times a month, a score of three represented intake once a week, a score of four denoted consumption several times

a week, and a score of five referred to daily intake (2). To determine overall dietary patterns, average scores were calculated for each participant based on the frequency scores of individual food items. These average scores were then classified into three distinct categories. A score ranging from 1.0 to 2.9 was categorized as low consumption, scores between 3.0 and 4.4 were considered moderate consumption, and those between 4.5 and 6.0 were classified as high consumption.

In addition to this scoring framework, the NOVA food classification system was applied to categorize foods according to the degree and purpose of processing. This system was originally developed by the Center for Epidemiological Studies in Health¹ and Nutrition at the School of Public Health, University of São Paulo, Brazil. According to NOVA, food processing refers to the physical, biological, and chemical changes that occur after foods are separated from nature and before they are consumed or used in the preparation of dishes and meals. In the present study, food items adapted from the WHO oral health assessment performa were reassigned into NOVA categories. Accordingly, fruits were placed in Group 1, vegetables were included in Group 2, bakery items were assigned to Group 3, and biscuits, cakes, pastries, soft drinks, chocolates, candies, and processed junk foods such as pizza, burgers, and cheese fries were classified under Group 4. In the Indian context, vegetables were categorized in Group 2, as they are generally consumed in cooked form, which typically includes the use of oils, spices, and salt. To determine overall dietary patterns based on the NOVA groups, average scores were calculated for each participant using the frequency scores of food items within the four groups. For analysis, the five different food items placed under Group 4 were considered collectively as a single category, and average scores were computed. These average scores were subsequently divided into three categories: low consumption, moderate consumption, and high consumption, corresponding to the scoring ranges described earlier. The scoring process involved three key steps. First, scoring for each food item was adapted from the diet history section of the WHO oral health assessment performa. Second, food items were reassigned into groups according to the NOVA food classification system. Third, average scores for each item were calculated according to the defined score ranges, thereby generating the final classification of participants’ dietary consumption patterns.

¹Petrus RR, do Amaral Sobral PJ, Tadini CC, Gonçalves CB. The NOVA classification system: A critical perspective in food science. *Trends in Food Science & Technology*. 2021 Oct 1;116:603–8.

²Oral health surveys: basic methods - 5th edition [Internet]. [cited 2025 Aug 20]. Available from: <https://www.who.int/publications/i/item/9789241548649>

Table S1: Socio-demographic characteristics of study participants

Demographic Characteristics	Overall sample (n = 372) n (%)
Sex	
Male	187 (50)
Female	185 (50)
Religion	
Hindu	316 (85)
Christian	34 (9)
Muslim	22 (6)
Income categories (INR)	
<10,702	76 (20)
10,703-31,977	114 (31)
31,978-53,360	26 (7)
53,361-80,109	113 (30)
80,110-1,06,849	22 (6)
1,06,850-2,13,813	21 (6)
Mother education	
No formal education	54 (14)
Primary school	20 (5)
Middle school	80 (22)
High school	56 (15)
Intermediate/diploma	21 (6)
Graduate	84 (23)
Professional degree	57 (15)
Father education	
No formal education	44 (12)
Primary school	30 (8)
Middle school	81 (22)
High school	49 (13)
Intermediate/diploma	25 (7)
Graduate	80 (21)
Professional degree	63 (17)
Mother occupation	
Legislators, senior officials and managers	4 (1.1)
Professionals	38 (10)
Technicians and associate professionals	1 (0.3)
Clerks	3 (0.8)
Skilled workers and shop and market sales workers	3 (0.8)
Craft and related trade workers	6 (2)
Elementary occupation	79 (21)
Unemployed	238 (64)
Father occupation	
Legislators, senior officials and managers	21 (5.7)
Professionals	96 (25.8)
Technicians and associate professionals	14 (3.8)
Skilled workers and shop and market sales workers	106 (28.5)
Skilled agricultural and fishery workers	1 (0.3)
Craft and related trade workers	7 (1.9)
Plant and machine operators and assemblers	27 (7.3)
Elementary occupation	98 (26.3)
Unemployed	2 (0.5)
Socio-economic class	
Upper (I)	9 (2)
Upper Middle (II)	151 (41)
Lower Middle (III)	62 (17)
Upper Lower (IV)	131 (35)
Lower (V)	19 (5)

Table S1. Continued

Demographic Characteristics	Overall sample (n = 372) n (%)
Type of family	
Nuclear	282 (76)
Joint	90 (24)
Family history of obesity	
Yes	46 (12)
No	326 (88)

Note: Socio-economic status assessed by Modified Kuppuswamy Scale 2024. The Modified Kuppuswamy Socio-economic Status (SES) scale includes family monthly income, education and occupation of the head of the household, which is typically the father in Indian homes. Family history of obesity refers to self-reported obesity in first-degree relatives.

Table S2: Socio-demographic characteristics of study participants by type of school

Demographic Characteristics	Central government (n = 93) n (%)	Government-fully aided (n = 93) n (%)	Government-partially aided (n = 93) n (%)	Private (Un-aided) (n = 93) n (%)	Total (n = 372) n (%)
Sex					
Male	49 (53)	47 (51)	47 (51)	44 (47)	187 (50)
Female	44 (47)	46 (49)	46 (49)	49 (53)	185 (50)
Religion					
Hindu	77 (83)	75 (81)	84 (90)	80 (86)	316 (85)
Christian	11 (12)	7 (7)	6 (7)	10 (11)	34 (9)
Muslim	5 (5)	11 (12)	3 (3)	3 (3)	22 (6)
Father education					
No formal education	0	22 (24)	22 (24)	0	44 (12)
Primary, Middle school	1 (1)	52 (56)	52 (56)	6 (6.5)	111 (30)
High school, Intermediate/Diploma	27 (29)	18 (19)	18 (19)	11 (12)	74 (20)
Graduate, Professional degree	65 (70)	1 (1)	1 (1)	76 (82)	143 (38)
Mother education					
No formal education	0	27 (29)	27 (29)	0	54 (14)
Primary, Middle school	2 (2.2)	49 (53)	49 (53)	0	100 (27)
High school, Intermediate/Diploma	24 (26)	17 (18)	17 (18)	19 (20)	77 (21)
Graduate, Professional degree	67 (72)	0	0	74 (80)	141 (38)
Father Occupation					
Legislators, senior officials and managers, Professionals, Technicians and associate professionals	78 (84)	0	1 (1.1)	52 (56)	131 (35)
Clerks, Skilled workers and shop and market sales workers, Skilled agricultural and fishery workers, Craft and related trade workers, Plant and machine operators and assemblers	14 (15)	48 (52)	38 (41)	41 (44)	141 (38)
Elementary occupation, Unemployed	1 (1)	45 (48)	54 (58)	0	100 (27)
Mother Occupation					
Un-employed	64 (69)	56 (60)	46 (49)	72 (77)	238 (64)
Employed	29 (31)	37 (40)	47 (51)	21 (23)	134 (36)
Socio-economic class					
Upper	83 (89.3)	0	0	77 (83)	160 (43)
Middle	10 (11)	21 (23)	15 (16)	16 (17)	62 (17)
Lower	0	72 (77)	78 (84)	0	150 (40)
Type of family					
Nuclear	80 (86)	52 (56)	80 (86)	70 (75)	282 (76)
Joint	13 (14)	41 (44)	13 (14)	23 (25)	90 (24)
Family history of obesity					
Yes	23 (25)	3 (3)	3 (3)	17 (18)	46 (12)
No	70 (75)	90 (97)	90 (97)	76 (82)	326 (88)

*Note: Socio-economic class was assessed using the Modified Kuppuswamy Scale. For analysis, categories were regrouped as follows - *Upper (I)* and *Upper Middle (II)* combined into "Upper"; *Upper Lower (IV)* and *Lower (V)* combined into "Lower"; *Lower Middle (III)* retained as a separate category.*

Table S3: Distribution of dietary behaviours, physical activity, screen time, sleep and snacking patterns by sex and socio-economic status among study participants (n = 372)

Predictors	Categories	Total (n = 372)	Male (n = 187)	Female (n = 185)	Upper (I) + Upper Middle (II)	Lower Middle (III)	Upper Lower (IV) + Lower (V)
Number of meals consumed per day	2 or <2	158 (42)	81 (43)	77 (42)	9 (6)	30 (48)	119 (79)
	3	133 (36)	65 (35)	68 (37)	81 (51)	21 (34)	31 (21)
	More than 3	81 (22)	41 (22)	40 (22)	70 (44)	11 (18)	0
Frequency of consuming breakfast at home	4-5 times a week	96 (26)	61 (33)	47 (25)	19 (12)	23 (37)	66 (44)
	1-3 times a week	168 (45)	77 (41)	91 (49)	71 (44)	24 (39)	73 (49)
	Rarely	108 (29)	49 (26)	47 (25)	70 (44)	15 (24)	11 (7)
The NOVA food classification system – consumption							
Group 1: Unprocessed or minimally processed foods	Moderate	302 (81)	149 (80)	153 (83)	121 (76)	55 (89)	126 (84)
	High	70 (19)	38 (20)	32 (17)	39 (24)	7 (11)	24 (16)
Group 2: Processed culinary ingredients (Oils, fats, salt, and sugar)	Moderate	48 (13)	24 (13)	24 (13)	24 (15)	6 (10)	18 (12)
	High	324 (87)	163 (87)	161 (87)	136 (85)	56 (90)	132 (88)
Group 3: Processed foods	Moderate	207 (56)	104 (56)	103 (56)	125 (78)	35 (57)	47 (31)
	High	165 (44)	83 (44)	82 (44)	35 (22)	27 (44)	103 (69)
Group 4: Ultra-processed foods	Low	208 (56)	104 (56)	104 (56)	51 (32)	37 (60)	120 (80)
	Moderate	164 (44)	83 (44)	81 (44)	109 (68)	25 (40)	30 (20)
Physical activity level	Low PA	235 (63)	111 (60)	124 (67)	109 (68)	41 (66)	85 (57)
	Moderate PA	97 (26)	51 (27)	46 (25)	38 (24)	12 (19)	47 (31)
	High PA	40 (11)	25 (13)	15 (8)	13 (8)	9 (15)	18 (12)
Daily screen time	Less than 1 hour	49 (13)	24 (13)	25 (13)	15 (9)	5 (8)	29 (19)
	1-2 hours	123 (33)	57 (31)	66 (36)	49 (31)	23 (37)	51 (34)
	3-4 hours	141 (38)	73 (39)	68 (37)	62 (39)	21 (34)	58 (39)
	More than 4 hours	59 (16)	33 (18)	26 (14)	34 (21)	13 (21)	12 (8)
Sleep duration	Less than 6 hours	191 (51)	92 (49)	99 (54)	98 (61)	33 (53)	60 (40)
	6 to 10 hours	168 (45)	88 (47)	80 (43)	56 (35)	26 (42)	86 (57)
	More than 10 hours	13 (3)	7 (4)	6 (3)	6 (4)	3 (5)	4 (3)
Frequency of snacking between meals	Daily	158 (43)	79 (42)	79 (43)	46 (29)	9 (14)	0
	2-3 times a week	159 (15)	80 (43)	80 (43)	74 (46)	26 (42)	59 (39)
	Occasionally	55 (15)	28 (15)	27 (15)	40 (25)	27 (44)	91 (61)
Anthropometric measurements	Average height (cm) (Mean $\pm$ SD)	162.19 $\pm$ 9.22	168.78 $\pm$ 6.70	155.54 $\pm$ 6.13	162.7 $\pm$ 8.93	161.56 $\pm$ 9.89	161.92 $\pm$ 9.28
	Average weight (kg) (Mean $\pm$ SD)	54.48 $\pm$ 12.62	58.83 $\pm$ 11.95	50.09 $\pm$ 11.76	58.23 $\pm$ 13.08	55.33 $\pm$ 14.60	50.14 $\pm$ 9.61
	Average body mass Index (Mean $\pm$ SD)	20.65 $\pm$ 4.25	20.63 $\pm$ 4.01	20.68 $\pm$ 4.50	21.93 $\pm$ 4.46	21.16 $\pm$ 5.07	19.08 $\pm$ 3.00
	Waist Hip Ratio (WHR) (Mean $\pm$ SD)	0.82 $\pm$ 0.05	0.84 $\pm$ 0.05	0.79 $\pm$ 0.05	0.82 $\pm$ 0.06	0.81 $\pm$ 0.05	0.81 $\pm$ 0.04
Body Mass Index (BMI)	Underweight (<5 th Percentile)	105 (28)	43 (23)	62 (33)	23 (14)	19 (31)	63 (42)
	Healthy weight (5 th to <85 th Percentile)	203 (55)	122 (65)	81 (44)	99 (62)	29 (47)	75 (50)
	Overweight (85 th to <95 th Percentile)	42 (11)	14 (7)	28 (15)	27 (17)	5 (8)	10 (7)
	Obesity (95 th Percentile or Greater)	22 (6)	8 (4)	14 (8)	11 (7)	9 (14)	2 (1)
Waist-Hip Ratio (WHR)	Low risk (<0.90 for men, <0.85 for female)	320 (86)	164 (88)	156 (84)	128 (80)	54 (88)	138 (92)
	High risk ($\geq$ 0.90 for men, $\geq$ 0.85 for female)	52 (14)	23 (12)	29 (16)	32 (20)	8 (13)	12 (8)

Table S4: Nutritional status of adolescents by school type

Variable (N = 372)	Central government (n = 93)	Government -Fully aided (n = 93)	Government -Partially aided (n = 93)	Un-aided (Private; n = 93)	Total (n = 372) n (%)
Body Mass Index (BMI)					
Underweight (<5 th Percentile)	14 (15)	36 (39)	40 (43)	15 (16)	105 (28)
Healthy weight (5 th to <85 th Percentile)	56 (60)	49 (53)	43 (46)	55 (59)	203 (55)
Overweight (85 th to <95 th Percentile)	16 (17)	5 (5)	8 (9)	13 (14)	42 (11)
Obesity (95 th Percentile or Greater)	7 (8)	3 (3)	2 (2)	10 (11)	22 (6)
Waist Hip Ratio (WHR)					
Low risk (<0.90 for men, <0.85 for female)	76 (81.7)	87 (94)	87 (94)	70 (75)	320 (86)
High risk ($\geq$ 0.90 for men, $\geq$ 0.85 for female)	17 (18.3)	6 (6)	6 (6)	23 (25)	52 (14)

Table S5: Multivariate analysis of under-weight in adolescents (Under-weight versus Normal Weight)

Variable	Overweight and Obese (N = 64)			
	Crude (OR,95%CI)	P value	AOR (95%CI)	P value
Sex				
Male	1		1	
Female	2.17 (1.34, 3.50)	0.002**	2.21 (1.30, 3.75)	0.003**
Age	0.92 (0.69, 1.23)	0.604	0.95 (0.68, 1.33)	0.791
Mother education				
No formal education	1		1	
Primary, Middle school	0.72 (0.35, 1.45)	0.362	0.78 (0.36, 1.70)	0.543
High school, Intermediate/Diploma	0.31 (0.14, 0.70)	0.005**	0.60 (0.22, 1.64)	0.326
Graduate, Professional degree	0.23 (0.11, 0.48)	<0.001**	0.79 (0.20, 3.06)	0.739
Mother Occupation				
Un-employed	1		1	
Employed	1.22 (0.74, 1.99)	0.423	1.00 (0.55, 1.81)	0.993
Socio-economic class				
Upper	0.27 (0.15, 0.48)	<0.001**	0.61 (0.17, 2.14)	0.447
Middle	0.77 (0.39, 1.52)	0.466	1.21 (0.49, 2.95)	0.668
Lower	1		1	
Type of family				
Nuclear	1		1	
Joint	0.73 (0.42, 1.28)	0.280	0.62 (0.33, 1.18)	0.149
Family history of obesity				
Yes	0.39 (0.15, 0.98)	0.047*	0.48 (0.16, 1.40)	0.182
No	1		1	
Number of meals consumed per day				
<2 or 2	1		1	
3	0.52 (0.31, 0.88)	0.017*	1.14 (0.54, 2.39)	0.729
More than 3	0.25 (0.12, 0.55)	<0.001**	0.82 (0.22, 3.02)	0.767
Frequency of consuming breakfast at home				
4-5 times a week	0.23 (0.11, 0.47)	<0.001**	0.26 (0.10, 0.67)	0.005**
1-3 times a week	0.58 (0.34, 1.00)	0.053	0.73 (0.37, 1.42)	0.362
Rarely	1		1	
The NOVA food classification system – consumption				
Group 1: Unprocessed or minimally processed foods				
Moderate	1		1	
High	0.69 (0.37, 1.29)	0.254	0.86 (0.40, 1.82)	0.698
Group 2: Oils, fats, salt, and sugar				
Moderate	1		1	
High	1.29 (0.62, 2.64)	0.485	1.45 (0.63, 3.33)	0.374
Group 3: Processed foods				
Moderate	1		1	
High	1.49 (0.92, 2.39)	0.098	0.80 (0.42, 1.52)	0.504

Table S5. Continued

Variable	Overweight and Obese (N = 64)			
	Crude (OR,95%CI)	P value	AOR (95%CI)	P value
Group 4: Ultra-processed foods				
Low	1		1	
Moderate	0.54 (0.33, 0.89)	0.016*	0.80 (0.42, 1.52)	0.512
Canteen availability (n = 93)				
Yes	0.44 (0.23, 0.84)	0.012*	0.50 (0.15, 1.63)	0.255
No	1		1	
Physical activity level				
Low PA	1		1	
Moderate PA	0.90 (0.52, 1.54)	0.708	0.44 (0.44, 1.53)	0.539
High PA	0.61 (0.28, 1.33)	0.216	0.20 (0.20, 1.21)	0.127
Daily screen time				
Less than 1 hour	1		1	
1-2 hours	0.92 (0.44, 1.91)	0.828	0.49 (0.49, 2.59)	0.764
3-4 hours	0.75 (0.36, 1.54)	0.443	0.42 (0.42, 2.21)	0.949
More than 4 hours	0.65 (0.27, 1.55)	0.338	0.40 (0.40, 3.36)	0.773
Sleep duration				
Less than 6 hours	1		1	
6 to 10 hours	1.33 (0.82, 2.16)	0.238	1.36 (0.75, 2.46)	0.298
More than 10 hours	1.12 (0.32, 3.91)	0.857	1.86 (0.41, 8.30)	0.416
Frequency of snacking between meals				
Daily	0.44 (0.20, 0.94)	0.035*	1.51 (0.48, 4.72)	0.474
2-3 times a week	1.49 (0.43, 1.15)	0.167	0.97 (0.52, 1.80)	0.940
Occasionally	1		1	

Note: OR = odds ratio; AOR = adjusted odds ratio; CI = confidence interval; p-values <0.05 considered statistically significant. *p < 0.05; **p < 0.01 (Pooled p-values shown).

ref = reference category. Models adjusted for age, sex, socio-economic status, physical activity, sleep duration, and dietary factors. Pooled p-values denote combined statistical tests across categories.