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Original Research Article

A cross-sectional study on burden and predictors of obesity and anemia in school-going adolescents from Northern India

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ABSTRACT

Background: Adolescence, a period of rapid growth and high nutritional demand, faces a dual burden of malnutrition. This study assessed anemia and obesity prevalence and their demographic, dietary and anthropometric associations among school-going adolescents in India.
Methods: A cross-sectional study was conducted from August 2023 to January 2025 in selected schools in Sitapur, India, enrolling 386 adolescents via multistage random sampling. Data on sociodemographic, dietary habits and clinical history were collected through structured interviews. Anthropometry (weight, height, body mass index (BMI), waist-hip ratio (WHR), mid-upper arm circumference (MUAC)) and hemoglobin levels (automated hematology analyser) were measured. Anemia and obesity were classified using WHO guidelines and CDC BMI percentiles/WHR cut-offs, respectively. Data were analyzed using SPSS v26.0; $p<0.05$ was considered significant.
Results: The mean age was 14.19±2.63 years. Overweight and obesity prevalence were 7.8% and 30.8%, respectively, with 10.6% underweight. Central obesity was present in 45.6% (WHR). Anemia affected 32.4% and was associated with female gender (OR=2.77, $p<0.001$), nuclear family (B=-0.900, OR=0.41, p=0.005), vegetarian diet (B=-1.903, OR=0.15, $p<0.001$) and low socioeconomic status (OR=10.26, $p<0.001$). Obesity was linked to non-vegetarian diet (OR=2.467, p=0.009), daily fast-food intake (OR=3.323, p=0.005) and inversely associated with lower SES (B=-2.083, OR=0.124, $p<0.001$). No significant association was observed between BMI and anemia (p=0.591).
Conclusions: High prevalence of overweight/obesity (38.6%) and anemia (32.4%), with notable coexistence, highlights the dual burden of malnutrition. Integrated school-based interventions focusing on screening, nutrition education and early management are essential to improve adolescent health in India.

Keywords: Adolescent health, Anemia, Obesity, Body mass index, Cross sectional studies, Dietary habits, Nutritional status, Public health, Socioeconomic status, Waist hip ratio

INTRODUCTION

Adolescence is a crucial developmental period marked by rapid physical, hormonal and psychosocial changes that significantly influence an individual's current and future health status.[1] The World Health Organization (WHO) defines adolescence as the age range between 10 and 19 years, a time characterized by increased nutritional requirements due to accelerated growth and sexual maturation.[1] Adolescence represents the transitional period between childhood and adulthood and is typically categorized into three stages: early adolescence (10–13 years), middle adolescence (14–16 years) and late adolescence (17–19 years).[2] During this phase, both undernutrition and overnutrition can have profound effects on physical growth, cognitive development and metabolic health.[3] Globally, adolescents are disproportionately affected by anemia, with iron deficiency being the primary underlying cause of this nutritional disorder.[4] It disproportionately affects adolescent girls due to the onset of menstruation, poor dietary iron intake and increased physiological demands during puberty.[5] The WHO reports that 30% of women aged 15 to 49, 37% of pregnant women and 40% of children aged 6 to 59 months are anaemic globally.[6] The prevalence of anaemia among Indian adolescent girls and boys aged 15 to 19 years has slightly increased between the 2005-2006 and 2019-2021 National Family Health Survey (NFHS) surveys, i.e., from 55.8% to 59.1% in girls and from 30.2% to 31.1% in boys.[7] Anaemia during adolescence has far-reaching consequences, including impaired academic performance, fatigue, delayed growth, reduced work productivity and compromised immunity.[4]

At the other end of the nutritional spectrum, obesity among adolescents is rising at an alarming rate due to lifestyle transitions such as increased consumption of energy-dense foods, sedentary behaviour and reduced physical activity.[2,8,9] The combined prevalence of overweight and obesity was 19.6% based on the International Obesity Task Force (IOTF) classification; however, it escalated to 27% in comparison to the WHO guidelines.[10] A number of variables influence optimal nutrition, such as the size of the family, socioeconomic status, psychological health, dietary beliefs and misconceptions, hygiene, financial capacity and education.[11,12]

Alarmingly, obesity often coexists with micronutrient deficiencies, giving rise to the so-called "double burden of malnutrition", a paradox where individuals have excess caloric intake but insufficient intake or absorption of essential nutrients such as iron.[13] Emerging research suggests that overweight and obese adolescents are at higher risk of iron deficiency not only due to poor dietary habits but also due to chronic low-grade inflammation and disrupted iron metabolism mediated by hepcidin, a regulatory hormone that inhibits iron absorption.[14,15] This interaction challenges traditional views that associate anaemia solely with undernutrition and underscores the need for a nuanced understanding of adolescent nutrition. Understanding how obesity and anaemia relate to anthropometric measures in adolescents is crucial for early detection of at-risk individuals and for designing preventive strategies. With India facing the dual challenge of micronutrient deficiencies and rising lifestyle diseases, generating localized data is essential for policy-making and program implementation in adolescent health. This study aims to evaluate the prevalence of anaemia and obesity among adolescents and to analyze whether obese adolescents have an increased risk of anemia.

METHODS

Study design and settings

This cross-sectional study was conducted over 18 months (August 2023–January 2025) among school-going adolescents aged 10–19 years in Sitapur, India. Ethical approval was obtained (IHEC-HIMSA/MD-MS-22/RD-31/07-23) and written consent/assent was secured from parents/guardians and participants.

Inclusion and exclusion criteria

Adolescents aged 10–19 years from selected government and private secondary schools who were present on the screening day and provided parental/guardian consent and assent were included. Exclusion criteria were chronic illness (e.g., tuberculosis, diabetes, thalassemia), recent blood transfusion or iron supplementation (past 3 months), acute illness, hormonal disorders (e.g., Cushing's) or use of obesity-inducing drugs.

Sampling method and sample size

A multi-stage random sampling method was used: schools were first randomly selected, followed by students chosen through simple random sampling from class registers. Sample size was calculated using Cochran's formula for prevalence studies ($n=z^2 (p\times q) / e^2$) at 95% confidence ($z=1.96$, $p=0.5$, $q=0.5$, $e=0.05$), assuming an infinite population.[7] The required sample size was 384.

Data collection

Data were collected using a pretested questionnaire covering demographics, dietary habits, clinical history, examination, anthropometry and investigations. Demographic variables included age, gender, religion, livelihood, family type and socioeconomic status (modified Kuppuswamy scale 2023).[16] Dietary history assessed vegetarian/non-vegetarian diet and junk food frequency. Information was obtained via face-to-face interviews, followed by private anthropometric assessments, with a female staff member present for female participants.

Anthropometric measurements

Weight (in kilograms (kg)) and height (in centimeters (cm)) were measured using a digital scale and stadiometer and Body Mass Index (BMI) was calculated as weight (kg) divided by height in meters squared (m^2). BMI percentiles were determined using CDC age- and sex-specific growth charts and classified as underweight (<5th), healthy weight (5th–<85th), overweight (85th–<95th) and obese (≥95th percentile).[8]

Waist-Hip Ratio (WHR) was assessed to evaluate fat distribution. Waist circumference (WC) was measured using a non-stretchable measuring tape at the midpoint between the lower margin of the last palpable rib and the iliac crest and hip circumference (HC) at the widest part of the buttocks, both in centimeters. WHR was calculated as waist circumference divided by hip circumference

(WC/HC). A WHR>0.90 in males and>0.85 in females indicated central obesity, as per WHO criteria.[17]

Mid-upper arm circumference (MUAC) was measured on the left arm at the midpoint between the acromion and olecranon process, using a flexible, non-stretchable tape, with accuracy up to 0.1 centimetre. MUAC served as a proxy for nutritional status, but no established cut-off exists for overweight or obesity.[18,19]

Haematological Assessment: A 2 milliliter (ml) venous blood sample was collected in Ethylenediaminetetraacetic acid (EDTA) tubes and analysed using a 5-part haematology analyser (Mindray) for complete blood counts. Anemia was defined by WHO criteria: hemoglobin<115 g/l (10–11 years), <120 g/l (girls 12–19 years and boys 12–14 years) and<130 g/l (boys 15–19 years). Severity was classified as mild (110–114 g/l for respective age/sex cut-offs or 110–129 g/l for boys 15–19 years), moderate (80–109 g/l) and severe (<80 g/l).[20] All anthropometric and laboratory procedures were performed by trained personnel using standardized protocols and calibrated equipment.

Statistical analysis

Data were entered in Microsoft Excel and analyzed with IBM SPSS version 26.0. Descriptive statistics (frequencies, percentages, means and standard deviations) were applied. Chi-square tests assessed categorical associations and Pearson's correlation examined relationships between continuous variables. Binary logistic regression identified predictors of anemia and obesity. Statistical significance was set at $p<0.05$.

RESULTS

The mean age of the adolescents was 14.19±2.63 years. The average waist circumference (WC) was 73.97±6.34 cm and the mean hip circumference (HC) was 85.65±6.24 cm, resulting in a mean waist-hip ratio (WHR) of 0.86±0.049. The average mid-upper arm circumference (MUAC) was 23.42±1.69 cm. The mean weight of the participants was 47.55±10.64 kg, with a mean height of 1.50±0.12 meters, resulting in a mean Body Mass Index (BMI) of 21.32±5.37 kg/m². These values provide a general overview of the nutritional and growth status of the adolescent population under study.

Table 1 shows the demographic profile of 386 adolescents. Most were early adolescents (41.2%), with nearly equal gender distribution. A large majority were rural (86%), Hindu (63%) and from nuclear families (58.8%). Socioeconomically, most belonged to upper lower (34.5%) or lower (34.2%) classes. Vegetarian diet (66.6%) was more common and 28.5% reported daily fast-food consumption.

Among 386 adolescents, half had a healthy BMI (50.8%), while 30.8% were obese. WHR-defined obesity was seen in 45.6% (Table 2). Anemia was present in 32.4%, mostly of moderate severity (16.8%). The commonest type of general blood picture (GBP) was normocytic normochromic (64%), followed by microcytic hypochromic (18.4%) (Table 2). The overall mean hemoglobin level was 11.85±1.56 g/dl, with anemic adolescents showing significantly lower levels (10.26±1.57 g/dl) compared to non-anemic peers (12.62±0.78 g/dl). Among the 125 anemic participants, 37.6% (47/125) had mild anemia with a mean hemoglobin of 11.77±0.60 g/dl, 52.0% (65/125) had moderate anemia with 9.67±1.05 g/dl and 10.4% (13/125) had severe anemia with 7.67±0.23 g/dl. The most prevalent anemic blood picture was microcytic hypochromic anemia (71/125; 56.8%).

BMI was significantly associated with socioeconomic status, fast-food frequency, anemia severity and blood picture categories ($p<0.0001$), but not with age, gender, religion, family type, livelihood, diet or WHR (Table 3). Underweight and obesity were more prevalent among adolescents from lower socioeconomic classes, while daily fast-food intake was more common in those who were overweight or obese. Moderate-to-severe anemia occurred more frequently in participants with abnormal BMI.

Anemia was significantly associated with female gender, nuclear family type, lower socioeconomic status and vegetarian dietary habits ($p<0.0001$), but not with age, religion, residence, fast-food intake, BMI or WHR (Table 4). No statistically significant association was observed between waist-hip ratio (WHR) categories and either the severity of anemia ($p=0.338$) or the morphological types of anemia based on general blood picture (GBP) ($p=0.311$). The absence of significant p-values and weak correlation coefficients suggests that WHR is not a strong determinant of anemia type or severity in this population.

Multinomial logistic regression showed that lower and upper-lower socioeconomic status significantly reduced the odds of obesity compared to upper-middle class. Non-vegetarian diet (OR=2.467) and daily fast-food intake (OR=3.323) were associated with higher odds of obesity (Table 5). Adolescents reporting no fast-food intake had higher odds of obesity (OR=10.07, $p=0.010$), possibly reflecting misreporting or compensatory behaviors. Adolescents with a microcytic normochromic blood picture had significantly lower odds of obesity (OR=0.057, $p=0.041$), indicating an inverse association with this anemia type.

Binary logistic regression showed higher odds of anemia in females (OR=2.77, $p<0.001$) and adolescents from lower SES groups (OR=10.26, $p=0.001$), while joint-family residence (OR=0.41, $p=0.005$) and non-vegetarian diet (OR=0.15, $p<0.001$) were protective. Age, religion, BMI, WHR and fast-food intake were not significant predictors (Table 6).

Table 1: Demographic parameters of adolescents (n=386).

Demographic parameters		Number (N)	%
Age in years	Early adolescents (10-13)	159	41.2
	Mid adolescents (14-16)	139	36
	Late adolescents (17-19)	88	22.8
Gender	Male	196	50.8
	Female	190	49.2
Religion	Hindu	243	63
	Muslim	112	29
	Others	31	8
Type of family	Nuclear family	227	58.8
	Joint family	159	41.2
Livelihood	Rural	332	86
	Urban	54	14
Socioeconomic status (SES)	Upper	15	3.9
	Upper middle	43	11.1
	Lower middle	63	16.3
	Upper lower	133	34.5
	Lower	132	34.2
Dietary habit	Vegetarian	257	66.6
	Non- Vegetarian	129	33.4
Fast food frequency	Daily	110	28.5
	Once a week	84	21.8
	2-3 times/week	112	29
	1-3 times/month	48	12.4
	No fast food	32	8.3

Table 2: Prevalence of BMI Categories, WHR categories, anemia, anemia severity and types of anemia based on GBP among adolescents (n=386).

Parameters	Category	Number (N)	%
BMI categories	Underweight (BMI<5th Percentile)	41	10.6
	Healthy weight (BMI 5th –<85th Percentile)	196	50.8
	Overweight (BMI>85th –<95th Percentile)	30	7.8
	Obesity (BMI≥95th Percentile)	119	30.8
WHR categories	Non-Obese	210	54.4
	Obese	176	45.6
Anemia	Present	125	32.4
	Absent	261	67.6
Anemia Severity	No anemia	261	67.6
	Mild anemia	47	12.2
	Moderate anemia	65	16.8
	Severe anemia	13	3.4
Types of morphology (based on GBP)	Dimorphic	11	2.8
	Macrocytic	10	2.6
	Microcytic Hypochromic	71	18.4
	Microcytic Normochromic	47	12.2
	Normocytic Normochromic	247	64.0

Table 3: Association of demographic factors, dietary habits, WHR groups, anemia severity and blood picture categories with BMI categories among adolescents (n=386)*.

Parameters		BMI groups				χ^2	P value	r	P (corr.)
		UW	N	OW	OB				
Age groups (years)	Early (10-13)	14	88	11	46	4.068	0.667	0.012	0.813
	Mid (14-16)	18	62	13	46				
	Late (17-19)	9	46	6	27				

Continued.

Parameters		BMI groups				χ²	P value	r	P
Gender	Male	24	95	12	65	3.503	0.320	-0.014	0.789
	Female	17	101	18	54				
Religion	Hindu	23	133	18	69	7.097	0.312	0.018	0.720
	Muslim	12	49	9	42				
	Others	6	14	3	8				
Family type	Joint	16	80	11	52	0.653	0.884	-0.028	0.584
	Nuclear	25	116	19	67				
Livelihood	Rural	37	166	27	102	1.299	0.729	0.009	0.861
	Urban	4	30	3	17				
Socio-economic status	Upper	0	0	1	14	107.786	<0.0001	-0.438	<0.0001
	Upper middle	2	14	5	22				
	Lower middle	0	20	15	28				
	Upper lower	14	78	6	35				
	Lower	25	84	3	20				
Dietary Habit	Vegetarian	27	139	19	72	3.784	0.286	0.080	0.115
	Non-Vegetarian	14	57	11	47				
Fast Food Frequency	Daily	2	40	14	54	174.452	<0.0001	-0.350	<0.0001
	Once a week	3	55	7	19				
	2-3 times/week	8	66	8	30				
	1-3 times/month	5	32	1	10				
	No fast food	23	3	0	6				
WHR group	Non-obese	17	88	16	55	1.063	0.786	-0.028	0.588
	Obese	24	108	14	64				
Severity of anaemia	No anemia	24	136	21	80	42.372	<0.0001	0.085	0.097
	Mild	7	30	7	3				
	Moderate	9	30	2	24				
	Severe	1	0	0	12				
GBP categories	NN	24	123	20	80	35.118	<0.0001	0.051	0.315
	MN	7	29	7	4				
	MH	8	37	3	23				
	Ma	2	6	0	2				
	D	0	1	0	10				

*BMI=Body Mass Index; UW=Underweight; N=Normal weight; OW=Overweight; OB=Obese; WHR=Waist-Hip Ratio; GBP=General Blood Picture; NN=Normocytic Normochromic, MN=microcytic normochromic, MH=microcytic hypochromic, Ma=Macrocytic, D=dimorphic, χ²=Chi-square test statistic; r=Pearson correlation coefficient; p (corr.)=Corrected p-value, statistical significance was considered at p<0.05.

Table 4: Association of demographics, dietary habits, BMI and WHR groups with anemia among adolescents (n=386)*.

Parameters		Anaemia		χ2	P	r	P (corr.)
		No	Yes				
Age groups (in years)	Early (10-13)	110	49	0.817	0.665	-0.007	0.890
	Mid (14-16)	90	49				
	Late (17-19)	61	27				
Gender	Male	158	38	30.172	<0.0001	-0.282	<0.0001
	Female	103	87				
Religion	Hindu	169	74	1.326	0.515	-0.040	0.430
	Muslim	71	41				
	Others	21	10				
Family type	Joint	136	23	39.643	<0.0001	-0.320	<0.0001
	Nuclear	125	102				
Livelihood	Rural	226	106	0.225	0.635	-0.024	0.636

Continued.

Parameters		Anaemia		χ2	P	r	P (corr.)
		No	Yes				
	Urban	35	19				
Socio-economic status	Upper	11	4	49.779	<0.0001	-0.285	<0.0001
	Upper middle	40	3				
	Lower middle	47	16				
	Upper lower	103	30				
	Lower	60	72				
Dietary habit	Vegetarian	144	113	47.139	<0.0001	0.349	<0.0001
	Non-vegetarian	117	12				
Fast food frequency	Daily	73	37	2.014	0.728	-0.020	0.691
	Once a week	60	24				
	2-3 times/week	78	34				
	1-3 times/month	29	19				
	No fast food	21	11				
BMI groups	UW	24	17	1.911	0.591	0.019	0.713
	N	136	60				
	OW	21	9				
	OB	80	39				
WHR group	Obese	127	49	3.049	0.081	-0.089	0.081
	Non-Obese	134	76				

*BMI=Body Mass Index; UW=Underweight; N=Normal weight; OW=Overweight; OB=Obese; WHR=Waist-Hip Ratio; χ^2=Chi-square statistic; r=Pearson correlation coefficient; p (corr.)=corrected p-value, Significance threshold: p<0.05.

Table 5: Multinomial Logistic Regression Predicting Obesity Compared to Normal BMI (n=386)*.

Predictor variable		B	SE	P value	OR (Exp(B))	95% CI for OR
Socioeconomic status	Lower vs. Upper middle	-2.083	0.551	<0.001	0.124	0.042 – 0.366
	Upper lower vs. Upper middle	-1.434	0.468	0.002	0.238	0.095 – 0.596
Dietary pattern	Non-Vegetarian vs. Vegetarian	0.903	0.346	0.009	2.467	1.253 – 4.856
Fast food frequency	Daily vs. Once a week	1.201	0.424	0.005	3.323	1.447 – 7.634
	No fast food vs. Once a week	2.310	0.897	0.010	10.070	1.735 – 58.463
Blood picture morphology	MN vs. NN	-2.861	1.398	0.041	0.057	0.004 – 0.886

*Multinomial logistic regression was conducted with normal BMI as the reference category. Only statistically significant predictors (p<0.05) are shown. B=unstandardized coefficient; OR (Exp(B))=odds ratio; SE=standard error; p=significance; CI=confidence interval; NN=Normocytic Normochromic, MN=microcytic normochromic.

Table 6: Binary logistic regression analysis for predictors of anemia among adolescents (n=386)*.

Predictor variable	B	SE	P value	OR (Exp(B))	95% CI for OR
Gender: Female vs. Male	1.018	0.283	<0.001	2.77	1.59–4.82
Family type: Joint vs. Nuclear	-0.900	0.321	0.005	0.41	0.22–0.76
SES: Lower vs. Upper Middle	2.328	0.733	0.001	10.26	2.44–43.13
SES: Upper lower vs. Upper middle	1.340	0.701	0.056	3.82	0.97–15.09
Diet: Non-vegetarian vs. Vegetarian	-1.903	0.383	<0.001	0.15	0.07–0.32

*Binary logistic regression was conducted with no anemia as the reference category. Only statistically significant predictors (p<0.05) are shown. B=unstandardized coefficient; OR (Exp(B))=odds ratio; SE=standard error; p=significance; CI=confidence interval; SES=socioeconomic status.

DISCUSSION

This study highlights the dual burden of malnutrition among school-going adolescents in Sitapur, India, with obesity (30.8%) and anemia (32.4%) emerging as major public health concerns amid the country's ongoing nutritional transition.

The high prevalence of obesity in our study reflects the rising national and global trends.[10] Sharma et al reported overweight and obesity among Indian adolescents ranging from 12%–29%, reaching 22.3% (IOTF) and 29.8% (WHO).[10] Our combined prevalence of 38.6% exceeds these estimates, likely due to daily fast-food intake (28.5%), urbanizing lifestyles in rural areas and limited physical activity. Similar findings were reported by Singh et al, (2024) in Eastern Uttar Pradesh, where obesity was significantly higher among adolescents from higher socioeconomic status ($p<0.0001$), reinforcing the impact of dietary and lifestyle transitions.[8] The 10.6% prevalence of underweight in our study is concerning, as adolescent undernutrition can impair growth, immunity and academic performance.[4] Its coexistence with obesity underscores the "double burden of malnutrition," an emerging challenge in low- and middle-income countries like India.[13]

Anemia prevalence was 32.4%, consistent with NFHS-5 estimates, reflecting its continued burden among Indian adolescents.[7] Microcytic hypochromic anemia (56.8%) was the most common type, supporting iron deficiency as the leading cause.[4,5] The higher risk among females (OR=2.77, $p<0.001$) aligns with literature linking it to menstrual blood loss and increased iron needs during puberty.[5,6]

No significant association was observed between BMI and anemia ($p=0.591$), suggesting that BMI alone may not reflect the multifactorial risk of nutritional anemia, which can coexist with obesity due to poor diet or metabolic dysfunctions.[13-15] Multiple aetiologies, like nutritional, infectious or genetic, may mask obesity-related trends. Nonetheless, the predominance of dimorphic anemia among obese adolescents (90.9%) and the higher rates of moderate-to-severe anemia in this group ($\chi^2=42.372$, $p<0.0001$) support the concept of obesity-associated anemia, potentially mediated by inflammation-driven hepcidin overexpression as found by Panichsillaphakit et al.[15]

Adolescents from joint families had significantly lower odds of anemia (OR=0.41, $p=0.005$), consistent with findings by Kumari et al.[4] In contrast, no significant association was found between family type and obesity ($p>0.05$), aligning with the study by Singh et al.[8] Lower socioeconomic status reduced obesity odds (OR=0.124, $p<0.001$) but greatly increased anemia risk (OR=10.26), highlighting a social gradient where economic constraints protect against overnutrition yet raise micronutrient deficiency risk.[4,8,9,11,12] Dietary practices significantly influenced outcomes. Vegetarians had higher odds of anemia ($p<0.001$), likely due to low iron intake or bioavailability, consistent with Chouraqui et al.[5] The non-vegetarian diet (OR=2.47, $p=0.009$) and daily fast-food intake (OR=3.32, $p=0.005$) predicted obesity, while unexpectedly, no fast-food intake also increased obesity odds (OR=10.07, $p=0.010$), possibly reflecting misreporting or unhealthy substitutes. These results highlight the role of diet in adolescent malnutrition, aligning with national and global evidence.[9,11]

Anthropometric measures provided additional insights. WHR was elevated in 45.6% of adolescents, indicating central obesity and potential metabolic risk beyond BMI, though it showed no link with anemia.[9,17] Mean MUAC was 23.42±1.69 cm, while less validated in adolescents, it shows promise as a simple, low-cost tool for detecting malnutrition in resource-limited settings.[18,19]

Obesity showed no significant association with age, gender, religion or livelihood ($p>0.05$), consistent with Singh et al.[8] Similarly, anemia was unrelated to religion or livelihood, in line with Kumari et al.[4] However, unlike Kumari et al., we found no association between anemia and age ($\chi^2=0.817$, $p=0.665$).[4] Anemia Mukt Bharat, a flagship initiative under the Poshan Abhiyaan (National Nutrition Mission), aims to reduce anemia through multisectoral preventive and curative strategies, aligned with the Sustainable Development Goals.[21-24] In light of our findings, these efforts must be further strengthened, with school-based screening integrated to detect severe anemia, undernutrition and stunting, ensuring timely referral and intervention.

The Eat Right India initiative, launched by the Food Safety and Standards Authority of India (FSSAI) under the Food Safety and Standards Act, 2006, promotes access to safe, nutritious and sustainable food.[25] With the tagline "Sahi Bhojan, Behtar Jeevan", it integrates regulatory, collaborative and educational strategies, engaging stakeholders across government, industry and civil society.[25] Aligned with programs such as Ayushman Bharat, POSHAN Abhiyaan, Anemia Mukt Bharat and Swachh Bharat, the initiative adopts a 'whole-of-government' and 'whole-of-society' approach to strengthen preventive healthcare and reduce diet-related diseases.[25]

At the 75th World Health Assembly (2022), Member States endorsed the WHO Acceleration Plan to Stop Obesity, promoting multisectoral strategies for global obesity prevention and management.[26] The WHO Anaemia Action Alliance similarly brings together governments and stakeholders to accelerate anemia reduction through coordinated, evidence-based actions and strengthened accountability.[27]

The high prevalence of anemia observed among adolescents in our study is particularly concerning because it has long-term implications beyond this age group. Adolescent girls who enter pregnancy with depleted iron stores are more likely to develop maternal anemia, which in turn adversely affects neonatal haematological status. Rathoria et al, demonstrated that maternal anemia significantly lowers cord blood hemoglobin levels, with a clear linear correlation between maternal and neonatal haemoglobin.[28]

Therefore, tackling anemia during adolescence is essential to prevent its progression into adulthood and to interrupt the intergenerational transfer of poor haematological health.

Strengths: This study's strengths include a robust sample, comprehensive anthropometry (BMI, WHR), dietary and socioeconomic profiling and haematological assessment. Multinomial and binary logistic regression identified key predictors of obesity and anemia, while standardized CDC BMI percentiles, WHO hemoglobin thresholds and morphological classification ensured methodological rigor and comparability.

Limitations include exclusion of out-of-school adolescents, limiting representation of marginalized groups and the cross-sectional design, which precludes causal inference. Findings were not stratified by rural–urban residence, gender or age, restricting subgroup analyses. Dietary data were self-reported, introducing recall and reporting bias. Key biochemical markers (serum ferritin, transferrin saturation, CRP, hepcidin) were not measured, limiting insights into mechanisms linking obesity and anemia.

The coexistence of obesity and anemia underscores the need for integrated strategies addressing under and overnutrition. School health programs should combine anemia screening, anthropometric assessment and nutritional counselling. Future research should use geographically stratified, longitudinal designs with biochemical markers, dietary assessments and subgroup analyses by gender and age to clarify causal pathways and guide targeted interventions.

CONCLUSION

This study highlights the dual burden of malnutrition among Indian adolescents, with 38.6% overweight/obese and 32.4% anaemic and central obesity present in 45.6% (WHR). Obesity and anemia were influenced by overlapping factors: female gender, vegetarian diet, nuclear or lower socioeconomic households increased anemia risk, while non-vegetarian diet and high fast-food intake were linked to obesity. The high prevalence of dimorphic anemia and greater severity among obese adolescents indicates complex nutritional imbalances. These findings emphasize the need for comprehensive, school-based programs combining screening, tailored nutrition education and early intervention to address both under- and overnutrition and improve adolescent health outcomes.

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REFERENCES

1. Guan KW, Adlung C, Keijsers L, Smit CR, Vreeker A, Thalassinou E, et al. Just-in-time adaptive interventions for adolescent and young adult health and well-being: protocol for a systematic review. BMJ open. 2024;1;14(7):e083870.
2. Sawyer SM, Azzopardi PS, Wickremarathne D, Patton GC. The age of adolescence. The lancet child & adolescent health. 2018;1;2(3):223-8.
3. Ragelienė T, Grønhøj A. The influence of peers′ and siblings′ on children's and adolescents′ healthy eating behavior. A systematic literature review. Appetite. 2020;1;148:104592.
4. Kumari G, Rathoria E, Khan FA, Singh SK, Lahari R, Rathoria R, et al. Prevalence of stunting, thinness and anaemia among adolescents and their association with demographics and dietary habits. Int J Contemp Pediatr. 2024;11(12):1711.
5. Chouraqui JP. Dietary approaches to iron deficiency prevention in childhood-a critical public health issue. Nutrients. 2022;12;14(8):1604.
6. World Health Organization. Anaemia. Who.int (Internet). (cited 2025 Jul 5). Available from: https://www.who.int/health-topics/anaemia
7. Scott S, Lahiri A, Sethi V, de Wagt A, Menon P, Yadav K, et al. Anaemia in Indians aged 10-19 years: Prevalence, burden and associated factors at national and regional levels. Maternal & child nutrition. 2022;18(4):e13391.
8. Singh A, Rathoria E, Singh SK, Rathoria R, Yadav SK, Bansal U. Prevalence of overweight and obesity and associations with socio-demographic and etiological factors. Int J Contemp Pediatr. 2024;11(10):1400-5.
9. Bansal U, Raja A, Agarwal P. The influence of family history of cardiovascular disease on blood pressure, waist hip ratio and body mass index in adolescents. International J Contemp Pediat. 2020;7(4):733.
10. Sharma N, Sanjeevi RR, Balasubramanian K, Chahal A, Sharma A, Sidiq M. A systematic review on prevalence of overweight and obesity among school children and adolescents in Indian population. Indian J Endocrinol Metabol. 2024;1;28(2):104-16.
11. Fatima S, Bansal U, Suryavanshi P. Complementary feeding practices in India and improvement strategies. International J Sci Res. 2021;10(3):29-32.
12. Singh A, Rathoria E, Khan FA. Clinical profile and co-morbidities in children with moderate and severe acute malnutrition. International J Contemp Pediat. 2025;12(2):266.
13. Davis JN, Oaks BM, Engle-Stone R. The double burden of malnutrition: a systematic review of

operational definitions. Current Dev Nut. 2020;1;4(9):127.
14. Jeong J, Cho Y, Cho IY. Association between obesity and anemia in a nationally representative sample of South Korean adolescents: a cross-sectional study. In Healthcare. 2022;10(6):1055.
15. Panichsillaphakit E, Suteerojntrakool O, Pancharoen C. The Association between hepcidin and iron status in children and adolescents with obesity. J Nutrit Metabol. 2021;21(1):9944035.
16. Dalvi T, Kalghatgi S. A 2023 Update of Kuppuswamy Socioeconomic Status Classification Scale for the Indian Population. J Indian Assoc Publ Heal Dentistr. 2023;21(3):282-3.
17. Sommer I, Teufer B, Szelag M, Nussbaumer-Streit B, Titscher V, Klerings I, et al. The performance of anthropometric tools to determine obesity: a systematic review and meta-analysis. Scientific Reports. 2020;29;10(1):12699.
18. Sisay BG, Hassen HY, Jima BR, Atlantis E, Gebreyesus SH. The performance of mid-upper arm circumference for identifying children and adolescents with overweight and obesity: a systematic review and meta-analysis. Public Health Nutrition. 2022;25(3):607-16.
19. Nogueira-de-Almeida CA, Ruffo P, Martinez EZ. Cutoff points of mid-upper arm circumference (MUAC) for diagnosis of adolescent obesity: A systematic review with metanalysis and MOSTA tape proposal: MUAC cutoff for diagnosis of adolescent obesity. Global Pediat. 2024;1;8:100135.
20. World Health Organization. Guideline on hemoglobin cutoffs to define anaemia in individuals and populations. 2024. Available at: https://www.who.int/publications. Accessed on 21 August 2025.
21. Jeevan J, Karun KM, Puranik A, Deepa C, Mk L, Barvaliya M. Prevalence of anemia in India: a systematic review, meta-analysis and geospatial analysis. BMC Public Health. 2025;5(1):1270.
22. Salis VM, Kini PS, Devi NB, Devi TD, Padashetti SI. Effectiveness of Self-Instructional Module on Knowledge Regarding Prevention of Iron Deficiency Anemia Among Adolescent Girls at Selected Pre-University Colleges of Moodbidri. International J Immunol Nurs. 2024;10(2):1-7.
23. George L, Kiran A, Nalini N, Kujur M, Kumar A. Prevalence of malnutrition among adolescent tribal girls in India: a systematic review and meta-analysis. Indian J Publ Heal. 2025;69(2):197-202.
24. POSHAN abhiyaan - PM's overarching scheme for holistic nourishment. Available at: https://www.india.gov.in/spotlight/poshan-abhiyaan-pms-overarching-scheme-holistic-nourishment. Accessed on 21 August 2025.
25. Eat Right India. Available at: https://eatrightindia.gov.in/eatrightindia.jsp. Accessed on 21 August 2025.
26. World Health Organization; 2023. WHO acceleration plan to stop obesity. Available at: https://www.who.int/publications. Accessed on 21 July 2025.
27. Anaemia Action Alliance. Available at: https://www.who.int/teams/nutrition-and-food-safety/anaemia-action-alliance. Accessed on 21 August 2025.
28. Rathoria R, Rathoria E. Effect of maternal anemia on cord blood haemoglobin of newborn. Int J Reprod Contrac Obst Gynecol. 2021;11(1):64.

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