ORIGINAL RESEARCH ARTICLE

# Nutritional Status, Body Composition, and Dietary Adequacy among School-Aged Children (6-12 Years) From A Low Socioeconomic Urban Cluster in Maharashtra, India: A Cross-Sectional Study

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## ABSTRACT

**Background:** Growth in school-aged children reflects the balance between fat and lean tissue and is influenced by dietary adequacy. Inadequate diets may result in poor growth or increased adiposity. The study aimed to assess growth patterns, body composition, and dietary adequacy among school-aged children.

**Methods:** A cross-sectional study was conducted among 984 children (6-12 years) selected from six primary schools under the Nagar Palika cluster of Khopoli, Raigad District, Maharashtra, India, representing a lower socioeconomic population. Anthropometric measurements and body composition were assessed using the InBody J30 pediatric analyzer. Nutrient intake was assessed using a 24-hour diet recall and analyzed using DietCal software. Data were analyzed using SPSS software v25.

**Results:** Majority of children showed normal growth pattern; however, both undernutrition and excess adiposity were observed. Approximately 17% (158) of children had elevated body fat levels, with evidence of discordance between BMI and BFP. Energy, fat, and micronutrient intake were below recommended levels, while protein intake was generally adequate.

**Conclusion:** The findings highlight the dual burden of malnutrition and the presence of hidden adiposity among children. Body composition assessment provides additional insight beyond BMI in identifying adiposity. Improving diet quality through targeted nutrition interventions is essential for promoting healthy growth.

**Keywords:** Nutritional Status, Body Composition, Dietary Adequacy, School-aged Children, Malnutrition, India

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## INTRODUCTION

Childhood is a critical period of growth and development, during which nutritional status plays an important role in determining health outcomes.[1] The increasing prevalence of overweight and obesity among children reflects a growing burden of altered body composition and associated health risks.[1] Early identification of nutritional imbalances is essential, as changes during childhood can influence long-term health outcomes.[2] India is experiencing a dual burden of malnutrition, characterized by the coexistence of undernutrition and rising overweight and obesity among school-aged children, as reported in the Comprehensive National Nutrition Survey (CNNS, 2016-18).[3] This transition reflects broader shifts in dietary patterns and lifestyle factors associated with nutritional change.[4] Studies from India also reported the persistence of undernutrition, including stunting and underweight, particularly among children from socioeconomically disadvantaged populations.[5,6]

Assessment of nutritional status in children primarily relies on anthropometric indicators such as height-for-age, weight-for-age, BMI-for-age, and MUAC, as recommended in Indian growth references.[7] However, BMI does not differentiate between fat mass and lean mass and may not accurately reflect BFP. Therefore, assessment of body composition provides a more comprehensive evaluation of nutritional status in children.[8] Evidence from Indian populations highlights age- and sex-related differences in fat mass and fat-free mass, with reference centile curves demonstrating variability in adiposity and lean tissue distribution.[9]

Dietary adequacy plays a central role in determining growth and tissue development during school age. Indian studies indicate that children often consume cereal-based diets with limited dietary diversity, leading to inadequate energy and essential micronutrients like calcium, iron, folate, and vitamin B12.[10,11]

Despite the availability of Indian growth standards and body composition reference data, limited research has examined growth, body composition and dietary adequacy simultaneously among school-aged children from lower socioeconomic backgrounds. Furthermore, there is limited evidence from peri-urban regions such as the Raigad district of Maharashtra.

Therefore, the present study aimed to assess growth patterns, body composition, and dietary adequacy among school-aged children (6-12 years) in Khopoli, Raigad district, Maharashtra, with a particular focus on lower SES. The study also explored the association between macronutrient intake and body composition parameters.

## METHODOLOGY

This school-based cross-sectional study was conducted among children aged 6-12 years enrolled in primary schools under the Nagar Palika cluster of Khopoli, Khalapur block, Raigad district, Maharashtra. A list of all primary schools under the Nagar Palika cluster was obtained, comprising a total of sixteen schools. From these, eight schools (50%) were selected using a random sampling method. However, permission was granted by only six schools and the study was conducted in these schools. Students from the selected schools were included based on predefined inclusion and exclusion criteria. The total enrolment of children aged 6-12 years in these six schools was 1,103. The inclusion criteria were regular school attendance (≥75%) and the absence of any known acute or chronic illness at the time of data collection. A total of 984 children met the eligibility criteria and provided complete data; these participants were included in the final analytical sample. The proper consent had been taken from the parents and verbal or written assent had taken from the children before the data collection

Sociodemographic information was collected from the parents during parent's teacher meeting in schools. The interview was taken by the investigator with the help of structured questionnaire. The questionnaire included details on age, sex, religion, family type, parental education and dietary habits. Information required for socioeconomic classification, including parental education, occupation, and monthly income of the primary earning member, was obtained primarily from parents using the updated Kuppuswamy Scale (2024)[12]. In addition, basic demographic information such as age, sex, and school-related details was cross-verified using school records maintained by teachers.

Body composition was assessed using a BIA device (InBody J30 pediatric analyzer)[13]. Similar InBody-based body composition assessment has been used in school-aged children and adolescents in previous study[14].The assessment provided measures including weight, height, BFM, FFM, SLM, SMM, BFP, TBW, BMI, Protein, Minerals. Standardized measurement protocols were followed to ensure accuracy. Participants were evaluated at least 2-3 hours after food intake and were instructed to avoid fluid consumption immediately prior to assessment. Children were asked to empty their bladder before measurement to reduce the influence of internal fluid variations. Measurements were conducted with participants barefoot and in light clothing to ensure optimal electrode contact and all external metal objects were removed to prevent interference with electrical conductivity. These standardized procedures were followed to minimize measurement variability and improve the reliability of body composition assessment.

BMI was calculated automatically by the Inbody J30 using the Quetlet formula weight in kg divided by height in meter square. BMI-for-age, Weight for age & Height for age values were compared against the Revised IAP Growth Charts for Height, Weight and BMI for 5-18-year-old Indian children (2015)[7].

MUAC was measured using UNICEF-standard, non-stretchable tapes following recommended procedures. Students with MUAC values below the 3rd percentile were classified as thin, representing undernutrition. Those between the 3rd and 95th percentiles were considered normal, reflecting healthy nutritional status. Students with MUAC values above the 95th percentile were classified as obese, indicating overnutrition. These reference percentiles were derived from studies that developed MUAC centiles specifically for assessing the nutritional status of Indian children[15].

Body-fat percentage (BFP) was interpreted using Indian reference percentile curves proposed by Chiplonkar SA et al. (2017) and adopted by the IAP. These reference centiles were developed using BIA measured with a Tanita body composition analyzer in Asian Indian children and adolescents. BFP values were classified as low fat (<3rd percentile), normal fat (3rd to <75th percentile), over-fat (75th to <85th percentile), and excess fat (≥85th percentile)[9].

Dietary intake was assessed using a 24-hour recall over three non-consecutive days (two weekdays and one weekend day) following a structured multiple-pass method. Recalls were conducted through face-to-face interviews by trained investigators using standardized probing techniques and portion size estimation with household measures. For younger children or when needed, information was supplemented through follow-up communication with parents and responses were cross-checked to improve accuracy.

The nutrient contribution of the MDM was estimated based on the actual quantity of food consumed by the children, using standard food composition values as per ICMR-NIN (2024) guidelines[16].

Dietary data were analyzed using DietCal software (version 13.0) and compared with age- and sex-specific EAR as per ICMR-NIN guidelines. The guidelines have recommended that fat should provide 25% of total energy so on the basis of that fat intake has been presented as percentage of EAR[17,18].

Data were analyzed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA)[19]. Descriptive statistics were used to summarize the data. Frequency and percentage were used to describe demographic variables. Continuous variables, including anthropometric measurements, body composition parameters, and nutrient intake, were expressed as mean ± standard deviation. Categorical variables such as nutritional status were expressed as frequencies and percentages. The association between BMI-for-age and body-fat percentage was assessed using the Fisher-Freeman-Halton test, as some expected cell frequencies were less than 5, making it more appropriate than the chi-square test[20]. Pearson's correlation was used to examine relationships between macronutrient intake and body composition parameters. A p-value <0.05 was considered statistically significant. No significant missing data were observed; only complete cases were included in the analysis.

Dietary intake assessed using a 24-hour recall may be subject to recall bias; however, a three-day recall (two weekdays & one weekend) with standardized interviewing and probing methods was used to minimize this. Body composition measurements were conducted by trained investigators following standardized procedures.

**Ethical considerations:**

The study was approved by the MGM Institute of Health Sciences Institutional Ethics Committee (Reg. No ECR/457/Inst/MH/ 2013/RR-20) dated 18/10/ 2023. Informed consent was obtained from parents or guardians.

## RESULTS

As shown in Table 1, the majority of children were aged 10-12 years. Girls constituted a higher proportion of the study population than boys. Most participants were enrolled in grades 4-7. The study population predominantly belonged to lower socioeconomic groups, with 59.0% classified as lower class and 41.0% as upper-lower class. All children enrolled in the selected schools were beneficiaries of the MDM programme and received the meal on school days.

**Table 1: Sociodemographic profile of the participants**

| Variables | Participants (%) |
|---|---|
| **Age** | |
| 6-9 years | 412(41.9) |
| 10-12 years | 572(58.1) |
| **Gender** | |
| Male | 413(42) |
| Female | 571(58) |
| **Standard** | |
| 1st - 3rd | 401(40.7) |
| 4th - 7th | 583(59.7) |
| **Food Habits** | |
| Vegetarian | 65(6.6) |
| Ovo-vegetarian | 12(1.2) |
| Non-vegetarian | 907(92.1) |
| **Family type** | |
| Joint | 484(49.1) |
| Nuclear | 500(50.8) |
| **Attendance** | |
| Regular | 984(100) |
| **Highest Level of Parents Education** | |
| Primary school | 200(20.3) |
| Secondary School | 784(79.6) |
| **Socio economic class** | |
| Upper lower | 403(41) |
| Lower | 581(59) |
| **Nutrient Supplementation** | 0 |
| **Family Medical History** | |
| Yes | 158(16) |
| No | 826(84) |
| **Menstrual Cycle** | |
| Yes | 33(5.7) |
| No | 538(94.2) |

**Table 2: Mean Anthropometric measurements and Body Composition of study participants (N=984)**

| Body Composition Variable | Boys 6 y (n=56) | Girls 6 y (n=74) | Boys 7-9 y (n=176) | Girls 7-9 y (n=236) | Boys 10-12 y (n=181) | Girls 10-12 y (n=261) |
|---|---|---|---|---|---|---|
| Height (cm) | 113.46 ± 5.56 | 112.09 ± 7.42 | 123.38 ± 6.10 | 123.17 ± 7.52 | 138.02 ± 9.05 | 139.43 ± 8.14 |
| Weight (kg) | 18.02 ± 3.39 | 17.31 ± 3.38 | 21.82 ± 4.08 | 22.30 ± 5.79 | 30.11 ± 7.73 | 32.09 ± 8.45 |
| BMI (kg/m2) | 13.90 ± 1.60 | 13.71 ± 1.22 | 14.24 ± 1.80 | 14.51 ± 2.18 | 15.60 ± 2.57 | 16.29 ± 3.02 |
| MUAC (cm) | 18.09 ± 3.27 | 18.01 ± 3.04 | 18.12 ± 2.78 | 18.20 ± 2.81 | 18.70 ± 2.73 | 18.30 ± 2.81 |
| BFP (%) | 15.71 ± 6.69 | 14.61 ± 5.47 | 13.77 ± 3.29 | 14.00 ± 5.36 | 14.76 ± 7.50 | 15.13 ± 9.72 |
| BFM (kg) | 2.98 ± 3.34 | 2.58 ± 1.23 | 3.16 ± 3.18 | 4.31 ± 4.14 | 4.84 ± 3.91 | 6.34 ± 5.09 |
| SLM (kg) | 14.19 ± 3.12 | 13.89 ± 2.50 | 17.62 ± 3.43 | 16.97 ± 3.54 | 23.81 ± 4.75 | 23.24 ± 4.46 |
| SMM (kg) | 6.84 ± 2.30 | 6.72 ± 1.58 | 9.17 ± 2.16 | 8.68 ± 2.92 | 12.97 ± 2.99 | 12.54 ± 2.92 |
| TBW (L) | 11.08 ± 2.32 | 10.82 ± 1.94 | 13.70 ± 2.73 | 13.22 ± 2.76 | 18.55 ± 3.70 | 18.13 ± 3.44 |
| Protein (kg) | 2.91 ± 0.77 | 2.87 ± 0.53 | 3.70 ± 0.72 | 3.54 ± 0.97 | 4.96 ± 0.99 | 4.82 ± 0.97 |
| Mineral (kg) | 1.03 ± 0.31 | 1.02 ± 0.22 | 1.26 ± 0.38 | 1.24 ± 1.07 | 1.76 ± 0.35 | 1.80 ± 0.35 |

All values in mend ± SD

BMI-Body Mass Index; MUAC-Mid-Upper Arm Circumference; BFP-Body Fat Percentage; BFM-Body Fat Mass; SLM-Soft Lean Mass; SMM-Skeletal Muscle Mass; TBW-Total Body Water

**Table 3: Nutritional Status of School-aged Children on the basis of Body Mass Index for age (N=984)**

| Nutritional Status | Boys (%) (n=413) | Girls (%) (n=571) | Total (%) (N=984) |
|---|---|---|---|
| **Body Mass Index for age** | | | |
| Normal | 340 (82.3) | 463 (81.1) | 803 (81.6) |
| Overweight | 17 (4.1) | 52 (9.1) | 69 (7.0) |
| Obese | 15 (3.6) | 12 (2.1) | 27 (2.7) |
| Underweight | 26 (6.3) | 33 (5.8) | 59 (6.0) |
| Severe underweight | 15 (3.6) | 11 (1.9) | 26 (2.6) |
| **Weight for age** | | | |
| Normal | 369 (89.4) | 500 (87.5) | 869 (88.3) |
| Underweight | 37 (8.9) | 67 (11.8) | 104 (10.6) |
| Severely underweight | 7 (1.7) | 4 (0.7) | 11 (1.1) |
| **Height for age** | | | |
| Normal | 373 (90.3) | 520 (91.1) | 893 (90.8) |
| Stunted | 37 (9.0) | 44 (7.7) | 81 (8.2) |
| Severely stunted | 3 (0.7) | 7 (1.2) | 10 (1.0) |
| **Mid-Upper Arm Circumference*** | | | |
| Thinness | 20 (4.8) | 27 (4.7) | 47 (4.8) |
| Normal | 378 (91.5) | 516 (90.4) | 894 (90.9) |
| Obesity | 15 (3.6) | 29 (5.1) | 44 (4.5) |
| **Body Fat Percentage (BFP)#** | | | |
| Low | 0 (0.0) | 17 (3.0) | 17 (1.7) |
| Normal | 357 (86.4) | 452 (79.1) | 809 (82.2) |
| Over | 3 (0.7) | 3 (0.5) | 6 (0.6) |
| Excess | 53 (12.8) | 99 (17.3) | 152(15.4) |

*Mid-Upper Arm Circumference. Classification based on Khadilkar et al. (2021) reference percentiles: Thinness = below 3rd percentile; Normal = 3rd-95th percentile; Obesity = above 95th percentile[15].

#BFP: Body Fat Percentage, Low <3rd, Normal 3rd-<75th, Over 75th-<85th, Excess ≥85th percentile[9].

**Table 4: Distribution of BFP Across BMI Categories Among School-aged Children (N = 984)**

| BMI (N=984) | BFP n(%) | | | | Total | Fisher -Freeman-Halton Test | P value |
|---|---|---|---|---|---|---|---|
| | Low | Normal | Over | Excess | | | |
| Normal | 8 (1) | 726 (90.3) | 5(0.6) | 65(8.1) | 804 (81.7) | 481.4 | 0.000** |
| Overweight | 0 (0) | 7 (10.1) | 1 (1.4) | 61 (88.4) | 69 (7) | | |
| Obese | 0 (0) | 3 (11.1) | 0 (0.0) | 24 (88.9) | 27 (2.7) | | |
| Underweight | 6 (10.3) | 51(87.9) | 0 (0) | 1(1.7) | 58 (5.8) | | |
| Severe underweight | 3(11.5) | 22 (84.6) | 0(0) | 1(3.8) | 26(2.6) | | |
| Total | 17(1.7) | 809(82.2) | 6(0.6) | 152(15.4) | 984(100) | | |

$p < 0.05$* considered significant; $p < 0.01$** highly significant.; Values are presented as n (percentage).;

BMI-Body Mass Index, BFP-Body Fat Percentage

Mean anthropometric and body composition variables are presented in Table 2. Height, weight, BMI, MUAC, BFM, BFP, SMM, SLM, protein, TBW, and mineral content increased with age in both boys and girls, while BFP showed minimal variation.

Assessment of nutritional status indicated that most school-aged children were within the normal range across parameters, as shown in Tables 3. Based on BMI-for-age, most children were classified as normal, with fewer classified as undernourished or over nourished. Height-for-age and weight-for-age findings also showed that most children were within the normal range, although stunting and underweight were observed in some participants.

**Table 5: Nutrient Adequacy in Boys (n=413) and Girls (n=571) Aged 6-12 Years**

| Nutrients | EAR | Boy (Mean ± SD (% EAR)) | Adequacy | EAR | Girl (Mean ± SD (% EAR)) | Adequacy |
|---|---|---|---|---|---|---|
| **6 year** | | **(n=56)** | | | **(n=74)** | |
| Energy (kcal) | 1360 | 961.1 ± 87.1 (70.7%) | Inadequate | 1360 | 960.2 ± 82.3 (70.6%) | Inadequate |
| Protein (g) | 13 | 14.0 ± 2.8 (107.7%) | Adequate | 13 | 14.8 ± 2.5 (113.0%) | Adequate |
| Total Fat (g)* | 37.8 | 19.3 ± 10.2 (51.1%) | Inadequate | 37.78 | 15.4 ± 8.6 (40.8%) | Inadequate |
| Iron (mg) | 8 | 4.4 ± 2.1 (55.0%) | Inadequate | 8 | 4.8 ± 2.5 (59.9%) | Inadequate |
| Calcium (mg) | 450 | 254.4 ± 123.3 (56.5%) | Inadequate | 450 | 226.5 ± 125.0 (50.3%) | Inadequate |
| Folate (µg) | 111 | 64.3 ± 36.6 (57.9%) | Inadequate | 111 | 61.2 ± 36.8 (43.1%) | Inadequate |
| Vit B12 (µg) | 2 | 0.9 ± 0.5 (45.0%) | Inadequate | 2 | 0.8 ± 0.4 (37.9%) | Inadequate |
| **7-9 years** | | **(n=176)** | | | **(n=236)** | |
| Energy (kcal) | 1700 | 1036.5 ± 152.6 (61.0%) | Inadequate | 1700 | 1036.3 ± 149.9 (61.0%) | Inadequate |
| Protein (g) | 19 | 18.5 ± 1.3 (97.4%) | Inadequate | 19 | 17.9 ± 1.3 (94.2%) | Inadequate |
| Total Fat (g)* | 47.2 | 18.2 ± 11.4 (38.5%) | Inadequate | 47.22 | 18.3 ± 9.7 (38.8%) | Inadequate |
| Iron (mg) | 10 | 4.9 ± 2.6 (49.0%) | Inadequate | 10 | 5.1 ± 2.8 (51.3%) | Inadequate |
| Calcium (mg) | 500 | 236.5 ± 134.1 (47.3%) | Inadequate | 500 | 226.9 ± 136.3 (45.4%) | Inadequate |
| Folate (µg) | 142 | 67.8 ± 39.2 (47.7%) | Inadequate | 142 | 67.1 ± 36.2 (47.3%) | Inadequate |
| Vit B12 (µg) | 2 | 0.8 ± 0.4 (40.0%) | Inadequate | 2 | 0.8 ± 0.5 (42.0%) | Inadequate |
| **10-12 years** | | **(n=181)** | | | **(n=261)** | |
| Energy (kcal) | 2220 | 1250.6 ± 160.7 (56.3%) | Inadequate | 2060 | 1223.2 ± 96.8 (59.4%) | Inadequate |
| Protein (g) | 26 | 23.0 ± 1.9 (88.5%) | Inadequate | 27 | 23.2 ± 1.8 (85.1%) | Inadequate |
| Total Fat (g)* | 61.7 | 23.8 ± 13.9 (38.6%) | Inadequate | 57.22 | 22.9 ± 13.0 (40.0%) | Inadequate |
| Iron (mg) | 12 | 7.7 ± 3.8 (64.2%) | Inadequate | 16 | 9.8 ± 5.5 (61.3%) | Inadequate |
| Calcium (mg) | 650 | 309.5 ± 170.9 (47.6%) | Inadequate | 650 | 301.7 ± 172.3 (46.4%) | Inadequate |
| Folate (µg) | 180 | 86.6 ± 44.8 (48.1%) | Inadequate | 186 | 86.9 ± 45.3 (46.7%) | Inadequate |
| Vit B12 (µg) | 2 | 0.9 ± 0.4 (45.0%) | Inadequate | 2 | 0.8 ± 0.5 (41.7%) | Inadequate |

"Values are based on Indian Council of Medical Research-National Institute of Nutrition (ICMR-NIN), 2024. Recommended Dietary Allowances for Indians".
*Fat values were derived as 25% of recommended energy intake as per ICMR-NIN (2024).
EAR -Estimated Average Requirement

**Table 6: Nutrient intake through MDM Primary and Upper Primary classes school children (N=984)**

| Nutrient | Primary (6-9 years, n=412) Mean ± SD | Percent intake of nutrient through MDM | Upper Primary (10-12 years, n=572) Mean ± SD | Percent intake of nutrient through MDM |
|---|---|---|---|---|
| Energy (kcal) | 294.49 ± 10.82 | 29.0% | 384.59 ± 8.73 | 31.0% |
| Carbohydrate (g) | 44.27 ± 5.88 | 44.3% | 61.55 ± 7.09 | 48.5% |
| Protein (g) | 7.83 ± 0.74 | 48% | 11.35 ± 3.86 | 49% |
| Fat (g) | 7.77 ± 2.10 | 43.6% | 9.02 ± 2.64 | 41.0% |
| Iron (mg) | 2.5 ±0.5 | 52.1% | 3.0 ± 0.8 | 34.0% |
| Calcium (mg) | 96.12 ± 25.29 | 40.7% | 115.19 ± 35.14 | 37.0% |
| Folate (µg) | 19.44 ± 3.89 | 29.9% | 24.82 ± 19.58 | 29.0% |
| Vitamin B12 (µg) | 0.02 ± 0.02 | 2.4% | 0.03 ± 0.02 | 3.5% |

MDM: Mid-Day Meal

**Table 7: Frequency of Food Group Consumption among School-aged Children (6-12 years)**

| Food groups | Frequency (%) | | | | | |
|---|---|---|---|---|---|---|
| | Daily | 2-4 times/week | Once/week | Twice/week | Once/month | Never |
| Cereals & millets | 85.4 | 7.6 | 3.8 | 1.9 | 0.9 | 0 |
| Pulses | 96.5 | 3.5 | 0 | 0 | 0 | 0 |
| Nuts & oilseeds | 6.8 | 18.4 | 14.7 | 9.3 | 16.2 | 34.6 |
| Milk & milk products | 32.5 | 28.7 | 17.6 | 9.8 | 5.4 | 6 |
| Meat, poultry, fish & eggs | 5.2 | 34.8 | 26.9 | 18.6 | 8.1 | 6.4 |
| Green leafy vegetable | 12.4 | 32.6 | 25.8 | 16.9 | 6.3 | 6 |
| Other vegetable | 54.7 | 21.9 | 13.6 | 6.8 | 1.7 | 1.3 |
| Roots & tubers | 36.9 | 29.4 | 15.7 | 8.6 | 4.2 | 5.2 |
| Fruits | 11.6 | 19.8 | 31.4 | 21.3 | 8.9 | 7 |
| Beverages | 45.3 | 27.6 | 14.1 | 7.2 | 2.9 | 2.9 |
| Bakery food items | 24.8 | 28.3 | 21.6 | 9.7 | 7.4 | 8.2 |
| Packed food items | 5.6 | 21.4 | 38.9 | 19.6 | 9.1 | 5.4 |
| Fats / oils | 95.6 | 3.1 | 0.8 | 0.3 | 0.2 | 0 |
| Sugar & jaggery | 82.7 | 11.4 | 5.1 | 0 | 0 | 0.8 |

MUAC findings showed similar trends, with most children classified as normal and a small number identified as thin or obese. In terms of body composition, most children had body fat within the normal range; however, 158 children (16%) were classified as having elevated body fat.

**Table 8: Correlation between Macronutrient Intake and Body Composition (N = 984)**

| Body Composition Variable | Energy (kcal) r value (p-value) | Protein (g) r value (p-value) | Fat (g) r value (p-value) | Carbohydrate (g) r value (p-value) |
|---|---|---|---|---|
| BFP (%) | -0.045 (0.16) | -0.001 (0.98) | -0.021 (0.51) | -0.051 (0.11) |
| BFM (kg) | -0.036 (0.26) | -0.001 (0.97) | 0.054 (0.09) | -0.040 (0.20) |
| SLM (kg) | 0.052 (0.10) | 0.005 (0.87) | -0.008 (0.80) | 0.029 (0.36) |
| SMM (kg) | 0.052 (0.10) | 0.001 (0.97) | 0.003 (0.92) | 0.016 (0.62) |

**Table 9: Agewise Correlation between macronutrient intake and body composition parameters among (6-12 years) (boys =413) and girls = 571)**

| Nutrient | Boys | | | | Girls | | | |
|---|---|---|---|---|---|---|---|---|
| | BFP r (p) | BFM r (p) | SLM r (p) | SMM r (p) | BFP r (p) | BFM r (p) | SLM r (p) | SMM r (p) |
| **Age 6 years** | | | | | | | | |
| Energy (kcal) | -0.10 (0.63) | -0.19 (0.35) | -0.18 (0.36) | -0.26 (0.20) | -0.07 (0.67) | -0.08 (0.59) | -0.09 (0.55) | -0.11 (0.50) |
| Protein (g) | -0.07 (0.74) | -0.12 (0.57) | -0.10 (0.61) | -0.17 (0.41) | -0.02 (0.90) | -0.03 (0.82) | -0.04 (0.79) | -0.06 (0.72) |
| Fat (g) | **0.32 (0.02)*** | -0.19 (0.34) | -0.20 (0.32) | -0.27 (0.17) | -0.02 (0.89) | -0.04 (0.80) | -0.05 (0.76) | -0.06 (0.70) |
| Carbohydrate (g) | -0.33 (0.10) | -0.34 (0.09) | -0.34 (0.08) | 0.09 (0.41) | -0.25 (0.10) | -0.26 (0.08) | -0.27 (0.07) | -0.29 (0.06) |
| **Age 7 years** | | | | | | | | |
| Energy (kcal) | 0.00 (0.99) | -0.02 (0.86) | -0.03 (0.82) | -0.05 (0.74) | 0.03 (0.84) | 0.02 (0.90) | 0.01 (0.94) | 0.00 (0.99) |
| Protein (g) | 0.10 (0.48) | 0.08 (0.56) | 0.06 (0.65) | 0.04 (0.77) | -0.17 (0.20) | -0.16 (0.24) | -0.14 (0.28) | -0.13 (0.34) |
| Fat (g) | 0.05 (0.91) | 0.09 (0.07) | 0.08 (0.34) | 0.08 (0.42) | -0.09 (0.48) | -0.08 (0.54) | -0.07 (0.59) | -0.06 (0.65) |
| Carbohydrate (g) | 0.03 (0.81) | 0.02 (0.88) | 0.01 (0.93) | 0.00 (0.97) | -0.01 (0.95) | -0.02 (0.91) | -0.02 (0.88) | -0.03 (0.84) |
| **Age 8 years** | | | | | | | | |
| Energy (kcal) | -0.04 (0.73) | -0.05 (0.66) | -0.06 (0.59) | -0.07 (0.53) | -0.02 (0.86) | -0.03 (0.80) | -0.03 (0.74) | -0.04 (0.69) |
| Protein (g) | 0.05 (0.14) | 0.22 (0.06) | 0.21 (0.08) | 0.20 (0.10) | 0.16 (0.12) | 0.15 (0.16) | 0.13 (0.20) | 0.12 (0.26) |
| Fat (g) | 0.01 (0.95) | 0.01 (0.92) | 0.02 (0.88) | 0.03 (0.84) | 0.01 (0.52) | -0.19 (0.06) | -0.18 (0.07) | -0.17 (0.10) |
| Carbohydrate (g) | 0.02 (0.81) | 0.03 (0.50) | 0.22 (0.07) | 0.21 (0.08) | -0.05 (0.62) | -0.06 (0.56) | -0.07 (0.50) | -0.08 (0.45) |
| **Age 9 years** | | | | | | | | |
| Energy (kcal) | -0.02 (0.88) | -0.03 (0.83) | -0.04 (0.79) | -0.05 (0.74) | 0.12 (0.30) | 0.11 (0.34) | 0.10 (0.39) | 0.09 (0.45) |
| Protein (g) | -0.09 (0.52) | -0.09 (0.56) | -0.08 (0.59) | -0.07 (0.63) | -0.02 (0.86) | -0.03 (0.79) | -0.04 (0.72) | -0.05 (0.66) |
| Fat (g) | -0.13 (0.36) | -0.12 (0.40) | -0.11 (0.43) | -0.10 (0.50) | 0.09 (0.31) | 0.23 (0.05) | 0.22 (0.07) | 0.20 (0.09) |
| Carbohydrate (g) | 0.09 (0.53) | 0.08 (0.57) | 0.07 (0.60) | 0.06 (0.67) | -0.15 (0.20) | -0.14 (0.25) | -0.13 (0.29) | -0.11 (0.34) |
| **Age 10 years** | | | | | | | | |
| Energy (kcal) | -0.06 (0.61) | -0.07 (0.56) | -0.08 (0.52) | -0.08 (0.49) | -0.06 (0.58) | -0.06 (0.53) | -0.07 (0.48) | -0.08 (0.44) |
| Protein (g) | 0.08 (0.53) | 0.07 (0.58) | 0.06 (0.61) | 0.05 (0.66) | -0.06 (0.56) | -0.05 (0.60) | -0.05 (0.64) | -0.04 (0.69) |
| Fat (g) | -0.06 (0.64) | -0.05 (0.69) | -0.04 (0.73) | -0.04 (0.77) | -0.03 (0.77) | -0.02 (0.81) | -0.02 (0.86) | -0.01 (0.91) |
| Carbohydrate (g) | -0.19 (0.12) | -0.18 (0.13) | -0.17 (0.16) | -0.16 (0.19) | -0.01 (0.90) | -0.02 (0.84) | -0.03 (0.78) | -0.03 (0.74) |
| **Age 11 years** | | | | | | | | |
| Energy (kcal) | 0.04 (0.72) | 0.05 (0.67) | 0.06 (0.62) | 0.07 (0.58) | 0.02 (0.83) | 0.03 (0.78) | 0.04 (0.73) | 0.05 (0.69) |
| Protein (g) | -0.05 (0.69) | -0.04 (0.74) | -0.04 (0.77) | -0.03 (0.82) | -0.03 (0.78) | -0.02 (0.83) | -0.02 (0.89) | -0.01 (0.93) |
| Fat (g) | 0.03 (0.79) | 0.03 (0.82) | 0.02 (0.86) | 0.02 (0.90) | 0.03 (0.76) | 0.03 (0.81) | 0.02 (0.86) | 0.01 (0.90) |
| Carbohydrate (g) | -0.09 (0.48) | -0.08 (0.52) | -0.07 (0.56) | -0.06 (0.61) | 0.06 (0.58) | 0.05 (0.63) | 0.05 (0.68) | 0.04 (0.73) |
| **Age 12 years** | | | | | | | | |
| Energy (kcal) | -0.02 (0.89) | -0.02 (0.85) | -0.03 (0.81) | -0.03 (0.77) | -0.03 (0.72) | -0.04 (0.67) | -0.05 (0.62) | -0.05 (0.59) |
| Protein (g) | -0.04 (0.72) | -0.04 (0.77) | -0.03 (0.81) | -0.02 (0.85) | 0.15 (0.10) | 0.14 (0.14) | 0.13 (0.18) | 0.12 (0.22) |
| Fat (g) | 0.03 (0.77) | 0.03 (0.81) | 0.02 (0.85) | 0.02 (0.89) | -0.03 (0.77) | -0.02 (0.83) | -0.01 (0.88) | -0.01 (0.93) |
| Carbohydrate (g) | 0.03 (0.77) | 0.03 (0.81) | 0.02 (0.84) | 0.02 (0.88) | -0.01 (0.89) | -0.02 (0.48) | -0.03 (0.80) | -0.03 (0.75) |

p <0.05* considered significant; p <0.01** highly significant.

A significant association was observed between BMI-for-age and BFP, as shown in Table 4, with 70 children (8.7%) out of 804 identified as having elevated body fat within the normal BMI-for-age category. Among children aged 6-12 years, mean daily energy intake ranged from approximately 960 kcal in younger children to 1,250 kcal in older children, which was below the EAR for both boys and girls. Protein intake met or was close to the EAR, whereas fat intake remained below recommended levels across all age groups.

Micronutrient intake was below the EAR for iron, calcium, folate, and vitamin B12 in both boys and girls, as presented in Tables 5.

Table 6 shows the nutrient intake through MDM among primary and upper primary school children. The MDM contributed 29.0% and 48.0% of total daily energy and protein intake, respectively, among primary school children, and 31.0% and 49.0%, respectively, among upper primary children. The MDM contributed moderate amounts of iron and calcium, whereas the contribution of folate was comparatively lower. Vitamin B12 contribution from the MDM was minimal in both age groups.

Food group consumption patterns showed that cereals and pulses were consumed daily by most children, whereas daily intake of milk and milk products, green leafy vegetables, fruits, and nuts and oilseeds was low. Intake of animal-source foods was also low

on a daily basis and more commonly reported on a weekly basis. Fats/oils and sugar/jaggery were consumed daily by most children, as shown in Table 7.

Pearson's correlation analysis showed weak and non-significant associations between macronutrient intake (energy, protein, fat, and carbohydrate) and body composition parameters in the overall sample (r ranging from −0.05 to +0.05; $p > 0.05$), as presented in Table 8.

Age- and sex-specific analysis showed a significant positive correlation between dietary fat intake and percent body fat in boys aged 6 years ($r = 0.32$, $p < 0.02$). No significant associations were observed in other age groups of boys or among girls, with correlations remaining weak and non-significant, as shown in Tables 9.

## Discussion

The present study provides evidence on anthropometric status, body composition, and dietary intake among school-aged children in Raigad district, Maharashtra. Age-related increases in height, weight, fat-free mass, and skeletal muscle mass were observed, reflecting expected growth patterns during middle childhood. Boys demonstrated higher lean mass, whereas girls had relatively higher BFP, consistent with sex-specific differences reported among Indian children.[21,22]

An important finding was the discordance between BMI-for-age and BFP, wherein a subset of children classified as normal by BMI exhibited elevated body fat. This indicates that BMI alone may not adequately capture adiposity, as it does not distinguish between fat mass and lean mass. Evidence from Indian populations reporting higher body fat at lower BMI levels further supports the need for complementary measures in nutritional assessment.[9,20]

The coexistence of undernutrition and elevated body fat observed in the study population reflects the dual burden of malnutrition. Similar patterns have been reported among Indian children.[22,23] This is supported by national data from the Comprehensive National Nutrition Survey (CNNS) indicating the presence of multiple forms of nutritional imbalance within the same population.[3,24]

Dietary assessment revealed inadequate intake of energy, fat and key micronutrients, including calcium, iron, folate and vitamin B12, while protein intake was generally adequate. The MDM contributed nearly one-third of total daily energy intake and about half of total protein intake among school children. It also contributed a moderate proportion of daily iron and calcium intake, whereas the contribution of folate was comparatively lower. Vitamin B12 contribution from the MDM was minimal in both age groups.

The overall inadequacy of energy and micronutrient intake observed in the present study is consistent with findings from the Comprehensive National Nutrition Survey (CNNS), which reported inadequate intake of several micronutrients among Indian children and adolescents[3]. Similar inadequacies in dietary intake and micronutrient deficiencies among school-aged children have also been reported in Indian studies.[25,26]

Nutritional transition and changing dietary patterns contributing to dietary imbalance in children have additionally been described in previous literature.[4] The observed food consumption pattern, characterized by a cereal-dominant diet with limited intake of milk, fruits, vegetables and animal-source foods, further supports this finding. Previous Indian studies have also reported low dietary diversity, inadequate intake of nutrient-rich food groups, and cereal-based dietary patterns among school-aged children.[10,11]

Correlation analysis demonstrated weak associations between macronutrient intake and body composition parameters, suggesting that short-term dietary intake may not directly influence body composition outcomes. However, a positive association between dietary fat intake and BFP was observed among younger boys, indicating possible age-specific sensitivity to dietary factors during early childhood.

Future research should focus on longitudinal studies to better understand causal relationships between dietary intake, growth, and body composition in children. Inclusion of physical activity and physical fitness assessment would provide a more comprehensive understanding of factors influencing body composition. Additionally, intervention-based studies targeting micronutrient deficiencies are warranted to improve nutritional outcomes among school-aged children.

## Limitations

A formal a priori sample size calculation was not performed; instead, a cluster census approach was adopted by enrolling all eligible children from randomly selected schools, which may have limited the precision of prevalence estimates. The cross-sectional design of the study restricts the ability to establish causal relationships between dietary intake and body composition outcomes. Dietary intake assessment based on a 24-hour recall over three days is subject to recall bias and may not accurately represent usual intake because of day-to-day variability. Body composition was assessed using a single bioelectrical impedance analysis (BIA) measurement, which may have been influenced by factors such as hydration status; furthermore, although validation studies exist for similar BIA devices, limited validation data for the InBody J30 model in the Indian pediatric population may affect the accuracy and generalizability of the measurements. The study was conducted among children from Nagar Palika cluster schools in Khopoli, representing a lower socioeco-

nomic population, thereby limiting the generalizability of the findings to populations with different socioeconomic or geographic backgrounds. In addition, physical activity and other lifestyle factors that could influence body composition and nutritional status were not assessed. The food group consumption data were also presented only for the overall study population without stratification by sex or socioeconomic status, which may have restricted the identification of subgroup-specific dietary patterns.

## Conclusion

The findings indicate the presence of both undernutrition and excess adiposity among school-aged children, reflecting a dual burden of malnutrition during middle childhood. This highlights that different forms of nutritional imbalance can coexist within the same population. The findings also support the use of body-composition assessment for better understanding of growth patterns in school-aged children, as dietary patterns influence body composition.

Dietary assessment and food-frequency patterns indicated poor diet quality, characterized by inadequate intake of several nutrients and low consumption of nutritionally important food groups among school-aged children. Therefore, effective nutrition interventions are recommended to improve their nutritional status. Future research should focus on longitudinal studies to better understand causal relationships, include assessment of physical activity, and explore intervention-based strategies to address micronutrient deficiencies.

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**Availability of Data:** The data supporting the findings of this study are available from the corresponding author upon reasonable request.

**Declaration of Non-use of Generative AI Tools:** This article was prepared without the use of generative AI tools for content creation, analysis, or data generation. All findings and interpretations are based solely on the authors' independent work and expertise.

**List of abbreviations:** BMI (Body Mass Index), MUAC (Mid-Upper Arm Circumference), BFP (Body Fat Percentage), BFM (Body Fat Mass), SLM (Soft Lean Mass), SMM (Skeletal Muscle Mass), TBW (Total Body Water), BIA (Bioelectrical Impedance Analysis), EAR (Estimated Average Requirement), ICMR-NIN (Indian Council of Medical Research - National Institute of Nutrition), IAP (Indian Academy of Pediatrics), SES (Socioeconomic Status), SPSS (Statistical Package for the Social Sciences), MDM (Mid-Day Meal).

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