

Dietary Diversity and Anthropometric Shifts in School-Going Adolescents: A Pre-Post Intervention Study in Urban India

Danika Manocha^{1*}; Priya Singla²

¹Research Scholar, Faculty of Engineering and Applied Sciences, Desh Bhagat University, Mandi Gobindgarh, Punjab, India

²Assistant Professor, Faculty of Engineering and Applied Sciences, Desh Bhagat University, Mandi Gobindgarh, Punjab, India

*Corresponding Author

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Abstract—

Background: Indian adolescents face a severe dual burden of malnutrition driven by poor dietary choices. This study evaluated changes in Individual Dietary Diversity Scores (IDDS) and anthropometric measurements following a six-month structured, school-based nutritional counselling intervention among 400 urban school-going adolescents (200 boys and 200 girls; aged 12–16 years) selected via purposive sampling from two schools in Gurgaon, Haryana, India.

Methods: Anthropometric measurements and 24-hour dietary recalls, stratified using the 9-group Individual Dietary Diversity Score (IDDS) (Food and Agriculture Organisation) framework, were assessed pre- and post-intervention. The six-month intervention comprised interactive sessions on balanced nutrition, recommended dietary allowances, healthy cooking methods, food hygiene, and healthy snack alternatives.

Results: Post-intervention data revealed significant ($p < 0.001$) improvements in anthropometric parameters and dietary optimization. Underweight prevalence declined from 41% to 18% in boys and from 54% to 38% in girls, with corresponding shifts into the normal-weight category while overweight and obesity rates remained stable. Mean IDDS improved for boys (4.12 to 4.78) and girls (3.54 to 4.59), driven by increased consumption of micronutrient-dense greens, vitamin A-rich produce, and quality proteins. Comparative analysis demonstrated that for boys, overall dietary diversity maintained a significant ($p < 0.05$) positive correlation with linear growth and healthy mass accumulation. Conversely, girls' anthropometric changes were associated with specific food groups rather than overall scores; notably, regular intake of milk and milk products showed a negative correlation with BMI ($p < 0.001$), suggesting a potential stabilizing effect against excessive adiposity.

Conclusions: Structured school-based nutritional education was associated with enhanced dietary diversity and positive anthropometric changes in this cohort. The findings highlight distinct gender-specific nutritional responses and suggest that school-based interventions may offer a promising strategy to address adolescent malnutrition.

Keywords— dietary diversity, anthropometric measurements, adolescents, nutrition education.

I. INTRODUCTION

Indian adolescents face a double burden of malnutrition on a national scale, characterized by high rates of undernutrition alongside emerging overnutrition. The Comprehensive National Nutrition Survey indicated that stunting and thinness affected 27% and 24% of adolescents, respectively, while overweight and obesity rates stood at 5% and 1%. Nutritional disparities are heavily driven by socio-demographic factors (income, education, and location), with older adolescents facing higher odds of stunting and urban, younger demographics showing increased vulnerability to overweight (Pandurangi et al., 2022).

The anthropometric dual burden is accompanied by a widespread crisis of micronutrient deficiencies and escalating metabolic risks, driven largely by poor dietary diversity. Nationally, half of all adolescents suffered from anaemia, impacting 40% of girls and 18% of boys. Furthermore, metabolic markers indicated early risks for non-communicable diseases, with 50% of

adolescents presenting with at least one cardiovascular and metabolic risk factor, including hypertension, low high-density lipoprotein cholesterol (HDL) (affecting roughly 25% to 39% of various demographic groups), or elevated haemoglobin A1c (HbA1c) levels, which put up to 20% of older adolescents at risk for diabetes (Comprehensive National Nutrition Survey [CNNS], 2019).

Dietary diversity acts as a crucial qualitative indicator of both household food access and individual nutrient adequacy. An increasing reliance on low-quality foods and a lack of dietary diversity directly mirror physiological risks. Alarming, fewer than 20% of adolescents consumed pulses and green leafy vegetables, and less than 10% consumed fruits daily. The dietary shift from healthy to low-nutrient items is further reflected in data showing that ultra-processed foods contribute over 16% of total daily energy intake (371 kcal) (CNNS, 2019; Jain & Mathur, 2020). Consequently, replacing nutrient-void options with wholesome, low-fat, low-sodium, and low-sugar snacks is essential to safely meet the heightened micronutrient and energy demands of the developmental phase (Dietary Guidelines for Indians, 2024; Hu, 2002; Kennedy et al., 2010).

Expanding dietary diversity is a critical factor for metabolic health; low dietary diversity scores are positively associated with a higher prevalence of obesity. To bridge this gap, structured nutritional counselling and education serve as vital interventions. Targeted nutrition education has been shown to substantially enhance nutritional knowledge and directly translate into higher dietary diversity among adolescents. Notably, the benefits of educational strategies extend beyond dietary practices, showing a strong positive correlation with improved academic performance (Idrees et al., 2024; Sumiati et al., 2024; Yazew et al., 2024).

This study analyzed changes in dietary diversity scores and anthropometric measurements among Indian adolescents from two schools in Gurgaon, and evaluated the relationship between these parameters from baseline to post-intervention following a structured nutritional counselling program.

II. MATERIALS AND METHODS

2.1 Study Design and Participants

A pre-post intervention study was conducted with a total sample of 400 adolescents (200 boys and 200 girls; aged 12–16 years) chosen from two selected schools in Gurgaon, Haryana, India, using purposive sampling.

2.2 Data Collection Procedures

- **Anthropometric Measurements:** Height (cm) and weight (kg) were measured at baseline and post-intervention using standardized procedures. Body Mass Index (kg/m^2) was calculated using the standard formula (weight in kilograms divided by height in meters squared). Measurements were compared with age- and sex-specific reference standards (IAP, 2015; ICMR, 2024).
- **Dietary Assessment:** The foods consumed by participants were categorized across nine standardized groups using the FAO Individual Dietary Diversity Score (IDDS) framework. Assessment was conducted via 24-hour dietary recalls at baseline and post-intervention. Dietary diversity scores were stratified into Low (0–3 groups), Medium (4–5 groups), and High (6–9 groups) diversity tiers.

2.3 Intervention

Participants underwent a six-month nutrition educational intervention consisting of interactive sessions. Session content included:

- Balanced diet principles and recommended dietary allowances (RDA) for adolescents
- Healthy cooking methods and food hygiene practices
- Identification and selection of nutrient-dense foods
- Smart snack alternatives to replace junk food

2.4 Outcome Measures

Primary outcomes included changes in:

- 1) Anthropometric parameters (height, weight, BMI)

- 2) Individual Dietary Diversity Scores (IDDS)
- 3) Relationship between dietary diversity and anthropometric parameters

2.5 Statistical Analysis

Data were analyzed using IBM SPSS Statistics (Version [31.0.2.0]). Continuous variables were expressed as mean \pm standard deviation (SD), and categorical variables as frequencies and percentages. Pre- and post-intervention changes were evaluated using paired t-tests for continuous variables. Relationships between IDDS and anthropometric measurements were assessed using Pearson correlation coefficients (r).

III. RESULTS AND DISCUSSION

3.1 Anthropometric Measurements of Participants

Table 1 reports the average changes in height, weight, and Body Mass Index (BMI) from baseline to post-intervention. The nutrition education program was associated with positive changes in physical development parameters for both boys and girls.

- **Height:** Average height increased by 1.03% for boys (166.31 to 168.02 cm) and 0.4% for girls (156.94 to 157.58 cm). These changes were statistically significant for both groups ($p < 0.001$) and fell within the expected range based on reference standards (IAP, 2015; ICMR, 2024).
- **Weight:** Average weight increased from 56.11 to 57.80 kg for boys (3.01% increase) and from 47.16 to 47.89 kg for girls (1.55% increase). Both changes were statistically significant ($p < 0.001$).
- **BMI:** Boys showed a statistically significant increase in BMI ($p < 0.05$; 1.05%), moving from 20.09 ± 4.06 kg/m² to 20.30 ± 3.50 kg/m². Girls showed a slight increase in BMI from 19.25 ± 4.45 kg/m² to 19.34 ± 3.69 kg/m² (0.47%), which was not statistically significant ($p > 0.05$). The non-significant change in girls' BMI reflects simultaneous height and weight increases maintaining the weight-to-height ratio.

These developmental trends are consistent with findings from urban Delhi involving boys and girls aged 11–17 years, which similarly observed that girls maintained higher BMI values between 14 and 16 years of age, prior to an acceleration in boys during later adolescence (Mani et al., 2022). This comparative regional data reinforces the distinct, gender-segregated growth trajectories seen during crucial pubertal years.

TABLE 1
EFFECT OF COUNSELLING ON ANTHROPOMETRIC MEASUREMENTS OF BOYS AND GIRLS (12-16 YEARS)

Particulars	Boys (n=200)		Girls (n=200)	
	Pre-counselling	Post-counselling	Pre-counselling	Post-counselling
Height (cm)	166.31 \pm 10.30	168.02 \pm 10.29	156.94 \pm 11.76	157.58 \pm 11.73
Height Std.	149-170 cm		150-157 cm	
t-value	32.512** (1.03%)		21.309** (0.4%)	
Weight (kg)	56.11 \pm 14.60	57.80 \pm 13.47	47.16 \pm 11.18	47.89 \pm 10.04
Weight Std.	39-59 kg		40-52 kg	
t-value	6.823** (3.01%)		3.471** (1.55%)	
BMI (kg/m²)	20.09 \pm 4.06	20.30 \pm 3.50	19.25 \pm 4.45	19.34 \pm 3.69
t-value	2.196* (1.05%)		0.927 (ns) (0.47%)	

Values in () indicate % change.

*(ns) = Not Significant ($p > 0.05$); * $p < 0.05$; ** $p < 0.001$*

(IAP, 2015; ICMR, 2024)

3.2 Adolescents' Distribution by BMI Category

The baseline data revealed a serious public health concern: more than half of the girls (54%) and nearly half of the boys (41%) were classified as underweight according to WHO criteria (WHO, 2025). The high rate of undernutrition points to severe gaps in baseline dietary habits, a lack of nutritional awareness, or skipping of nutrient-dense foods during crucial growth years (Table 2).

- **Major Decline in Underweight Status:** The percentage of underweight boys declined sharply from 41% to 18% (a recovery of 46 individuals). For girls, the underweight rate declined from 54% to 38% (a recovery of 32 individuals).
- **Surge in Normal Weight:** As students recovered from being underweight, they moved into the healthy, normal weight bracket (18.5–22.9 kg/m²). The proportion of normal-weight boys increased from 46% to 72%, while normal-weight girls expanded from 32% to 57%.
- **Management of Overweight and Obesity:** The counselling was also associated with stabilization at the upper end of the weight spectrum. Overweight boys declined from 12% to 10%, and obese cases dropped to nil. Overweight girls decreased from 12% to 4%, and obesity declined from 2% to 1%.

The adolescents were educated on improving dietary diversity, choosing calorie-dense whole foods, and meeting specific growth needs. The intervention promoted healthy, balanced mass accumulation rather than excessive weight gain. These findings suggest that introducing structured nutrition awareness programs in school settings may be a practical approach to support adolescent health and address nutritional deficiencies in urban school environments.

This trend is further supported by an intervention study among 100 adolescent girls aged 15–19 years across varied socioeconomic groups, which similarly demonstrated positive shifts toward normal BMI values, including a post-counselling mean BMI increase from 18.12 to 18.54 kg/m² among upper-class 16-year-olds within one month (Das & Das, 2023). Such comparable data supports the potential of structured nutritional education to address adolescent undernutrition.

TABLE 2
FREQUENCY DISTRIBUTION PROFILING OF ADOLESCENTS BY BMI CATEGORY

Particulars	Boys (n=200)		Girls (n=200)	
	Pre-counselling	Post-counselling	Pre-counselling	Post-counselling
Underweight (<18.5 kg/m ²)	82 (41%)	36 (18%)	108 (54%)	76 (38%)
Normal weight (18.5–22.9 kg/m ²)	92 (46%)	144 (72%)	64 (32%)	114 (57%)
Overweight (23–24.9 kg/m ²)	24 (12%)	20 (10%)	24 (12%)	8 (4%)
Obese (≥25 kg/m ²)	2 (1%)	0 (0%)	4 (2%)	2 (1%)

Values in () are percentages.

(A et al., 2014; WHO, 2025)

3.3 Dietary Diversity by Food Group

Table 3 records specific foods that students added to their diets to achieve higher scores. The data showed a targeted increase in protective, micronutrient-dense whole foods rather than empty calories.

- **Green and Yellow Vegetables:** The most dramatic changes occurred in the vegetable categories. Dark Green Leafy Vegetable consumption rose from 25% to 45% among boys and from 14% to 45% among girls. Similarly, consumption of Vitamin A-Rich Fruits and Vegetables doubled and tripled (16% to 32% for boys; 9% to 31% for girls).
- **Vital Proteins and Energy Sources:** Legumes, nuts, and seeds grew into a major dietary staple, reaching 86% for boys and 83% for girls (from 80% and 66% at baseline). Daily intake of Milk and Milk Products also solidified, expanding to 93% for boys and 88% for girls (from 85% and 75%). Animal protein sources like Meat/Fish and Eggs showed smaller but steady improvements (5-10% for boys and 4-10% for girls), while Starchy Staples remained a baseline constant at 100% for everyone.

These findings demonstrate that structured nutritional counselling was associated with improvements in dietary diversity, correcting monotonous, carbohydrate-heavy baseline diets by introducing accessible proteins and micronutrient-dense vegetables. This pattern aligns with an intervention in Puducherry among 140 adolescents, which significantly increased protein intake ($p < 0.001$) and reduced total calorie ($p < 0.001$) and fat ($p < 0.01$) consumption to control weight gain (Ponnambalam et al., 2022). Similarly, the increased intake of dairy, legumes, and greens in the cohort provided the structural tools necessary to support linear height and lean tissue development, suggesting that school-based education can drive objective anthropometric and macro-nutritional optimization.

TABLE 3
DIETARY DIVERSITY FREQUENCY DISTRIBUTION (PRE- VS POST-COUNSELLING)

Food Group	Pre-counselling	Post-counselling	Pre-counselling	Post-counselling
	Boys (n=200)		Girls (n=200)	
Starchy staples	200 (100%)	200 (100%)	200 (100%)	200 (100%)
Dark green leafy veg	50 (25%)	90 (45%)	28 (14%)	90 (45%)
Vitamin A-rich fruits/veg	32 (16%)	64 (32%)	18 (9%)	62 (31%)
Other fruits & veg	186 (93%)	192 (96%)	170 (85%)	186 (93%)
Organ meat	-	-	-	-
Meat and Fish	10 (5%)	20 (10%)	8 (4%)	20 (10%)
Eggs	16 (8%)	32 (16%)	2 (1%)	18 (9%)
Legumes, nuts & seeds	160 (80%)	172 (86%)	132 (66%)	166 (83%)
Milk and milk products	170 (85%)	186 (93%)	150 (75%)	176 (88%)

Values in () indicate percentages.

3.4 Evaluation of Individual Dietary Diversity Scores (IDDS)

The overall score improvements recorded in Table 4 show that the school-based nutrition education program was associated with enhanced daily food variety among participants.

- **Average Score Changes:** The average IDDS for boys increased significantly from 4.12 ± 1.06 to 4.78 ± 1.02 ($p < 0.001$; 16.02%), meaning the average male student added nearly one complete new food group to his regular diet. The improvement among girls was even more pronounced, increasing from a baseline mean of 3.54 ± 1.03 to 4.59 ± 0.99 ($p < 0.001$; 29.6%), a net gain of more than one full food group.
- **Decline in Low-Diversity Diets:** Before the counselling sessions, 56% of girls and 33% of boys were in the "Low Diversity" bracket (eating 3 or fewer food groups per day). Relying on such a narrow selection of foods may help explain the high underweight rates observed at baseline. These percentages fell sharply to 16% for girls and 8% for boys post-counselling.
- **Expansion of Healthy Categories:** Most students shifted successfully into the "Medium Diversity" tier (4–5 groups), which grew to include 63% of boys and 67% of girls (from 50% and 35%, respectively). Furthermore, the ideal "High Diversity" tier (6–9 groups) expanded from 17% to 29% for boys, and doubled from 9% to 17% for girls.

TABLE 4
CATEGORIES OF INDIVIDUAL DIETARY DIVERSITY (IDDS) FOR GIRLS AND BOYS

Particulars	Boys (n=200)		Girls (n=200)	
	Pre-counselling	Post-counselling	Pre-counselling	Post-counselling
	IDDS Category			
Low (0-3)	66 (33%)	16 (8%)	112 (56%)	32 (16%)
Medium (4-5)	100 (50%)	126 (63%)	70 (35%)	134 (67%)
High (6-9)	34 (17%)	58 (29%)	18 (9%)	34 (17%)
IDDS (0-9)	4.12 ± 1.06	4.78 ± 1.02	3.54 ± 1.03	4.59 ± 0.99
t-value	6.35**		10.39**	

Values in () are percentages.

**** $p < 0.001$**

3.5 Relationship between Dietary Diversity and Anthropometric Measurements

For the male cohort, overall dietary diversity showed a statistically significant positive association with all physical growth parameters during both phases of the study. At baseline, higher diversity scores correlated with greater height ($p < 0.001$) and weight ($p < 0.001$). This association continued post-counselling for both height ($p < 0.001$) and weight ($p < 0.001$). Higher diet scores also correlated with healthier BMI values both before counselling ($p < 0.01$) and after counselling ($p < 0.05$). These findings suggest that for boys, a broader, more diverse diet was associated with superior physical development (Table 5).

For the female group, the overall IDDS score showed non-significant correlations with height, weight, and BMI across both phases. This neutral trend indicates that for girls, the overall number of food groups alone was not sufficient to capture

nutritional adequacy. Instead, their physical changes were associated with specific, individual food choices rather than just a total score.

The significant positive correlation observed between overall IDDS and boys' anthropometric growth metrics aligns with established nutritional epidemiological frameworks. Multi-country evaluations demonstrated that overall dietary diversity scores functioned as reliable indicators of macro- and micronutrient adequacy, directly translating into linear skeletal growth and lean tissue accumulation during accelerated development phases (Arimond & Ruel, 2004).

TABLE 5
COMPARISON BETWEEN DIETARY DIVERSITY (IDDS) AND ANTHROPOMETRIC MEASUREMENTS (PRE- AND POST-COUNSELLING)

Particulars	Boys (n=200)		Girls (n=200)	
	Pre-counselling	Post-counselling	Pre-counselling	Post-counselling
	Dietary Diversity			
Height (cm)	0.307**	0.229**	0.050 (ns)	0.089 (ns)
Weight (kg)	0.302**	0.224**	0.013 (ns)	0.042 (ns)
BMI (kg/m ²)	0.215*	0.139†	0.032 (ns)	0.032 (ns)

ns = Not Significant (p>0.05)

†Correlation is significant at the 0.05 level

**Correlation is significant at the 0.01 level*

***Correlation is significant at the 0.001 level*

3.6 Individual Food Groups vs. BMI Dynamics

Table 6 presents correlations between specific food groups and BMI, highlighting foods that showed the most notable associations.

- **Vitamin A-Rich Foods:** For boys, Vitamin A-Rich Fruits & Vegetables maintained a significant positive correlation with BMI at baseline ($p<0.001$) and post-counselling ($p<0.01$), suggesting a consistent association between nutrient-dense produce and healthy growth.
- **Dark Green Leafy Vegetables:** Baseline consumption of greens also showed a significant positive association with BMI ($p<0.05$).
- **Eggs:** Post-counselling, egg consumption showed a significant negative correlation ($p<0.05$), meaning it was inversely associated with higher body mass.
- **Dairy Products:** For girls, milk and milk products showed a significant negative correlation with BMI both at baseline ($p<0.001$) and post-counselling ($p<0.001$). The inverse relationship suggests that regular dairy intake was associated with lower BMI, potentially indicating protection against excessive weight accumulation. This pronounced vulnerability among female adolescents aligns with European research revealing that up to 73% of adolescents failed to meet daily dairy serving guidelines, leaving nearly two-thirds of female adolescents below the estimated average requirement for calcium (Dror & Allen, 2014).
- **Fresh Produce:** Girls also showed a strong baseline positive correlation between other fruits and vegetables and BMI ($p<0.001$), which normalized to a neutral status ($p>0.05$) post-intervention.

The correlation results provide statistical support for the intervention, demonstrating associations between structured dietary modifications and positive changes in adolescent anthropometrics. The data highlight distinct, gender-specific physiological pathways through which nutritional improvements may translate into structural development.

For boys, the findings demonstrate a physiological benefit derived from overall dietary variety. Higher IDDS—driven by increased consumption of micronutrient-dense vegetables—was associated with accelerated linear growth, weight gain, and healthy mass accumulation. The observed benefit of dietary variety in boys mirrors findings in Indian adolescents, where higher dietary diversity scores were associated with reduced stunting and thinness, serving as a critical driver of structural development during active pubertal growth spurts (Nithya & Bhavani, 2018).

Conversely, girls' body composition appeared more sensitive to the targeted quality of specific functional food groups rather than a cumulative score of food categories. The introduction of protective, calcium- and protein-rich dairy products was

associated with an inverse relationship with BMI, potentially serving as a metabolic stabilizer. Concurrently, targeted plant-based food groups were associated with recovery from baseline undernutrition states.

TABLE 6

COMPARISON BETWEEN INDIVIDUAL FOOD GROUP CONSUMPTION AND BMI (PRE- VS POST-COUNSELLING)

Food group category	Boys (n=200)		Girls (n=200)	
	Pre-Counselling BMI	Post-Counselling BMI	Pre-Counselling BMI	Post-Counselling BMI
Dark green leafy veg	0.155*	0.070 (ns)	0.031 (ns)	0.045 (ns)
Vitamin A-rich fruits/veg	0.311***	0.215**	0.042 (ns)	0.031 (ns)
Other fruits & vegetables	0.085 (ns)	0.083 (ns)	0.276***	0.053 (ns)
Meat and fish	0.009 (ns)	0.137 (ns)	0.049 (ns)	0.106 (ns)
Eggs	0.130 (ns)	0.168*	0.103 (ns)	0.077 (ns)
Legumes, nuts and seeds	0.133 (ns)	0.104 (ns)	0.138 (ns)	0.001 (ns)
Milk and milk products	0.017 (ns)	0.029 (ns)	0.353***	0.283***

ns = Not Significant (p>0.05)

**Correlation is significant at the 0.05 level (2-tailed)*

***Correlation is significant at the 0.01 level (2-tailed)*

****Correlation is significant at the 0.001 level (2-tailed)*

IV. LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

Several limitations affect this study, including a pre-post design without a control group that prevents causal inference, and a purposive sample of two urban schools that restricts broader generalizability. Furthermore, the use of self-reported, single 24-hour dietary recalls introduces recall and social desirability biases, while the six-month follow-up may not confirm long-term sustainability. To address these gaps, future research should utilize randomized controlled trials (RCTs) with extended follow-up periods and multisite designs encompassing rural and diverse socioeconomic cohorts. Additionally, incorporating mixed-methods qualitative evaluations would significantly strengthen the evidence base.

V. CONCLUSION

The study demonstrated that a six-month structured school-based nutritional counselling intervention was associated with improved dietary diversity and positive anthropometric changes among urban Indian adolescents. The intervention was associated with a substantial decline in underweight prevalence, driven by increased consumption of protective, micronutrient-dense food groups. The findings highlight distinct gender-specific nutritional responses: for boys, overall dietary diversity was significantly associated with physical development, while for girls, specific food groups—particularly dairy products—showed stronger associations with anthropometric outcomes.

The results suggest that structured school-based dietary education may be a promising strategy to address the dual burden of adolescent malnutrition. However, the pre-post design without a control group limits causal inference, and further research with randomized controlled designs, longer-term follow-up, and diverse settings is warranted to confirm these findings and establish the effectiveness and scalability of this approach.

The gender-specific findings underscore the importance of tailoring nutritional interventions to meet distinct biological requirements. As India continues to face a dual burden of undernutrition and emerging overnutrition among adolescents, evidence-based, scalable interventions that address gender-specific needs and improve dietary quality are urgently needed.

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CONFLICT OF INTEREST

The authors declare that they have no competing financial interests or personal relationships that could have influenced the work presented in this paper.

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