The Dual Burden of Malnutrition: Exploring the Association between Micronutrient Deficiency, Stunting, and Overweight Among Adolescents in India

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Abstract: **Despite India's rapid economic growth, undernutrition and micronutrient deficiencies remain significant public health concerns, particularly among adolescents. Nutrition plays a crucial role in growth, yet food insecurity negatively impacts both physical and psychosocial health. Gender disparities further influence dietary patterns, with adolescent boys often having greater access to protein- and vitamin-rich foods than girls. This pro-boy dietary gap is exacerbated by parental aspirations, particularly at mid-adolescence. The prevalence of stunting among adolescents has increased, with 34.1% of 15-19-year-olds affected, while overweight and obesity are rising, especially among boys. Micronutrient deficiencies such as vitamin A, B12, and zinc are linked to stunting, while vitamin D, folate, and iodine deficiencies influence overweight status. The study highlights the dual burden of malnutrition and calls for targeted interventions, especially in early adolescence. Addressing gender inequalities and improving dietary diversity is critical to ensuring optimal adolescent health and development.**

Keywords: **Malnutrition, Micronutrient, Stunting, CNNS**

1. INTRODUCTION

In India, undernutrition and micronutrient deficiencies are widespread, despite rapid economic growth (Coffey et al., 2013). The economic growth in a country eventually leads to a shift in food preferences and consumption pattern and affects nutritional status of the people (Sharma et.al, 2019). For better health and elimination of malnutrition, a diversified and balanced food basket is required (Sangeetha *et al.*, 2013). Adolescents and school age children population are very important and fragile population to take care of but although adolescents are considered to be the relatively healthy segment of the population, they are vulnerable to illness in constrained situations such as food insecurity (Casey et al., 2005).Food insecurity is associated with a range of poor health outcomes in adolescents, adults, and children (Tefera et.al, 2011). It also affects both psychosocial and physical health outcomes (Hadley, C., & Patil, C. L., 2006) and leads to overall poorer health among members of food-insecure households (Heflin et al., 2005).

However, gender inequalities in health have been consistently documented (Gold et al., 2002). Biologically, female subjects have an advantage for better health and longer survival because of the role of sex hormones in modulating lipid levels and increasing immune response (Tefera et.al, 2011) (Lawlor, D. A., Ebrahim, S., & Smith, G. D. 2001). In addition, the difference in morbidity and mortality between boys and girls is further related to individual lifestyle, the use of health care, and health and illness behaviours and practices.13–15 For example, adolescent boys are more likely to smoke and have higher propensities of taking greater risks that expose them to injury (Christie, B. 2004).

Although female subjects have biological and behavioural advantages, established gender norms and values in developing countries contribute to the loss of the “female advantage” throughout the life cycle (Fikree, F. F., & Pasha, O. 2004).

A study from India suggests that while boys are favoured at most ages (except for 12 years old), the male advantage in dietary diversity is particularly wide at 15 years old (Aurino, 2016). The pro-boy gap in mid-adolescence is mostly driven by the consumption of protein- and vitamin-rich foods, such as eggs, legumes, root vegetables and fruit (Aurino, 2016) Adolescent boys are also advantaged in the consumption of milk and meat, although this is not statistically significant. (Aurino, 2016). The result is robust to the inclusion of indicators related to puberty, school enrolment, time use and dietary behaviours (Aurino, 2016). Moderation analysis explores further whether gender gaps in diets during adolescence vary by levels of maternal education, poverty, place of residence, or caregiver's education aspirations as a proxy measure for parental attitudes towards the adolescent (Aurino, 2016). While no differences are detected along the maternal education, poverty or place of residence axes, the treatment of adolescent boys and girls in respect of receiving a nutritious diet varied according to the levels of caregivers' aspirations. (Aurino, 2016). At 15 years old, the pro-boy gap is particularly marked amongst adolescents with caregivers that would like the adolescent to graduate at least from secondary school (Grade 12). Although the framework employed in this paper only allows for descriptive evidence and not full causal analysis, this result is suggestive that parental attitudes and aspirations towards the adolescent may constitute an exacerbating factor for gender differentials in diet during mid-adolescence (Aurino, E 2017).

The world's largest adolescent population is found in India, where there are 253 million adolescents, that is one in every five Indians (UNICEF, 2022). Adolescence is a period of rapid physical development, psychological change, and hormonal maturation in the life cycle, all of which increase a person's need for macro or micronutrients or both nutrients (Engidaw &, Gebremariam, 2019).In this period 15% to 25% of adult height is achieved, while up to 45% of skeletal growth occurs (WHO, 2005). Throughout infancy, childhood, and adolescence, nutrition affects growth and development; however, the adolescent period has higher dietary requirements than any other time following birth (Lifshitz, et al., 1993).

Despite of growth in the economy and advancement in technology, India continues to experience unacceptable levels of malnutrition (Johnson et.al, 2022). The prevalence of stunting among 15-19 years as per the National Family Health Survey (NFHS- 4) is 34.1%, higher than the previous NFHS-3, where 29.1% were stunted (Bhargava & Bhargava, 2020). A study found that one in every seven adolescents stunted in Bangalore city in India. The prevalence of stunting among early adolescents was 10.4% and nearly doubled among late adolescents (19.3%) (Johnson et.al, 2022). Determinants of stunting included lower socio-economic class and not taking weekly IFA supplements, a large proportion (81%) of the stunted children was classified as normal/overweight/obese using BMI-for-age, indicating that height-for-age is a vital metric (Johnson et.al, 2022). A key indicator of adolescent's nutritional status is their height for age, along with other metrics (Johnson et al., 2022). However, data from NFHS surveys is lacking for the pivotal stage of early adolescence (10–14 years), when puberty starts, when a significant growth spurt occurs, and when interventions to prevent stunting could be highly beneficial. According to a study on metropolitan south Indian residents, normal group boys consumed significantly more protein than the wasted, stunted, and wasted and stunted groups (39.2±21.17g vs. 35.6±15.75 to 26.4±10.91g/day, P<0.01) respectively (Shafiee et al., 2025).

Over half (54%) of adolescents aged (10-17) stunted. The higher proportion of adolescents from low-income families in the West Bengal study may explain it (Pal et al., 2017). The terrifying pattern of rising overweight/obesity among adolescents has been stated in several research on malnutrition and overnutrition among Indian adolescents (Ranjani et al., 2016& Panda et al., 2021). The prevalence of overweight and obesity was found to be 10.8% and 6.2%, respectively, in the South Indian state of Karnataka in 2019 (Gautam & Jeong, 2019). Males tended to have higher prevalence than females. The main causes of overweight and obesity among adolescents are poor food or insufficient physical activity (or both) (NIH & NHLBI, 2022).

2. SOURCE OF DATA

The study uses data from the Comprehensive National Nutrition Survey (CNNS 2016-2018) India.The age criteria of the survey was pre-schoolers (0–4 years), school-age children (5–9 years) and adolescents (10–19 years) through interviews, a comprehensive set of anthropometric measures and biochemical indicators (CNSS, 2018).

3. SAMPLE DESIGN AND SIZE

The CNNS was carried out via a multi-stage survey design that included households in both rural and urban areas across all 30 states of India. Three target population groups were surveyed: young children (ages 0–4), school-age children (ages 5–9), and adolescents (ages 10–19). A minimum sample size of

1000 for anthropometric and 500 for biochemical indicators was defined for each age group in each state, considering design effects and optimising the sample power with the available resources (CNSS, 2018).

The projected sample was estimated to consist of 122,100 children and adolescents from 2035 primary sampling units (PSUs) nationwide (CNSS, 2018).. For the anthropometric measurements and household survey, a sample size of 40,700 persons was planned for each age group, whereas 20,350 individuals were included in the biological samples for each age group. Using a multi-stage sampling approach, the CNNS selected a representative sample of households and individuals aged 0 to 19 across 30 states. For each state, the rural sample was selected in two phases. Probability proportional to size (PPS) sampling was used in the first stage to select Primary Sampling Units (PSUs), followed by the random systematic selection of households within each PSU in the second stage.

For all participants in the CNNS, a household and individual questionnaire was employed.

Furthermore, to find out the sex differential of the issue, we have done the whole analysis for boys and girls separately.

4. METHODOLOGY

Descriptive statistics, bivariate analysis are used to find the expected results.

The binary logistic regression is used to estimate the effects of micronutrient deficiency on Stunting and overweight among adolescents. The expected outcome variable will be binary, i.e. 0 “No” and 1 “Yes”.

The model is usually put into a more compact form as follows:

$$ln(Pi1 - Pi) = \beta 0 + \beta 1x1 + \cdots + \beta Mxm - 1, x1,2,3 \ldots n = explantory\ variables$$

Where β 0,….., are the regression coefficients signify the proportional impact of a specific explanatory variable on the outcome, and these coefficients vary depending on the context of the analysis within the study. To examine the association between the binary outcome variable and other explanatory variables, the study employed the binary logistic regression method.

The equation for logistic distribution

$$ln(\pi 1 - \pi) = \alpha + \beta 1X1 + \beta 2X2 + \beta 3X3 \ldots \ldots . \beta nXn$$

Where β 0,….., are regression coefficients represent the relative influence of a specific explanatory variable on the outcome, and these coefficients may vary depending on the analytical context within the study.

Objective of the study

To explore the association between micronutrient deficiency and stunting and overweight among adolescents in India

5. RESULTS

Level of Overweight by different Micronutrients among Adolescents

The table 1 delineates the prevalence of stunting by different micronutrient deficiencies stratified by age and sex. Stunted boys aged 10-14 have percentages of 30.41%, 23.3%, and 22.47% for vitamin A, B12, and zinc deficiencies, respectively. For those aged 15-19, the percentages are 18.39%, 21.4%, and 29.49%, respectively. Stunted girls aged 10-14 have percentages of 30.1%, 28.2%, and 30.39% for vitamin A, B12, and zinc deficiencies, respectively. For those aged 15-19, the percentages are 27.44%, 39%, and 29.54%, respectively.

Table 1. Prevalence of Overweight by different Micronutrient stratified by age and sex

Overweight				
	Boys		*Girls*	
Age	*10-14 Years*	*15-19 Years*	*10-14 Years*	*15-19 Years*
Micronutrients				
Vitamin D				
Non- Deficient	4.84	4.23	4.24	3.61
Deficient	8.38	7.76	7.39	5.42
Folate				
Non- Deficient	5.19	4.19	2.88	3.84
Deficient	6.17	5.04	7.95	5.15

Zinc				
Non- Deficient	6.19	4.56	4.68	3.72
Deficient	5.53	4.86	6.38	6.24
Iodine				
Non- Deficient	4.47	4.24	4.35	4.27
Deficient	7.98	4.83	6.76	5.07

Prevalence of Stunting by different Micronutrient among Adolescents

This 2 table outlines the prevalence of overweight by different micronutrient deficiencies stratified by age and sex. Overweight boys aged 10-14 have percentages of 8.83%, 6.17%, 5.53%, and 7.98% for vitamin D, folate, zinc, and iodine deficiencies, respectively. For those aged 15-19, the percentages are 7.76%, 5.04%, 4.86%, and 4.83%, respectively. Overweight girls aged 10-14 have percentages of 7.39%, 7.95%, 6.38%, and 6.76% for vitamin D, folate, zinc, and iodine deficiencies, respectively. For those aged 15-19, the percentages are 5.42%, 5.15%, 6.24%, and 5.07%, respectively.

Table 2. Prevalence of Stunting by different Micronutrient stratified by age and sex

	Stunting			
	Boys		*Girls*	
Age	*10-14 Years*	*15-19 Years*	*10-14 Years*	*15-19 Years*
Micronutrients				
Vitamin A				
Non- Deficient	21.6	25.5	26.28	34.34
Deficient	30.41	18.39	30.1	27.44
Vitamin B12				
Non- Deficient	25.03	30.33	25.83	31.08
Deficient	23.3	21.4	28.2	39
Zinc				
Non- Deficient	23.78	22.69	25.92	32
Deficient	22.47	29.49	30.39	29.54

Association between overweight and Micronutrient among Adolescents

The table 3 illustrates the odds for stunting by different micronutrient deficiencies among adolescents aged 10-19 years. Males with vitamin A deficiency are less likely to have stunting (OR- 0.84; CI 0.66, 1.06). Males with vitamin B12 deficiency are 21 times more likely to have stunting, while those with zinc deficiency have lower odds of stunting (OR- 0.96; CI 0.81, 1.14). Similar observations can be seen for females with vitamin A deficiency, vitamin B12 deficiency, or zinc deficiency

Table 3. Odds for s overweight by different micronutrient deficiencies among adolescents aged 10-19 years

Micronutrients	Male		Female	
	OR	95% C.I.	OR	95% C.I.
Vitamin D				
Non-Deficient*				
Deficient	0.62***	[0.48, 0.8]	0.70***	[0.55, 0.9]
Folate				
Non-Deficient*				
Deficient	0.73***	[0.57, 0.92]	0.85**	[0.66, 1.1]

Zinc				
Non-Deficient*				
Deficient	1.03	[0.82, 1.3]	0.75***	[0.59, 0.96]
Iodine				
Non-Deficient*				
Deficient	0.86**	[0.68, 1.1]	0.75***	[0.58, 0.97]

Note: OR-Odds Ratio; CI-Confidence Interval; *** p-value < 0.01 & ** 0.01 < p-value < 0.05; ^A Adjusted for attended school, place of residence, mother's education, father's education, mother's work status, father work's status, wealth index, caste, and religion.

Table 4 presents the odds of overweight by different micronutrient deficiencies among adolescents aged 10-19 years. Males with vitamin D deficiency are less likely to be overweight. Males with zinc deficiency are more likely to be overweight, although the results are not significant. Females with vitamin D, folate, zinc, and iodine deficiencies are less likely to be overweight.

Association between Stunting and Micronutrient among Adolescents

Table 4. Odds for stunting by different micronutrient deficiencies among adolescents aged 10-19 years

Micronutrients	Male		Female	
	OR	95% C.I.	OR	95% C.I.
Vitamin A				
Non-Deficient*				
Deficient	0.84**	[0.66, 1.06]	0.92	[0.74, 1.15]
Vitamin B12				
Non-Deficient*				
Deficient	1.21***	[1, 1.47]	0.95	[0.78, 1.15]
Zinc				
Non-Deficient*				
Deficient	0.96**	[0.81, 1.14]	0.98	[0.83, 1.16]

Note: OR-Odds Ratio; CI-Confidence Interval; *** p-value < 0.01 & ** 0.01 < p-value < 0.05; ^A Adjusted for attended school, place of residence, mother's education, father's education, mother's work status, father work's status, wealth index, caste, and religion

6. DISCUSSION

The findings presented very seamlessly also shed light on the complex relationship between micronutrient deficiencies, stunting, and overweight among adolescent boys and girls aged 10-19 years. These results provide valuable insights into the nutritional status and health outcomes of adolescents, highlighting the dual burden of malnutrition faced by this vulnerable population.

The prevalence of stunting and overweight, respectively, by different micronutrient deficiencies, stratified by age and sex reveals notable disparities in the prevalence of stunting and overweight across different age groups and sexes. For instance, stunted boys and girls aged 10-14 exhibit varying percentages of vitamin A, B12, and zinc deficiencies, with similar patterns observed among those aged 15-19. Similarly, overweight boys and girls show distinct percentages of vitamin D, folate, zinc, and iodine deficiencies across different age groups. There are several studies that go in line with the finding of the current study, micronutrient deficiencies, such as vitamin A, zinc, iron, and iodine, are associated with stunting, wasting, and underweight in children (Bhutta, 2008; Querol et al., 2021).

A study on adolescents in rural West Bengal, found that adolescents, are affected by the double burden of malnutrition, with underweight at 26.6% and stunting at 25% these numbers are quite high (Darling et al., 2020). Tan et al, (2021) in their study also discuss micronutrient deficiencies are associated with both overnutrition and undernutrition, with low serum iron being associated with overweight and obesity.

For the association between stunting and overweight and different micronutrient deficiencies among adolescents aged 10-19 years, the odds ratios provide insights into the likelihood of stunting and overweight associated with specific nutrient deficiencies. Interestingly, males with vitamin A deficiency exhibit lower odds of stunting, whereas those with vitamin B12 deficiency are substantially more likely to experience stunting. Similarly, females with vitamin A, B12, or zinc deficiencies show varying odds of stunting. Vassilakou, (2021) in his study also underline the fact that these deficiencies are associated with stunting and overweight in children, which leads to poor health and hindering personal development. Previously another study has also discussed stunting and micronutrient deficiencies in children coexist with obesity and nutrition-related chronic diseases, originating the double burden of nutritional disease (Uauy et al., 2008).

In contrast, the association between overweight and micronutrient deficiencies presents a more nuanced picture. Males with vitamin D deficiency are less likely to be overweight, while females with vitamin D, folate, zinc, and iodine deficiencies also exhibit reduced odds of overweight. However, the significance of these associations varies across different nutrients and sexes.

These findings have important implications for public health interventions aimed at addressing malnutrition among adolescents. Efforts to combat stunting should prioritize interventions targeting vitamin B12 deficiency, especially among males, while also addressing the complex interplay of other nutrient deficiencies. Similarly, strategies to address overweight should consider the differential impact of micronutrient deficiencies on weight status, with a focus on promoting balanced nutrition and healthy dietary practices.

7. CONCLUSION

In conclusion, the data presented in the tables underscore the intricate relationship between micronutrient deficiencies, stunting, and overweight among adolescents in different age groups and genders. The prevalence of deficiencies varies across different age groups and genders, with stunted boys and girls exhibiting high percentages of deficiencies in vitamin A, B12, and zinc. Conversely, overweight boys and girls show varying degrees of deficiencies in vitamin D, folate, zinc, and iodine.

Furthermore, the odds ratios reveal interesting associations between specific deficiencies and stunting or overweight. For instance, males with vitamin B12 deficiency have significantly higher odds of stunting, whereas females with the same deficiency exhibit similar trends. On the other hand, males with zinc deficiency show increased odds of overweight, although not statistically significant, while females with deficiencies in vitamin D, folate, zinc, and iodine are less likely to be overweight.

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