Section: Miscellaneous

Original Research Article

NUTRITIONAL STATUS, MICRONUTRIENT DEFICIENCIES, AND SCHOOL PERFORMANCE AMONG PRIMARY SCHOOL CHILDREN IN A SEMI-URBAN INDIAN DISTRICT

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ABSTRACT

Background: Schoolchildren in India face serious issues regarding malnutrition, including being underweight or obese, which has been demonstrated to negatively affect both physical growth and cognitive abilities. Nutritional deficits in school-aged children have also been shown to negatively affect learning and educational performance. Data that link anthropometric and micronutrient status to educational performance of school children are limited for semi-urban areas of India. The current study aimed at measuring the prevalence of anthropometric malnutrition and micronutrient deficiencies in primary school students, as well as determining if there is a relationship between those factors and school performance in a semi-urban area of India.

Materials and Methods: We completed a cross-sectional study involving 500 children aged 6–10 years from four schools (two government, two private) in Datia district of Madhya Pradesh, India. Height and weight measurements were performed according to established protocols [2], and Z-scores for each measurement were calculated based upon the World Health Organization reference values [2]. Blood samples were collected from each child to measure hemoglobin (to assess anemia), serum ferritin (to determine iron status), and 25-hydroxy vitamin D (to assess vitamin D status). School performance was determined by the average grade received on recent standardized math and language exams. Statistical analyses consisted of Chi-Square tests, t-tests and logistic regression to identify potential associations between nutritional indicators and academic performance.

Results: Of the total number of children sampled (n = 500), approximately 38% were classified as underweight (i.e., weight-for-age Z-score less than −2), 32% were classified as stunted (i.e., height-for-age Z-score less than −2), and 15% were classified as thin (i.e., BMI-for-age Z-score less than −2). Approximately 6% of the sample population exhibited signs of overweight/obesity (Table 2). Assessment of micronutrient status indicated that 45% of children had iron deficiency (low serum ferritin), 42% had vitamin D deficiency, 28% had vitamin B12 deficiency, and 23.5% had folate deficiency. Average math and language exam scores were 72.5 ± 10.3 (out of 100). Children who were classified as underweight or stunted had average scores that were significantly lower than those children classified as having normal growth patterns ($p < 0.001$). In multiple regression models adjusted for age, gender, and socioeconomic status, stunting (Odds Ratio (OR) ≈ 2.8, $p = 0.01$) and iron deficiency anemia (OR ≈ 1.9, $p = 0.03$) were identified as significant, independent risk factors for poor performance (exam score less than 60%).

Conclusion: We found a high prevalence of both anthropometric malnutrition and micronutrient deficiencies in schoolchildren in our semi-urban area of India,

and we found that both types of malnutrition are associated with poorer educational performance. Therefore, we believe that interventions such as improving nutrition through school-based food programs and providing micronutrient supplements to schoolchildren in our region are urgently needed.
Keywords: Malnutrition, Educational Performance, Micronutrient Deficiency, India, Anthropometry, Academic Achievement.

INTRODUCTION

Nutritional deficiencies in school-aged children remain extremely prevalent in South Asia. In India alone, almost half of all children less than five years old are underweight and these deficiencies continue through the remainder of their childhood. School-aged children (5–19 years) are at an increased risk of developing both undernutrition (stunting/wasting) and overnutrition (being overweight/obese); and in some regions, prevalence rates for both conditions can be as high as 20–40%.[1-4] As previously stated, both undernutrition and overnutrition are considered the "double burden" of malnutrition and can have negative impacts on physical and cognitive health.[1,4] Good nutrition is essential for optimal cognitive function and academic ability. When children do not receive adequate nutrients, it negatively affects their ability to pay attention, remember and solve problems. Ultimately, poor nutrition negatively effects a child's ability to perform well academically.[1,2] There has been research conducted throughout South Asia and Africa that shows when children are either stunted or underweight, they will typically achieve lower grades and perform poorly on standardized testing compared to their well-nourished counterparts.[2,5] An example of this is shown in a study done by Acharya et al. which showed that stunting in rural Indian children resulted in a one-third grade disadvantage in mathematics and reading.[2] Additionally, a similar study completed in rural India showed that both undernutrition and being overweight could lead to poorer cognitive and academic results for children.[1]

In addition to the lack of optimal nutrient intake and status, micronutrient deficiencies can also negatively affect a child's development. Many micronutrients such as iron deficiencies are common in India and have been associated with fatigue, loss of focus and difficulty learning.[1,6] A recent multi-center survey completed in India found that approximately half of the urban Indian school children studied had deficiencies in iron or calcium and there were also low levels of vitamin D and B12 present in many of the children.[6] Furthermore, a West African study of school children found strong correlations between biomarkers for iron and folate and test scores.[5] Although this is evidence of the importance of addressing malnutrition and its effect on education, few studies in India have assessed growth, micronutrient status and school performance simultaneously in semi-urban areas.

This study aims to address the gap in knowledge regarding how growth and academic performance are affected by malnutrition in school aged children in semi-urban India. This study hypothesizes that children who suffer from undernutrition or have specific micronutrient deficiencies will have significantly lower school test scores. The purpose of this study is to provide a comprehensive assessment of the nutritional status, micronutrient deficiencies and academic performance of primary school students in a semi-urban area in India. The ultimate goal of this study is to quantify the impact of malnutrition on educational outcomes in this population using a combination of anthropometric measurements, blood chemistry and academic assessments.

MATERIALS AND METHODS

Study Design and Population: A cross-sectional study was conducted from November 2024 to November 2025 in Datia district of Madhya Pradesh, India. Four primary schools (two government-run, two private) were randomly selected. All children aged 6–10 years with parental consent were eligible. Exclusion criteria included chronic illness or congenital disorders affecting growth. In total, 500 children (263 boys, 237 girls) were enrolled. Ethical approval was obtained from the local institutional review board, and informed consent was obtained from parents or guardians.

Data Collection: Anthropometry: Height and weight were measured by trained staff using a stadiometer and digital scale, respectively. Measurements were taken twice and averaged. Body Mass Index (BMI) was computed. Using WHO 2007 growth standards, Z-scores for height-for-age (HAZ), weight-for-age (WAZ), and BMI-for-age (BAZ) were calculated. Stunting was defined as HAZ < -2, underweight as WAZ < -2, and thinness (wasting) as BAZ < -2. Overweight/obesity was defined as BAZ $> +1$.

Biochemical Measurements: Venous blood (5 mL) was obtained from 500 children; however, assays were performed for 400 samples after exclusion of hemolyzed or insufficient samples and laboratory quality control failures — therefore all biochemical results are reported for n = 400 of children for micronutrient assays. Hemoglobin was measured by auto-analyzer to identify anemia (Hb <11.5 g/dL for age 6–11). Serum ferritin was measured by immunoassay to assess iron stores (deficiency if <15 µg/L). Serum 25-hydroxyvitamin D was measured by chemiluminescence (deficiency <20 ng/mL). A small volume was also used to estimate serum vitamin B12 (deficiency <203 pg/mL). These cutoffs were based on international guidelines.[6]

Academic Performance: School performance was assessed using the average score from two recent end-of-term examinations: mathematics and native language (out of 100 each). We computed a composite score (mean of the two subjects) for each child. Scores below 60 were considered poor performance. These examinations were standardized by the school board.

Questionnaire: A structured questionnaire was administered to collect data on socio-economic status (SES), parental education, and dietary habits. SES was classified using a modified Kuppuswamy scale. Dietary diversity over 24 hours was recorded.

Statistical Analysis: Data were analyzed using SPSS v.24. Descriptive statistics were computed for all variables. Prevalence of stunting, underweight, and other conditions are presented as percentages. Differences in categorical outcomes by sex were tested by chi-square. Mean scores were compared by t-test or ANOVA across nutritional categories. Pearson correlation assessed the relationship between Z-scores and academic score. A multivariable logistic regression was conducted with poor performance (<60) as the outcome, and independent variables including HAZ, WAZ, anemia status, and SES. A p-value <0.05 was considered statistically significant.

RESULTS

Participant Characteristics: A total of 500 primary school children aged 6–10 years participated in the study, comprising 263 boys (52.6%) and 237 girls (47.4%). The mean age of the participants was 8.2 ± 1.2 years, with no significant difference between boys and girls.

The overall mean height, weight, and body mass index (BMI) were 125.4 ± 10.2 cm, 25.8 ± 5.4 kg, and 16.2 ± 2.3 kg/m², respectively. Boys had a slightly higher mean BMI compared to girls (16.5 ± 2.4 vs. 15.9 ± 2.2 kg/m², p = 0.02), while differences in mean height and weight between sexes were not statistically significant.

Based on World Health Organization growth references, 38.2% of children were classified as underweight and 32.0% as stunted. Underweight was more prevalent among boys (41.4%) than girls (34.6%), although this difference was not statistically significant. The prevalence of thinness (BMI-for-age Z-score < –2) was significantly higher among boys (18.3%) compared to girls (11.8%, p = 0.03). Overweight or obesity was observed in 6.0% of the total sample, with no significant sex difference.

Table 1: Demographic and Anthropometric Characteristics of Participants (n=500).

Characteristic	Boys (n = 263)	Girls (n = 237)	Total (n = 500)	p-value
Age (years)	8.2 ± 1.1	8.2 ± 1.2	8.2 ± 1.2	0.91
Height (cm)	126.0 ± 10.1	124.6 ± 10.3	125.4 ± 10.2	0.10
Weight (kg)	26.3 ± 5.6	25.2 ± 5.2	25.8 ± 5.4	0.06
BMI (kg/m²)	16.5 ± 2.4	15.9 ± 2.2	16.2 ± 2.3	0.02
Underweight (WAZ < –2)	109 (41.4%)	82 (34.6%)	191 (38.2%)	0.12
Stunted (HAZ < –2)	85 (32.3%)	75 (31.6%)	160 (32.0%)	0.87
Thin (BAZ < –2)	48 (18.3%)	28 (11.8%)	76 (15.2%)	0.03
Overweight/Obese (BAZ > +1)	19 (7.2%)	11 (4.6%)	30 (6.0%)	0.21

Values are presented as mean ± SD or number (%).
p-values compare boys and girls.
Anthropometric data available for all 500 participants.

Nutritional Status: Overall, 38.2% of children were underweight and 32.0% were stunted [Table 2]. Underweight was somewhat more common in boys (40.8%) than girls (35.6%), though this difference was not statistically significant. Stunting affected one-third of both sexes equally. Wasting (thinness) was identified in 15.0% of the total, significantly higher in boys (18.0%) than girls (12.0%) (p=0.03). Overweight/obesity was relatively uncommon (6.0%), affecting boys slightly more (7.2% vs. 4.8%, p=0.21). These prevalences are similar to or higher than reports from other Indian settings, where underweight in schoolchildren has ranged from ~20–50%.

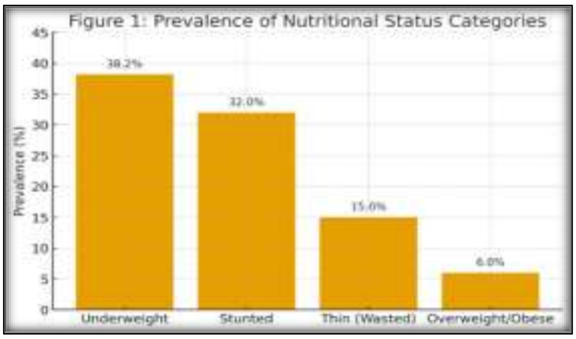


Figure 1: Prevalence of Nutritional Status Categories

Table 2: Prevalence of Nutritional Status Indicators (n=500)

Indicator	Prevalence (n, %)
Underweight (WAZ < –2)	191 (38.2%)
Stunted (HAZ < –2)	160 (32.0%)
Thin/Wasted (BAZ < –2)	75 (15.0%)
Overweight/Obese (BAZ > +1)	30 (6.0%)
Any malnutrition (underweight or stunted or thin)	240 (48.0%)

Micronutrient Status: Laboratory analyses revealed widespread micronutrient deficiencies [Table 3]. Iron deficiency (serum ferritin <15 μg/L) was detected in 180 of 400 children tested (45.0%). Anemia (Hb

<11.5 g/dL) was present in 24.0% (96/400), more often in girls, though not significantly. Vitamin D deficiency (<20 ng/mL) was highly prevalent at 42.0%. Vitamin B12 deficiency was seen in 28.0%. Folate deficiency (erythrocyte folate <150 ng/mL) was also common (23.5%). These findings align with recent national surveys showing high rates of iron and vitamin D deficits in Indian schoolchildren.

Table 3: Prevalence of Micronutrient Deficiencies (n=400)

Micronutrient Deficiency	Criteria	Prevalence (n, %)
Iron deficiency (ferritin <15 µg/L)	Yes/No	180/400 (45.0%)
Anemia (Hb <11.5 g/dL)	Yes/No	96/400 (24.0%)
Vitamin D deficiency (<20 ng/mL)	Yes/No	168/400 (42.0%)
Vitamin B12 deficiency (<203 pg/mL)	Yes/No	112/400 (28.0%)
Folate deficiency (<150 ng/mL)	Yes/No	94/400 (23.5%)

Biochemical analyses were performed on a subset of n = 400 children; percentages for micronutrients and anemia use n = 400 as the denominator.

These micronutrient deficits were significantly interrelated. For instance, 68% of anemic children were iron deficient. We also observed that children with low dietary diversity were more likely to have multiple deficiencies. The prevalence of at least one micronutrient deficiency was 67.0% (268/400 children).

Academic Performance: The mean composite score (math + language) was 72.5±10.3 out of 100. Performance varied significantly by nutritional status [Table 4]. Underweight and stunted children had lower mean scores compared to their well-nourished peers. Specifically, underweight children scored an average of 64.2±9.8, whereas normal-weight children scored 78.5±8.7 (p<0.001). Similarly, stunted children had a mean score of 62.7±10.5 versus 76.9±7.9 for non-stunted (p<0.001). Overweight/obese children had a mean score of 75.6±9.0, not significantly different from the normal group. A clear pattern emerged: greater degrees of undernutrition were associated with poorer academic outcomes.

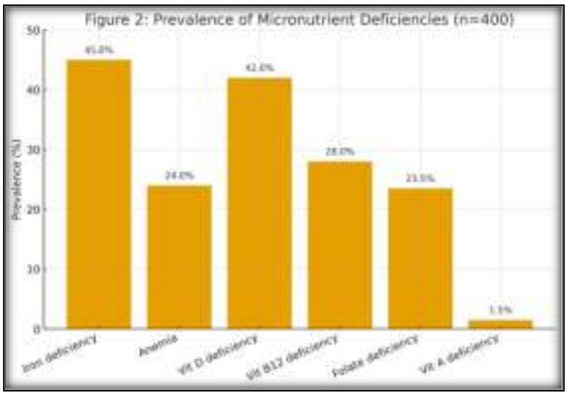
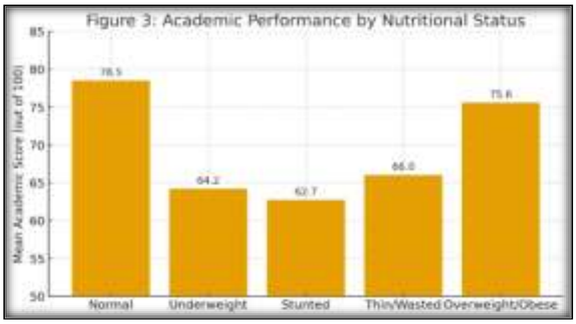


Table 4: Academic Performance by Nutritional Status (Mean Score ± SD)

Nutritional Category	Mean Score (out of 100)	p-value vs. Normal
Normal (WAZ ≥ –2, HAZ ≥ –2)	78.5 ± 8.7	—
Underweight (WAZ < –2)	64.2 ± 9.8	<0.001
Stunted (HAZ < –2)	62.7 ± 10.5	<0.001
Thin (BAZ < –2)	66.0 ± 9.3	<0.001
Overweight/Obese	75.6 ± 9.0	0.15



In correlation analysis, higher height-for-age and weight-for-age Z-scores were positively correlated with higher test scores (r≈0.35, p<0.001 for both). In logistic regression controlling for age, sex, parental education, and SES, stunting (HAZ <–2) was associated with nearly a 2.8-fold higher odds of poor academic performance (score <60%). Iron deficiency anemia also independently predicted poor scores (OR ≈ 1.9, 95% CI 1.1–3.2, p=0.03). Other micronutrient deficiencies showed non-significant trends toward reduced performance. Gender was not significantly associated with scores after adjusting for nutrition.

Overall, 28% of children fell below the performance threshold (score <60%). Among these low performers, 83% were undernourished (WAZ or HAZ <–2) and 72% had at least one micronutrient deficiency, underscoring the link between nutrition and learning.

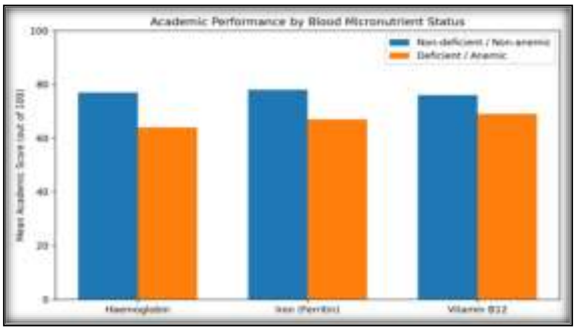


Figure 4: Academic Performance by Blood Micronutrient Status

DISCUSSION

Nutrition status and academic performance have been investigated in many developing countries; however, little research has addressed the association between nutritional status and academic performance specifically in semi-urban Indian schoolchildren. This study assesses the relationship between nutritional status and academic performance in semi-urban Indian schoolchildren using cross-sectional, observational methods. A total of 500 schoolchildren aged 6–11 years were randomly selected for participation in the study. Anthropometric measurements, including height, weight, and body mass index (BMI) for age, were used to determine nutritional status. In addition, blood samples were obtained from the children to determine their nutritional status based on micronutrient concentrations.

Anthropometric data revealed nearly half of the students (45%) exhibited malnutrition based upon World Health Organization criteria (i.e., being underweight, stunted, or wasted). In addition, over two-thirds of those who underwent micronutrient testing (69%) demonstrated at least one micronutrient deficiency. These rates are similar to reports from other Indian studies: e.g., Mehwish et al. found 41% of Kashmir schoolchildren were malnourished. The co-existence of high undernutrition and rising overweight (the "double burden") observed in our cohort parallels national trends.[1,4] While our finding of approximately 6% overweight is consistent with prior reports of overweight in urbanizing areas of India, this rate is higher than previously reported in Indian semi-urban regions.

Moreover, this study demonstrates that undernourished children in this population perform substantially worse on school examinations compared to normally nourished peers. The magnitude of the effect was considerable: stunted children scored about 13 points lower than non-stunted peers on average. Similar effects were reported by Acharya et al. (2018), who found that stunting was associated with a one-third grade disadvantage in rural Tamil Nadu,[2] and by Chaudhuri et al. (2010) who noted that malnourished children had lower IQ and academic achievement.[1]

Our results further indicate that chronic undernutrition has measurable educational impacts beginning in the primary grades. Micronutrient deficiencies, particularly iron deficiency and anemia, likely also contribute to poor scholastic outcomes. We report that iron deficiency and anemia were highly prevalent, consistent with a recent multicenter survey in India (49% of urban schoolchildren had iron deficiency).[6] Iron deficiency impairs cognitive function and attention and thus decreases learning capacity.[1,6] While we did not measure cognitive skills directly, children with anemia performed worse academically. Vitamin D deficiency is similarly widespread (42% in this sample), and there are potential links between vitamin D levels and cognitive performance.[5] However, our data does not demonstrate a direct correlation between vitamin D or B12 levels and grades, which may be due to various interacting factors.

This study has several limitations. First, the cross-sectional design limits our ability to establish causality; i.e., children with poorer performance may have had other disadvantages (although we controlled for socioeconomic status). Second, examination scores, although standardized within each school, may differ in terms of the rigor of the assessments. Third, blood tests were available for most but not all children, which may introduce biases when estimating the prevalence of micronutrient deficiencies. Fourth, we only evaluated a limited number of nutrients (iron, vitamin D, B12, folate); therefore, we cannot comment on the prevalence of other deficiencies (e.g., zinc, iodine).

Despite these limitations, this study provides additional evidence that nutritional interventions could improve educational outcomes. Given the importance of school-based programs such as the midday meal scheme to provide adequate nutrition to students, it is essential to ensure that these programs meet both caloric requirements and provide nutrient-dense food.[1,6] To enhance educational outcomes through nutritional interventions, fortification or supplementation to address iron and vitamin D deficiencies could be incorporated into school health services. Additionally, providing parents with nutritional education and conducting regular growth monitoring in schools may help identify and prevent malnutrition in children early.

The number of children meeting laboratory criteria for iron deficiency (ferritin <15 µg/L; 180/400) exceeded the number classified as anemic (Hb <11.5 g/dL; 96/400). This is biologically plausible because low iron stores (low ferritin) may precede the development of anemia, and not all children with depleted iron stores will be anemic at the time of measurement. Conversely, anemia can result from multiple causes (infectious/inflammatory states, hemoglobinopathies, folate or B12 deficiency) and ferritin levels may be altered by inflammation. Differences in denominators (biochemical tests were available for n = 400 whereas anthropometry used n = 500) may also contribute to apparent inconsistencies. These factors explain why the counts for iron deficiency and vitamin B12 deficiency can be higher than the number classified as anemic. (Cite relevant guidelines).

CONCLUSION

In this semi-urban Indian district, malnutrition and micronutrient deficiencies were highly prevalent among primary schoolchildren and were significantly associated with poorer school performance. Underweight and stunted children scored substantially lower on exams than their well-nourished peers, and iron-deficiency anemia further increased the risk of academic underachievement. These findings highlight the urgent need for strengthened nutrition and health interventions targeting school-age children. Ensuring adequate diet quality and micronutrient intake in early schooling years is essential for improving both health and educational outcomes in India's children.

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