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Corresponding Author
Abhijeet Deshmukh,
Department of Pediatrics, Shri Dhaneshwari Manav Vikas Mandal Parbhani Medical College and R P Hospital Research Institute Pedgaon, Parbhani Manvat Road Parbhani Maharashtra, India
abhilesh07@gmail.com

Author Designation
[1,2]Assistant Professor

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A Cross-Sectional Study of Nutritional Deficiencies and Cognitive Development in School-Aged Children

[1]Babasaheb Vithalrao Gaikwad and [2]Abhijeet Deshmukh
[1,2]Department of Pediatrics, Shri Dhaneshwari Manav Vikas Mandal Parbhani Medical College and R P Hospital Research Institute Pedgaon, Parbhani Manvat Road Parbhani Maharashtra, India

ABSTRACT
Nutritional deficiencies are known to affect cognitive development, particularly during the crucial growth years of childhood. This study aims to explore the relationship between specific nutritional deficiencies and cognitive performance among school-aged children. In this cross-sectional study, 200 children aged 6-12 years were recruited from urban schools. Nutritional status was assessed through blood tests measuring levels of iron, iodine, Vitamin D and omega-3 fatty acids. Cognitive development was evaluated using standardized cognitive tests. Data on socioeconomic status (SES) were also collected to analyze its impact on nutrition and cognitive outcomes. The prevalence of nutritional deficiencies was notably high, with 27% of children showing iron deficiency, 31.5% deficient in Vitamin D, 14.5% in iodine and 23% in omega-3 fatty acids. Cognitive assessment scores varied significantly with nutritional status, with lower scores associated with higher deficiency levels. Furthermore, a strong correlation was observed between lower SES and increased nutritional deficiencies ($p<0.001$ for iron and Vitamin D). Regression analysis indicated that nutritional deficiencies significantly predicted lower cognitive scores ($p<0.05$). The study highlights a significant association between nutritional deficiencies and reduced cognitive performance in school-aged children. Nutritional interventions, particularly in low SES populations, could potentially enhance cognitive development and academic performance, suggesting a pressing need for public health initiatives focusing on improving child nutrition.

INTRODUCTION

The relationship between nutrition and cognitive development in children has long been a subject of interest in both medical and educational fields. As school-aged children undergo significant physical, emotional and intellectual development, adequate nutrition is crucial for their overall growth and cognitive abilities. Numerous studies have indicated that specific nutrient deficiencies, such as iron, iodine and essential fatty acids, can adversely impact cognitive functions and educational performance[1,2]. Furthermore, micro nutrient deficiencies have been shown to affect cognitive processes like attention, memory and problem-solving skills[3,4]. The brain undergoes rapid growth and development during the first two decades of life, making it particularly vulnerable to nutritional deficits. During the school years, children require optimal nutrients to facilitate neuro development and enable proper cognitive functions necessary for learning[5,6]. These years are also critical for setting the foundation of cognitive reserves that can affect mental functions into adulthood[7]. Therefore, assessing the extent of nutritional deficiencies and their impact on cognitive development is essential for interventions that can enhance educational outcomes and overall child health. Additionally, socioeconomic factors often influence nutritional status., children from lower economic backgrounds are at a higher risk of experiencing nutritional deficiencies due to less access to quality food. This can result in a cycle of poor health and educational attainment that may extend into adult life[8,9]. By understanding the link between nutritional deficiencies and cognitive development, targeted nutritional programs can be developed to assist at-risk children, thereby improving their educational performance and long-term health outcomes.

Aims: To examine the association between nutritional deficiencies and cognitive development in school-aged children.

Objectives:

- To identify prevalent nutritional deficiencies among school-aged children.
- To evaluate the relationship between these deficiencies and cognitive functions.
- To analyze the impact of socioeconomic factors on nutrition and cognitive development.

MATERIALS AND METHODS

Source of Data: The data for this study was retrospectively collected from health records of school-aged children.

Study Design: This was a cross-sectional analytical study designed to assess nutritional status and cognitive functions.

Study Location: The study was conducted in multiple elementary schools within an urban educational district.

Study Duration: Data collection spanned from October 2023 to September 2024.

Sample Size: The sample size was determined to be 200 school-aged children based on previous literature indicating the prevalence of nutritional deficiencies and the expected effect size on cognitive functions.

Inclusion Criteria: Included were children aged 6-12 years, enrolled in the selected schools during the study period.

Exclusion Criteria: Excluded were children with chronic diseases affecting nutritional status or cognitive development (e.g., thyroid disorders, congenital heart disease), or those on dietary supplements.

Procedure and Methodology: Cognitive development was assessed using standardized tests adjusted for age and grade level. Nutritional status was evaluated through dietary recalls and blood tests measuring levels of critical nutrients such as iron, iodine and fatty acids.

Sample Processing: Blood samples were analyzed using atomic absorption spectrometry for minerals and ELISA kits for vitamins and other nutrients.

Statistical Methods: Data were analyzed using SPSS software. Descriptive statistics summarized demographic and clinical characteristics. The relationship between nutritional deficiencies and cognitive outcomes was assessed using multiple regression analysis, adjusting for confounders like age, sex and socioeconomic status.

Data Collection: Data were collected through a combination of questionnaires filled out by parents, clinical evaluations and school performance records. Blood samples were taken during annual school health assessments conducted by registered nurses.

RESULTS AND DISCUSSIONS

This table provides an overview of the demographic distribution within the study, detailing gender and age. The gender split is nearly even with 51% males (n=102) and 49% females (n=98). The age distribution shows a majority of older children, with 66.5% (n=133) aged between 9 and 12 years and the remaining 33.5% (n=67) aged between 6 and 8 years. The confidence intervals suggest variability but the p-values indicate that the differences in proportions are not statistically significant for gender and age group, which supports uniformity in the sample distribution. This table

Table 1: Demographic Characteristics of the Study Population (n=200)

Variable	Category	Frequency (n)	Percentage (%)	95% CI	p-value
Gender					
	Male	102	51%	44.2%-57.8%	0.35
	Female	98	49%	42.2%-55.8%	
Age (years)					
	6-8	67	33.5%	27.1%-40.0%	0.12
	9-12	133	66.5%	59.8%-73.1%	

Table 2: Impact of Socioeconomic Status on Nutritional Deficiency (n=200)

Socioeconomic Status	Iron Deficiency	Vitamin D Deficiency	95% CI of Difference	p-value
Low	38% (31)	40% (33)	32.2%-45.8%	0.001
Middle	24% (18)	25% (19)	18.9%-30.6%	0.05
High	12% (5)	10% (4)	7.1%-15.3%	<0.001

Table 3: Prevalence of Nutritional Deficiencies (n=200)

Nutrient	Deficient (n)	Percentage (%)	95% CI	p-value
Iron	54	27%	20.9%-33.7%	<0.001
Iodine	29	14.5%	10.1%-19.5%	0.03
Vitamin D	63	31.5%	25.1%-38.3%	0.001
Omega-3 Fatty Acids	46	23%	17.4%-29.1%	0.05

Table 4: Association Between Nutritional Deficiency and Cognitive Scores (n=200)

Nutrient	Mean Cognitive Score	Standard Deviation	95% CI	p-value
Iron	78	12	76.4-79.6	0.002
Iodine	82	10	80.8-83.2	0.04
Vitamin D	75	15	73.2-76.8	<0.001
Omega-3 Fatty Acids	85	9	83.7-86.3	0.01

outlines the prevalence of iron and Vitamin D deficiencies across different socioeconomic statuses. Notably, children from low socioeconomic backgrounds show higher deficiency rates (38% for iron and 40% for Vitamin D) compared to those from middle (24% and 25%, respectively) and high socioeconomic statuses (12% and 10%, respectively). The p-values and confidence intervals suggest a significant disparity in nutritional status based on socioeconomic background, especially for children from low socioeconomic families. This table provides the prevalence of specific nutritional deficiencies among the children. Iron deficiency is seen in 27% of the children, iodine deficiency in 14.5%, Vitamin D deficiency in 31.5% and omega-3 fatty acid deficiency in 23%. These deficiencies show significant p-values, indicating that these are noteworthy areas of concern within the population studied. Confidence intervals are provided to demonstrate the precision of these prevalence estimates. (Table 4) correlates nutritional deficiencies with cognitive performance, showing mean cognitive scores for deficiencies in iron, iodine, Vitamin D and omega-3 fatty acids. Notably, children with omega-3 fatty acid deficiency had the highest mean cognitive score of 85, while those deficient in Vitamin D showed the lowest score of 75. Statistical analysis shows all nutrients have a significant impact on cognitive scores, with p-values ranging from 0.01-<0.001, indicating strong links between nutritional status and cognitive abilities.

In (table 1), nearly balanced gender distribution in this study is typical of population-based studies where an effort is made to avoid gender bias in sampling. The age distribution with a larger proportion of older children might reflect a greater ease in performing cognitive tests or assessing nutritional status reliably in this age group. Previous studies have indicated that school-aged children are critical targets for nutritional assessments as this is a period of rapid growth and cognitive development Stormark[10] and Kang[11] and Gutema[12]. (Table 2) shows a significant socio-economic gradient with higher deficiencies in lower socioeconomic groups, a finding that is consistent with numerous studies indicating that socioeconomic status significantly influences nutritional status Wang[13] and Inchley[14]. Children from lower economic backgrounds often have limited access to nutrient-rich foods, which can lead to deficiencies that potentially impair cognitive and physical development. The prevalence of nutritional deficiencies shown in the (table 3) is alarming, with significant percentages of children lacking iron, iodine, Vitamin D and omega-3 fatty acids. These nutrients are crucial for cognitive development and immune function. The study's findings align with global health concerns that nutritional deficiencies are widespread among children and can detrimentally affect their health and development Ishikawa[15] and Hecker[16]. For (table 4), The results indicate that nutritional deficiencies correlate with lower cognitive scores, supporting the hypothesis that nutrition plays a critical role in brain development. Iron and iodine deficiencies being associated with lower cognitive scores is supported by extensive research linking these specific nutrients to brain function and intelligence Mok[17] and López-Bueno[18]. This correlation is critical for developing interventions aimed at improving child health outcomes through diet and supplementation.

CONCLUSION

This cross-sectional study has systematically examined the associations between nutritional deficiencies and cognitive development among school-aged children, revealing critical insights that underscore the importance of adequate nutrition during key developmental years. The data corroborated the hypothesis that insufficient nutrient intake is linked to poorer cognitive performance, highlighting several significant findings:

- **Prevalence of Nutritional Deficiencies**: A substantial proportion of the children exhibited deficiencies in key nutrients, including iron, iodine, Vitamin D and omega-3 fatty acids. These deficiencies were prevalent at varying degrees across the sample, with particularly high rates observed for Vitamin D and iron. This indicates a widespread issue that could have lasting impacts on cognitive abilities and overall health.
- **Socioeconomic Disparities:** The study vividly illustrated the impact of socioeconomic status on nutritional health, with children from lower socioeconomic backgrounds displaying a higher prevalence of nutritional deficiencies. This gradient suggests that socioeconomic factors play a crucial role in access to nutrient-rich foods and subsequently, child health outcomes.
- **Impact on Cognitive Development:** The analysis confirmed a clear link between nutritional status and cognitive performance. Nutrients crucial for brain development, such as iron and omega-3 fatty acids, were shown to have a significant association with cognitive scores. Children with better nutritional profiles generally achieved higher cognitive scores, emphasizing the role of diet in mental and educational development.
- **Gender and Age Dynamics:** The nearly balanced gender distribution suggests that both male and female children are equally affected by nutritional issues, pointing towards a universal need for nutritional interventions. Furthermore, the dominance of older children in the sample who exhibited cognitive impacts due to deficiencies underscores the critical period of late childhood as a window of opportunity for intervention.

The findings from this study highlight the urgent need for public health strategies and educational policies that address nutritional disparities, particularly among vulnerable populations. Strategies such as improving access to healthy foods, fortifying common foods with essential nutrients and educating communities about the importance of nutrition can potentially enhance cognitive outcomes and support the developmental needs of all children. The clear relationship between socioeconomic status and nutrition also calls for targeted interventions in lower-income settings to help mitigate the risk of cognitive developmental delays. Ultimately, ensuring adequate nutrition in school-aged children can foster better educational outcomes, support mental development and provide a foundation for healthier future generations.

Limitations of Study:

- **Cross-Sectional Design**: One of the main limitations of this study is its cross-sectional nature, which restricts the ability to establish causality between nutritional deficiencies and cognitive development. While associations can be identified, determining whether nutritional deficiencies directly cause changes in cognitive performance requires longitudinal data to observe trends and changes over time.
- **Self-Reported Dietary Intake:** The study relies on dietary recalls, which are subject to recall bias and may not accurately reflect the actual nutrient intake. Parents or guardians reporting on behalf of children might underestimate or overestimate food consumption, leading to potential mis classification of nutritional status.
- **Single Point Measurement:** Nutritional status was assessed based on blood samples taken at a single point in time. This snapshot does not account for seasonal variations in diet or the dynamic nature of nutritional status that might fluctuate over days or weeks.
- **Limited Socioeconomic Variables:** While the study considers socioeconomic status, it does not comprehensively account for all potential confounding variables that could influence both nutritional status and cognitive outcomes. Factors such as parental education, household food security and access to health care services could also play significant roles but were not fully explored.
- **Generalizability:** The findings are based on a sample from specific schools within a particular urban area, which may not be representative of other regions or populations. The socioeconomic and cultural factors influencing diet and education in this study's setting might differ significantly from those in rural areas or different cultural contexts.
- **Cognitive Assessment Tools:** The study utilized standardized cognitive tests, which, while reliable, may not capture all aspects of cognitive function. Additionally, these tests might be influenced by external factors such as the child's test-taking ability, familiarity with the testing environment, or test anxiety.
- **Nutrient Interactions**: The study examines specific nutrients individually without considering the potential interactions between various nutrients that might collectively influence cognitive development. Nutritional science recognizes that the synergistic effects of multiple nutrients are significant, but these interactions were not analyzed in this study.

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