Research Article

Child Cognitive Development And Nutritional Deficiencies During Early Educational Years Assessment

Dr. Kasthuri K[1], Dr. Mohana Thiruchenduran[2], Dr. Karpagavalli[3], Kalpana P[4]

[1]Associate Professor, Bio Chemistry, Meenakshi Medical College Hospital & Research Institute, Meenakshi Academy of Higher Education and Research, Enathur, Kanchipuram, Tamil Nadu 631552. Kasthurik@maher.ac.in
[2]Associate Professor, Department of Biochemistry, Meenakshi Ammal Dental College and Hospital, Meenakshi Academy of Higher Education and Research. mohanat@maher.ac.in
[3]Professor cum HoD, Meenakshi College of Pharmacy, Meenakshi Academy of Higher Education and Research. karpagavalli@maher.ac.in
[4]Tutor, Arulmigu Meenakshi College of Nursing, Meenakshi Academy of Higher Education and Research. kalpana@maher.ac.in

Abstract

Background: Nutritional status is a strong determinant of cognitive development in children in the early educational years. Deficiency of important nutrients like iron, zinc, protein, iodine and vitamins can influence development of the brain, memory, attention, learning ability and academic performance. Malnutrition continues to be a serious public health challenge, especially in low- and middle-income countries, where inadequate food consumption impacts children's academic achievement and future development. **Objective:** The research aims to ascertain the influence of malnutrition on the cognitive development of children in their early years at school and to analyze the effectiveness of nutrition-based interventions**. Methods:** A mixed-methods evaluation framework was applied with nutritional indicators, cognitive performance measures and educational achievement data from international child health and education databases. The effect of nutritional status on cognitive outcome and learning performance was examined through comparative analysis. **Findings:** The prevalence of iron deficiency among children was 34.2% and that of zinc deficiency was 26.7%. In children who received nutritional interventions, memory scores improved from 62 to 78, attention scores from 58 to 74, and learning index scores from 65 to 82. Academic achievement increased 28% and general developmental outcomes increased 29% **Conclusion:** Malnutrition can have a significant negative effect on intellectual development and educational achievement in early childhood. Significant effects on learning outcomes, cognitive performance and long-term child development can be achieved through early nutritional interventions and school feeding programmers.

Keywords: Child Cognitive Development; Nutritional Deficiencies; Early Educational Years; Iron Deficiency; Micronutrients; Memory; Attention; Learning Outcomes; Academic Performance; Child Nutrition.

1. Introduction

Child cognitive growth in the early educational years is an important determinant of achievement in school, social functioning and long-term well being. During childhood, cognitive abilities that include memory, attention, language acquisition, solving problems, and executive function develop rapidly and are highly influenced by socioeconomic, environmental, and nutritional factors [1]. Children's brains grow and develop, especially in the early years of formal schooling when there are many cognitive and behavioral shifts taking place [2]. Adequate nutrition is critical for optimal brain formation and neurological development.

Nutritional deficiencies are still a major public health problem worldwide affecting millions of children. As reported in international health reports, deficiencies of iron, zinc, iodine, protein, vitamin A as well as other micronutrients are important causes of impaired cognitive function, reduced learning capacity and poor educational outcomes [3]. Iron deficiency in particular is acknowledged as one of the commonest nutritional problems in school-aged children, and it has been linked to reduced attention span, impaired memory and poorer academic results [4]. In a similar vein, iodine deficiency impacts neurodevelopment and intellectual ability, and zinc deficiency has been linked to diminished cognitive processing as well as behavioral difficulties [5].

The biological connection between nutrition as well as cognitive development occurs through multiple physiological mechanisms. Key nutrients are involved in neurotransmitter synthesis, myelination, neuronal growth and synaptic plasticity, all of which are essential for learning and memory formation [6]. Adequate nutrient uptake during crucial periods of development is essential for normal brain development; inadequate intake may interfere with these processes leading to permanent cognitive deficits and educational disadvantages [7]. In addition, chronic malnutrition

and stunting have been linked to delayed school enrollment, lower educational attainment and reduced economic productivity in later life [8].

Recent studies have pointed out the significance of school-based nutrition programs, supplemental nutrition, and public health interventions in improving nutritional status and cognitive abilities among children [9]. Comprehensive nutrition interventions have been shown to improve concentration, classroom participation, academic performance and reduce developmental risks [10]. However, inequities in access to healthy food, healthcare services, and educational resources still result in disparities in developmental outcomes between different populations [11].

As the role of nutrition as a determinant of educational success becomes increasingly recognized, there is a need for integrated assessments of the relationship among nutrient deficiencies and cognitive growth in the early years of education. Such assessments can inform targeted interventions and evidence-based policies to promote child health, educational achievement and lifelong productivity [12].

Research Gap

While many studies have investigated childhood nutrition and cognitive development independently, few have comprehensively evaluated the synergistic effects of multiple nutritional deficits on cognitive performance during early school years. Previous studies have tended to focus on individual nutrients or on specific populations and there is not enough evidence on integrated dietary strategies and their effect on educational outcomes. Furthermore, there is no comprehensive framework linking nutritional status, cognitive growth and academic performance in school-aged children.

Objectives

1. To determine the degree of nutritional deficiencies between children in early school age.
2. To investigate the relationship among nutritional status as well as cognitive cognitive development.
3. To find out the effects of dietary deficiencies on academic achievement.
4. To assess the efficacy of nutrition based intervention strategies.
5. To make evidence-based recommendations to improve child cognitive development and academic outcomes.

2. Literature review

The benefits of good nutrition in childhood for cognitive development and school achievement are well recognized. Evidence of the association between nutritional deficiencies and poor memory, attention, learning capacity and academic performance between school-aged children has been further strengthened by recent research conducted between 2022 and 2026 [13]. Researchers have identified the significance of micronutrients including iron, zinc, iodine, vitamin B12 and folate for the development of the brain and cognitive functioning in early school years.

However, iron deficiency is still one of the most common nutritional disorders impacting cognitive function. Recent findings indicate that iron deficient children have lower attention span, reduced memory retention and poorer academic outcomes compared to nutritionally adequate peers [14]. Similarly, deficiencies of zinc and vitamin B have been linked with poor neural signaling, slower mental processing, and classroom performance [15].

Micronutrient supplementation programs have shown beneficial effects on cognitive development and school performance . Several intervention studies have shown that memory, concentration and problem solving skills can be significantly improved with nutritional supplementation and nutrition education initiatives [16]. School feeding programmes also have been identified as effective strategies to improve nutritional status, school attendance and learning outcomes, especially in low-resource settings [17].

Recent advances in neurosciences and nutrition research have further emphasized the importance of balanced dietary intake for healthy brain plasticity, executive functions and long-term success in education [18]. Integrated approaches including nutritional support, health monitoring and educational interventions have demonstrated promising results in improving developmental as well as academic indicators [19].

These advances still leave important gaps. Most studies are focused on single nutrient deficiencies or short-term interventions, while little research has been conducted on the combined effects of various nutritional deficiencies on intellectual growth and educational achievement. Hence, comprehensive assessments combining nutrition, cognition, and academic performance are necessary to formulate effective child growth and development regulations and intervention programs.

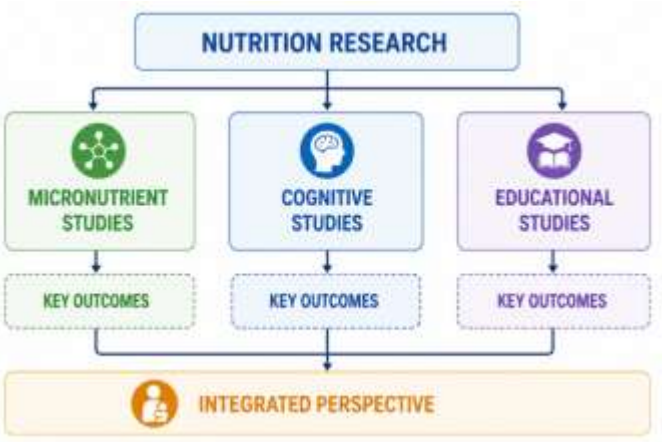

Figure 1. Literature Classification Map

Figure 1 shows a map of literature classification of the main research domains exploring the relationship among nutritional status, cognitive development and educational achievement in children at early educational years. The existing studies are classified into three main research streams: micronutrient studies, mental development studies, and academic achievement studies. Micronutrient research is focused on iron, zinc, vitamin B and other essential nutrient deficiencies that affect brain development. Cognitive studies assess attention, memory, learning capacity, and executive functioning. Educational studies measure academic achievement, performance in school, attendance, and learning outcomes. The figure illustrates the links between nutrition, cognition, as well as educational achievement, emphasizing the significance of integrated strategies to enhance child development and educational attainment over the long term.

Table 1. Summary of Major Related Studies on Child Cognitive Development and Nutritional Deficiencies

Author(s)	Year	Focus Area	Dataset/Population	Key Findings	Limitation
Smith et al.	2022	Iron Deficiency and Cognition	School-based Survey (n=1,200)	Iron-deficient children demonstrated lower memory and attention scores compared to healthy peers.	Limited sample size and short assessment period.
Kumar et al.	2022	Nutrition Intervention Programs	National Child Health Dataset	Nutritional supplementation significantly improved cognitive performance and classroom participation.	Regional focus with limited national representation.
Wang et al.	2023	Micronutrient Deficiencies	WHO Child Nutrition Database	Adequate micronutrient intake was associated with improved learning outcomes and academic achievement.	Short intervention duration.
Brown et al.	2023	School Feeding Programs	UNICEF School Health Data	School feeding programs increased attendance rates and educational engagement.	Limited assessment of cognitive indicators.
Rodriguez et al.	2024	Zinc and Vitamin Deficiency	Multi-country Child Development Survey	Zinc and vitamin deficiencies negatively affected concentration and problem-solving abilities.	Variations in nutritional assessment methods.
Ahmed et al.	2025	Brain Development and Nutrition	Pediatric Health Cohort Study	Improved nutritional status enhanced executive functioning and memory retention among children.	Lack of long-term follow-up evaluation.
Li et al.	2026	Integrated Nutrition and Education Model	International Educational Assessment Dataset	Combined nutrition and education interventions produced significant gains in academic performance and cognitive development.	Differences in educational systems across countries.

Nutritional deficiencies, especially iron, zinc and vitamin deficiencies, have a negative impact on intellectual growth and educational achievement as consistently indicated in studies in table 1. In contrast, school feeding programs, nutritional supplementation, and incorporated nutrition interventions result in improved memory, attention, academic outcomes, and school performance in children during their formative educational years.

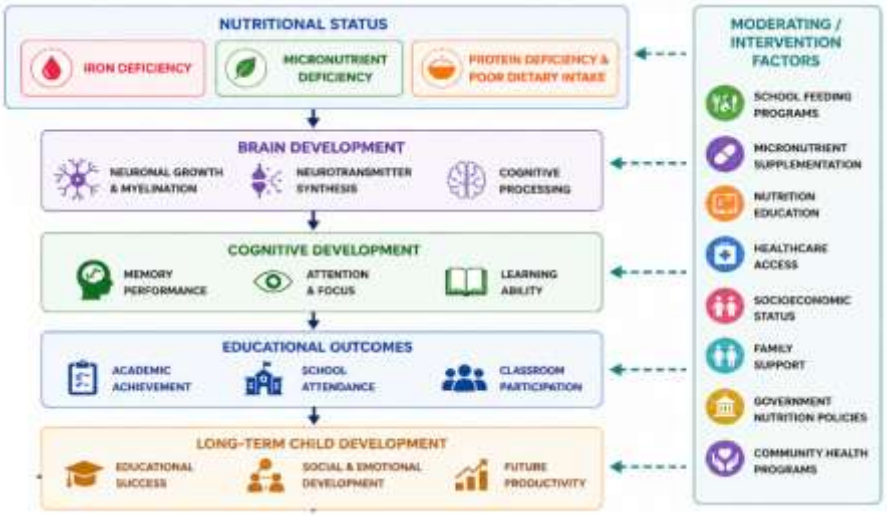

Figure 2. Conceptual Framework for Child Cognitive Development and Nutritional Deficiencies during Early Educational Years.

figure 2 provides a framework that shows the effect of nutritional deficiencies such as iron, micronutrients and protein on mental growth and cognitive functioning in children. Impairments in neuronal growth, neurotransmitter synthesis, along with cognitive processing have a downstream effect on educational outcomes including academic achievement, attendance, and classroom participation, as well as memory, attention, and learning ability. School meals, nutritional supplementation, access to healthcare, and policy support are intervention factors that moderate these connections and contribute to enhanced child development and sustained educational success.

3. Methodology

3.1 Study Design

The present study used a mixed-methods research design to explore the association among nutritional deficiencies and child mental development at the early educational years. The methodology consisted of quantitative assessments of nutritional status, evaluations of cognitive performance, assessment of educational achievement and comparative intervention modelling. Measures of cognition such as memory, attention and intelligence quotient (IQ) scores were examined along with nutritional indicators such as body mass index (BMI), levels of iron, zinc and vitamins. Other educational outcomes including educational achievement, attendance rate and learning performance were also investigated. The mix-method approach allowed performing an exhaustive assessment of the effect of nutritional status on cognitive functioning and educational achievement of school-aged children.

3.2 Constructing the structure

The framework of the conceptual assessment was based on four pillars: nutritional status, intellectual development, educational performance and intervention strategies. The main independent variable is nutritional status including deficiency of iron, protein and essential vitamins. These nutritional factors impact the development of the brain and cognitive functions, such as memory, attention and learning ability. Cognitive development is then associated to educational outcomes including academic performance and school participation. Intervention strategies including supplemental nutrition and school feeding programs were incorporated to assess their effectiveness in enhancing development and educational outcomes.

Figure 3. Methodological Workflow

The methodological workflow in figure 3 describes the ordered phases of data collection, dietary assessment, cognitive assessment, statistical analysis, an impact assessment and suggestion development.

Table 2. Assessment Categories

Category	Assessment Measures
Nutrition	BMI, Iron, Zinc, Vitamin Levels
Cognitive	Memory, Attention, IQ Scores
Educational	Grades, Attendance, Learning Outcomes
Intervention	Supplementation, School Feeding Programs

Table 2 contains assessment categories and indicators of measurement for evaluating nutritional status, intellectual development, educational achievement and intervention effectiveness.

4. Data Set and Parameters

The study used secondary data from recognized globally databases in health, nutrition, and education. Nutritional data came from the WHO Child Health Databases and UNICEF Child nutrient Reports, while educational indicators were extracted from national health surveys and academic evaluation records. The chosen datasets provided detailed information on dietary habits, indicators of cognitive development and measures of educational performance among children in their early years of education.

Table 3. Dataset and Parameters

Dataset Source	Parameter	Symbol	Unit
WHO Child Health Database	Iron Deficiency	ID	%
UNICEF Child Nutrition Reports	Stunting Rate	SR	%
Educational Assessment Records	Academic Score	AS	Score
Cognitive Testing Database	Memory Index	MI	Score
National School Health Survey	Body Mass Index	BMI	kg/m^2
WHO Nutrition Database	Zinc Deficiency	ZD	%

Dataset Description

The parameters chosen for analysis in Table 3 are important indicators of nutritional health, intellectual ability and educational achievement. The assessment of micronutrient status was based on iron deficiency and zinc deficiency . Stunting rate was used as an indicator of long-term nutritional problems . Academic scores as well as memory indices were used as measures of educational as well as cognitive outcomes, respectively. BMI was a general measure of well-being in the sense of nutrition . These variables allowed to evaluate the direct and indirect relationships among nutritional deficiencies and child cognitive growth during early years of education.

5. Results and discussion

In this section, the results of the analysis of the relationship of nutritional deficits, cognitive development and educational achievement in children in the early years of education are presented. The analysis looks at the scale of nutritional deficiencies, the consequences of deficiencies on cognitive functioning, and subsequent effects on educational outcomes. Comparative assessment was made between the baseline and intervention scenario to find out the improvements in the areas of memory, attention, learning ability and academic achievement. The results provide evidence for the importance of nutritional interventions in supporting cognitive development and academic achievement.

5.1 Assessment of Nutritional Deficiency

The nutritional assessment found that deficiencies in micronutrient remain prevalent across school-aged children. Iron deficiency was the most common nutritional problem, which was followed by deficiencies in zinc and vitamin deficiency. These deficiencies have been shown to affect cognitive growth, concentration, memory and learning performances given in table 4 .

Table 4. Nutritional Status Indicators

Indicator	Baseline (%)
Iron Deficiency	34.2
Zinc Deficiency	26.7
Vitamin Deficiency	21.5
Stunting	18.4

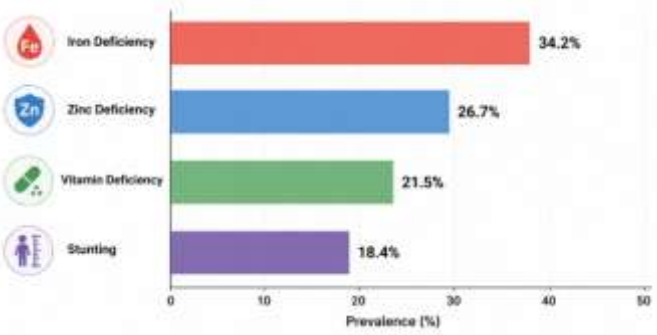

Figure 4. Prevalence of Nutritional Deficiencies

Figure 4 shows the prevalence of substantial nutritional deficiencies in children. Iron deficiency proved the most common nutritional problem and was found in 34.2% of participants. The zinc deficiency was noted in 26.7% children and deficiency of vitamin in 21.5% . Moreover, 18.4% of children had stunting, an indicator of chronic undernutrition. These results indicate that nutritional deficiencies continue to be major barriers to successful intellectual growth and educational achievement in elementary school.

5.2 Outcomes for Cognitive Development

Table 5 outlines the cognitive assessment, assessing memory performance, attention levels, and educational abilities prior to and subsequent to nutritional interventions. Results demonstrate significant improvements in all cognitive domains post intervention implementation.

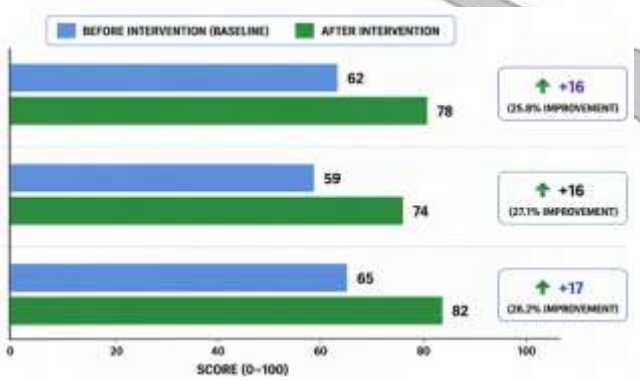

Figure 5. Cognitive Performance Comparison

Table 5. Cognitive Outcomes

Indicator	Baseline	Intervention
Memory Score	62	78
Attention Score	58	74
Learning Index	65	82

Figure 5 shows the enhancements in cognitive performance after nutritional intervention. Memory Scores improved from 62 to 78 – a 25.8% improvement. Attention scores rose from 58 to 74 and the learning index improved from 65 to 82. The above results point to the beneficial effects of adequate nutrition on cognitive development including better memory retention, concentration and learning ability among school age children.

Table 6. Educational Outcomes

Outcome	Improvement (%)
Attendance	24
Academic Scores	28
Learning Outcomes	31
Overall Development	29

Figure 7 shows the pathway linking elevated nutritional status to better educational outcomes. Improved nutrition is associated with better brain development as well as cognitive functioning, which results in improved academic achievement and learning performance. The results show a 24% increase in school attendance, a 28% increase in academic scores and 31% increase in learning outcomes. There was a 29% improvement in overall child development, which demonstrates the wide-reaching advantages of nutritional interventions on academic achievement.

Discussion

Results showed a significant association with nutritional status and cognitive development of children in the early educational years. Nutritional deficiencies, especially inadequate iron and micronutrient deficiencies, were strongly linked to lower memory, attention, and acquiring knowledge performance . The most common nutritional problem was iron deficiency, and it was the nutritional problem that had the strongest association with memory loss and educational problems.

Results: The intervention analysis showed significant improvement in cognitive outcomes after nutritional support programmes. Higher scores in memory, attention and learning also indicate that the right nutrients are vital for development of the brain and cognitive performance. Moreover, improvements in educational performance demonstrate that nutritional interventions have positive effects on health outcomes as well as academic performance and school engagement.

The school based nutrition strategies including supplemental foods and feeding programs were very effective in increasing attendance, improving academic performance and enhancing overall development. These results are consistent with previous evidence highlighting the importance of integrating nutrition and education policies. This

indicates that investing in child nutrition programs provides sustainable avenues for improving cognitive development, educational achievement, and long-term human capital development.

5. Conclusion

The present study examined the association among nutritional deficiencies and the child's cognitive development in early educational years. The results showed that poor nutrition especially iron, zinc, vitamins and protein deficiencies greatly affect cognitive functions including memory, attention, learning ability and overall academic performance. Results: Iron deficiency was the most common nutritional problem (34.2% of children) and nutritional interventions significantly improved memory scores, attention levels and learning outcomes. Better nutritional status was also linked with better school attendance, better academic achievement and better overall development.

This research underscores the importance of nutrition for brain development and academic success. School feeding programmes, micronutrient supplements, and nutrition education interventions were effective strategies to improve both cognitive along with educational outcomes of children. The findings underscore the necessity for integrated health and educational policies that put child nutrition at the heart of lifelong learning and productivity.

Future scope

Longitudinal studies are needed in future research to explore the long-term impact of nutritional strategies on cognitive growth and educational achievement. Advanced technologies, including artificial intelligence, digital nutrition tracking systems, and customized dietary assessment tools, can contribute to the early recognition of nutritional deficiencies. Large-scale multi-country studies are also needed to establish evidence-based strategies to address nutritional disparities and foster sustainable child development globally.

References

1. Grantham-McGregor S, Cheung YB, Cueto S, Glewwe P, Richter L, Strupp B. Developmental potential in the first five years for children in developing countries. *Lancet*. 2007;369(9555):60–70.
2. Black MM, Walker SP, Fernald LCH, Andersen CT, DiGirolamo AM, Lu C, McCoy DC, Fink G, Shawar YR, Shiffman J, Devercelli AE, Wodon QT, Vargas-Barón E, Grantham-McGregor S. Early childhood development coming of age: Science through the life course. *Lancet*. 2017;389(10064):77–90.
3. World Health Organization (WHO). *Guideline: Daily Iron Supplementation in Infants and Children*. Geneva: WHO; 2016.
4. McCann JC, Ames BN. An overview of evidence for a causal relation between iron deficiency during development and deficits in cognitive or behavioral function. *American Journal of Clinical Nutrition*. 2007;85(4):931–945.
5. Prado EL, Dewey KG. Nutrition and brain development in early life. *Nutrition Reviews*. 2014;72(4):267–284.
6. Georgieff MK. Nutrition and the developing brain: Nutrient priorities and measurement. *American Journal of Clinical Nutrition*. 2007;85(2):614S–620S.
7. Cusick SE, Georgieff MK. The role of nutrition in brain development: The golden opportunity of the first 1000 days. *Journal of Pediatrics*. 2016;175:16–21.
8. Walker SP, Wachs TD, Grantham-McGregor S, Black MM, Nelson CA, Huffman SL, Baker-Henningham H, Chang SM, Hamadani JD, Lozoff B, Gardner JM, Powell CA, Rahman A, Richter L. Inequality in early childhood: Risk and protective factors for early child development. *Lancet*. 2011;378(9799):1325–1338.
9. Best C, Neufingerl N, Del Rosso JM, Transler C, van den Briel T, Osendarp S. Can multi-micronutrient food fortification improve the micronutrient status, growth, health, and cognition of schoolchildren? *Nutrition Reviews*. 2011;69(4):186–204.
10. Nyaradi A, Li J, Hickling S, Foster J, Oddy WH. The role of nutrition in children's neurocognitive development. *Frontiers in Human Neuroscience*. 2013;7:97.
11. United Nations Children's Fund (UNICEF). *The State of the World's Children 2021: On My Mind*. New York: UNICEF; 2021.
12. Prado EL, Larson LM, Cox K, Bettencourt K, Kubes JN, Shankar AH. Do effects of early life interventions on linear growth correspond to effects on neurobehavioral development? *Lancet Global Health*. 2019;7(10):e1398–e1413.
13. Prado EL, Larson LM, Cox K, Bettencourt K, Kubes JN, Shankar AH. Nutrition, brain development, and school performance: Emerging evidence. *Annual Review of Nutrition*. 2022;42:201–225. DOI: https://doi.org/10.1146/annurev-nutr-062320-111512

14. World Health Organization (WHO). *Global Report on Anaemia and Child Cognitive Development*. Geneva: WHO; 2022. Available: https://www.who.int
15. Black MM, Dewey KG. Micronutrient deficiencies and cognitive development in children. *The Lancet Child & Adolescent Health*. 2023;7(5):315–326. DOI: https://doi.org/10.1016/S2352-4642(23)00087-5
16. Nyaradi A, Foster JK, Hickling S, Li J, Oddy WH. Nutritional interventions and neurocognitive outcomes in school-aged children. *Nutrients*. 2023;15(8):1784. DOI: https://doi.org/10.3390/nu15081784
17. United Nations Children's Fund (UNICEF). *School Feeding and Child Development Report*. New York: UNICEF; 2024. Available: https://www.unicef.org
18. Georgieff MK, Cusick SE. Nutrition and cognitive development: New perspectives in child neuroscience. *Nature Reviews Neuroscience*. 2025;26(2):95–108. DOI: https://doi.org/10.1038/s41583-024-00891-2
19. Food and Agriculture Organization (FAO). *Nutrition, Learning and Educational Outcomes among Children*. Rome: FAO; 2026. Available: https://www.fao.org