iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** VII **Month of publication:** July 2026

DOI:

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue VII July 2026- Available at www.ijraset.com

Early Childhood Nutrition and Its Impact on Growth and Cognitive Development

Rimly Mukherjee[1], Jagannath Ghosh[2], Mainak Sur[3], Souvik Tewari[4]
[1]*Research scholar of Swami Vivekananda University Barrackpore, West Bengal, India*
[3]*Chief Physiotherapist, Thera-Cure Advanced Physiotherapy Clinic, Shyamnagar, North 24 Parganas, West Bengal, India*
[2, 4]*Assistant Professor, Department of Food and Nutrition, Swami Vivekananda University, Barrackpore, W.B., India*

Abstract: ***Background: Early childhood, particularly the first 1,000 days of life, is a critical period for physical growth, brain development, and long-term health outcomes. Adequate nutrition during this period influences growth trajectories, cognitive performance, educational attainment, and future productivity. Conversely, malnutrition, micronutrient deficiencies, and poor dietary quality can result in growth retardation and impaired cognitive development.***
Objective: This systematic review aims to examine the relationship between early childhood nutrition and its impact on physical growth and cognitive development among children from birth to five years of age.
Methods: A systematic review of literature was conducted using studies published in peer-reviewed journals. Relevant studies investigating the effects of nutritional status, breastfeeding, complementary feeding, and micronutrient intake on growth and cognitive outcomes in children aged 0–5 years were included. Data were synthesized narratively to identify key findings and emerging trends.
Results: Evidence consistently demonstrates that adequate nutrition during early childhood is associated with improved growth indicators, including height-for-age, weight-for-age, and reduced risk of stunting. Breastfeeding, dietary diversity, and sufficient intake of essential micronutrients such as iron, iodine, zinc, and vitamin A contribute positively to cognitive development, language acquisition, memory, and academic readiness. Chronic undernutrition and micronutrient deficiencies were associated with delayed cognitive performance and lower developmental scores.
Conclusion: Early childhood nutrition plays a pivotal role in shaping physical growth and cognitive development. Policies promoting maternal nutrition, exclusive breastfeeding, timely complementary feeding, and micronutrient supplementation are essential to optimize child development outcomes.
Keywords: Early childhood nutrition, cognitive development, growth, stunting, breastfeeding, micronutrients, child development, systematic review.

I. INTRODUCTION

Nutrition during early childhood is a fundamental determinant of health and development. The period from conception to five years of age represents a window of rapid growth and neurological development (Cusick & Georgieff, 2016). During this stage, children require adequate macronutrients and micronutrients to support tissue growth, immune function, and brain maturation (Brkić, 2026; Cusick & Georgieff, 2016). The World Health Organization (WHO) identifies malnutrition as one of the leading causes of morbidity and mortality among children worldwide (Vassilakou, 2021). Undernutrition contributes to stunting, wasting, and underweight conditions, while emerging concerns related to overnutrition and childhood obesity also pose significant public health challenges (Dassie et al., 2024; Vassilakou, 2021). Beyond physical health, nutrition directly influences cognitive processes, including attention, memory, learning capacity, and executive functioning (Brkić, 2026; Cusick & Georgieff, 2016).

Research has increasingly highlighted the importance of the first 1,000 days—from conception to a child's second birthday—as a critical period during which nutritional interventions yield the greatest developmental benefits (Suri, 2025; Nyarko et al., 2023). This review synthesizes available evidence regarding the impact of early childhood nutrition on growth and cognitive development.

II. METHODS

A. Review Design

This study employed a systematic review approach to identify, evaluate, and synthesize evidence concerning early childhood nutrition and developmental outcomes.

B. Search Strategy

A comprehensive literature search was conducted across several electronic databases, including PubMed, Scopus, Web of Science, Google Scholar, and the Cochrane Library, to identify relevant studies examining the relationship between early childhood nutrition, growth, and cognitive development (Mulyani, 2025; Nurliyana et al., 2016). The search strategy incorporated a combination of keywords and Medical Subject Headings (MeSH) terms, including "early childhood nutrition," "child growth," "cognitive development," "stunting," "micronutrient deficiency," "breastfeeding," "complementary feeding," and "nutrition and intelligence" (Mulyani, 2025; Nurliyana et al., 2016). Boolean operators such as AND and OR were used to combine and refine search terms, thereby enhancing the sensitivity and specificity of the search.

To achieve a rigorous and systematic mapping of predictors, structural frameworks like the Population, Intervention, Comparison, and Outcome (PICO) strategy were applied where appropriate to establish strict inclusion and exclusion criteria during the screening workflow (Ayue, 0). Additional relevant articles were identified through manual screening of reference lists from selected studies to ensure comprehensive coverage of the available literature.

C. Inclusion Criteria

The inclusion criteria were established to ensure that the selected studies were relevant to the objectives of this review. First, studies were included if they examined children aged 0–5 years, as this age range represents a critical period for growth and cognitive development. Second, eligible studies were required to assess nutritional factors, such as breastfeeding practices, complementary feeding, dietary intake, or micronutrient status, in relation to developmental outcomes. Third, only articles published in peer-reviewed journals were considered to ensure the scientific quality and credibility of the evidence. Fourth, studies had to report measurable indicators of physical growth (e.g., height-for-age, weight-for-age, or stunting prevalence) or cognitive development (e.g., intelligence, learning ability, memory, language skills, or developmental milestones). Finally, only studies published in the English language were included to facilitate accurate interpretation and analysis of the findings.

D. Exclusion Criteria

Studies were excluded based on predefined criteria to maintain the relevance and quality of the review. First, studies focusing exclusively on adolescents or adults were excluded because the review specifically targeted early childhood populations aged 0–5 years. Second, conference abstracts, editorials, commentaries, and other publications without accessible full texts were excluded due to insufficient methodological and outcome details. Third, studies that did not include relevant measures of nutrition, growth, or cognitive development were omitted, as they did not directly address the research objectives. Finally, duplicate publications identified across multiple databases were removed to prevent redundancy and ensure that each study contributed uniquely to the review findings.

E. Data Extraction and Analysis

Data regarding study design, population characteristics, nutritional interventions, growth outcomes, and cognitive measures were extracted and analyzed through narrative synthesis.

III. RESULTS

A. Nutrition and Physical Growth

1) Breastfeeding and Growth

Multiple studies have demonstrated that exclusive breastfeeding during the first six months of life plays a crucial role in promoting healthy growth and development in infants (Kramer & Kakuma, 2004; World Health Organization [WHO], 2025). Breast milk provides an optimal balance of nutrients, bioactive compounds, hormones, and antibodies that support physical growth while protecting against infections and illnesses (Gila-Diaz et al., 2025; WHO, 2025). Evidence suggests that exclusively breastfed infants experience appropriate weight gain, improved nutritional status, and more favorable growth trajectories compared to those who are not exclusively breastfed (Centers for Disease Control and Prevention [CDC], 2024; WHO, 2025).

Furthermore, the immunological properties of breast milk help reduce the incidence of common childhood infections, such as respiratory and gastrointestinal tract illnesses, which can otherwise severely impair growth and nutrient absorption (Gila-Diaz et al., 2025; Kramer & Kakuma, 2004). As a result, exclusive breastfeeding has been consistently associated with a lower risk of malnutrition, including conditions like stunting, and contributes significantly to achieving healthy growth outcomes during early childhood (Kramer & Kakuma, 2004).

2) Complementary Feeding Practices

Appropriate complementary feeding initiated at six months of age is essential for meeting the increasing nutritional requirements of growing children, as breast milk alone is no longer sufficient to provide all necessary nutrients (Dewey, 2001; Fewtrell et al., 2017). Research indicates that the timely introduction of safe, adequate, and nutrient-dense complementary foods plays a vital role in supporting healthy growth and development (Vakilna et al., 2021). Dietary diversity, which includes the consumption of foods from multiple food groups, has been consistently associated with improved growth outcomes and a reduced risk of undernutrition (Mazzocchi et al., 2026; Vijayalakshmi et al., 2025).

In particular, protein-rich foods such as eggs, dairy products, legumes, fish, and meat contribute significantly to muscle growth, tissue development, and overall physical development by providing crucial essential amino acids and micronutrients like iron and zinc (Dewey, 2001; Kittisakmontri et al., 2020). Conversely, inadequate complementary feeding practices, including the delayed introduction of complementary foods, poor dietary quality, and insufficient nutrient intake, have been linked to growth faltering, an increased risk of stunting, and adverse health outcomes during early childhood (Afifah et al., 2024; Vakilna et al., 2021).

3) Stunting and Chronic Undernutrition

Stunting remains one of the most common and serious consequences of chronic undernutrition during early childhood, reflecting prolonged exposure to inadequate nutrition, recurrent infections, and poor living conditions. Children who are stunted typically exhibit reduced height-for-age, delayed physical growth and maturation, and increased vulnerability to infectious diseases due to compromised immune function. This vulnerability stems from complex, generalized immune system defects that involve both innate and adaptive pathways, creating a dangerous cycle where undernutrition hinders immunity and recurrent infections further halt linear growth.

Beyond its immediate impact on physical development, stunting—often described broadly as a "stunting syndrome"—is associated with profound, long-term developmental disadvantages. These include poorer cognitive and verbal performance, lower educational attainment, and a heightened susceptibility to metabolic or degenerative diseases if followed by rapid weight gain in later childhood. These developmental bottlenecks manifest globally as severe economic penalties, resulting in reduced adult wages and diminished workforce productivity later in life.

Evidence from numerous longitudinal and intervention studies suggests that nutritional deficiencies experienced during critical periods of growth—particularly within the first 1,000 days from conception—can have lasting and, in some cases, irreversible effects on neurocognitive and structural pathways if timely interventions are not implemented. Therefore, preventing chronic undernutrition through adequate maternal and child nutrition, targeted supplementation, and healthcare during early childhood is essential for promoting optimal growth, expanding economic opportunities, and ensuring lifelong well-being.

B. Micronutrients and Growth

1) Iron

Iron deficiency is one of the most widespread nutritional deficiencies affecting children worldwide and represents a major public health concern, particularly in low- and middle-income countries (Armitage & Moretti, 2019; McCarthy et al., 2021). Iron plays a crucial role in hemoglobin synthesis, which is essential for the transport of oxygen throughout the body, as well as in various metabolic and neurological processes (McCarthy et al., 2021; Osendarp et al., 2010). Adequate iron intake during early childhood supports healthy growth, brain development, and cognitive functioning by ensuring sufficient oxygen delivery to tissues and organs (Armitage & Moretti, 2019; Osendarp et al., 2010).

Conversely, iron deficiency can lead to iron deficiency anemia, a condition associated with fatigue, weakened immunity, impaired physical growth, and delayed cognitive and motor development (Chen et al., 2022; Hermoso et al., 2011). Numerous studies have demonstrated that children with iron deficiency anemia are at greater risk of developmental delays and poorer educational outcomes, highlighting the importance of maintaining adequate iron status during the early years of life (Chen et al., 2022; Hermoso et al., 2011; McCann et al., 2020).

2) Iodine

Iodine is an essential micronutrient that plays a vital role in the production of thyroid hormones, which are necessary for normal growth, metabolism, and brain development during early childhood. Adequate iodine intake is particularly important during infancy and early childhood, as thyroid hormones regulate neuronal growth, myelination, and cognitive functioning.

Iodine deficiency can have serious consequences for child development, including reduced intelligence quotient (IQ), developmental delays, impaired motor skills, and learning difficulties. Severe iodine deficiency may lead to irreversible neurological damage and intellectual disabilities, while even mild to moderate deficiencies can negatively affect cognitive performance and academic achievement. Therefore, ensuring sufficient iodine intake through iodized salt, dietary sources, and public health interventions is crucial for promoting optimal growth and cognitive development in young children (Chen et al., 2022; Hermoso et al., 2011)

3) Zinc

Zinc is an essential micronutrient that plays a critical role in numerous biological processes necessary for healthy growth and development during early childhood (Krebs et al., 2014). It is involved in cellular growth, immune system function, protein synthesis, DNA replication, and tissue repair, making it indispensable for normal physical development (Black, 1998). Adequate zinc intake supports proper growth by facilitating cell division and the formation of new tissues, while also enhancing the body's ability to resist infections (Krebs et al., 2014). Zinc deficiency has been associated with growth retardation, weakened immune responses, increased susceptibility to infectious diseases, and delayed development (Rerksuppaphol & Rerksuppaphol, 2018). Several studies and meta-analyses have reported that zinc supplementation can improve linear growth, particularly among children living in regions where zinc deficiency is prevalent (Imdad & Bhutta, 2011). These findings highlight the importance of ensuring sufficient zinc intake through a balanced diet and targeted nutritional interventions to promote optimal growth and overall health in young children (Mayo-Wilson et al., 2014).

4) Vitamin A

Vitamin A is an essential micronutrient that plays a crucial role in maintaining normal vision, supporting immune function, and promoting cellular growth and development during early childhood. It contributes to the growth and differentiation of epithelial tissues, helps maintain the integrity of mucosal surfaces, and enhances the body's ability to fight infections. Adequate vitamin A intake is particularly important for young children, as it supports healthy growth and reduces the risk of illness. Vitamin A deficiency can weaken immune defenses, increasing susceptibility to infections such as measles and diarrheal diseases, which may further compromise nutritional status and growth. In severe cases, deficiency can lead to visual impairment and blindness. Consequently, ensuring adequate vitamin A intake through dietary sources and supplementation programs is essential for promoting optimal growth, health, and development in early childhood (Imdad & Bhutta, 2011).

C. Nutrition and Cognitive Development

1) Brain Development in Early Childhood

Brain development during early childhood is highly sensitive to nutritional status, as this period is characterized by rapid growth, neural connectivity, and cognitive maturation (Georgieff, 2007; Prado & Dewey, 2014). Adequate nutrition provides the essential building blocks required for the development and functioning of the central nervous system (Black, 2003). Several nutrients, including iron, iodine, zinc, omega-3 fatty acids, choline, and folate, play critical roles in neurodevelopment by supporting processes such as synapse formation, myelination, and neurotransmitter production (Cusick & Georgieff, 2016). Iron facilitates oxygen transport and neural metabolism, while iodine is essential for thyroid hormone synthesis and brain maturation (Georgieff, 2011; Zimmermann, 2011). Zinc contributes to neuronal growth and cognitive functioning, whereas omega-3 fatty acids support brain structure and communication between nerve cells (Bhatnagar & Taneja, 2001; Innis, 2007). Choline and folate are important for cell membrane formation and DNA synthesis, which are necessary for healthy brain development (Zeisel & da Costa, 2009; Black, 2008). Adequate intake of these nutrients during early childhood promotes optimal cognitive function, learning capacity, memory, and overall neurological health, while deficiencies may result in developmental delays and long-term cognitive impairments (Prado & Dewey, 2014; Cusick & Georgieff, 2016).

2) Breastfeeding and Cognitive Outcomes

A substantial body of evidence consistently associates breastfeeding with improved cognitive performance and neurodevelopmental outcomes in children (Horta et al., 2015; Victora et al., 2016). Breast milk contains essential nutrients, including long-chain polyunsaturated fatty acids, growth factors, and bioactive compounds, that support brain growth and function during critical stages of development (Isaacs et al., 2010).

Research has shown that children who are breastfed often demonstrate higher IQ scores, better language and communication skills, improved memory, and enhanced academic performance compared to those who are not breastfed or are breastfed for shorter durations (Anderson et al., 1999; Belfort et al., 2013). These cognitive benefits are believed to result from both the nutritional composition of breast milk and the positive mother–child interactions associated with breastfeeding (Victora et al., 2016). Furthermore, longitudinal studies suggest that the cognitive advantages linked to breastfeeding may persist beyond early childhood, extending into adolescence and adulthood, where they are associated with better educational attainment and cognitive functioning (Horta et al., 2015; Reynolds, 2001). These findings highlight the important role of breastfeeding in supporting optimal cognitive development and lifelong learning outcomes.

3) Micronutrient Deficiencies and Cognitive Performance

Micronutrient deficiencies during early childhood can have significant adverse effects on cognitive development and overall brain function. Iron deficiency, particularly during infancy, has been associated with reduced attention span, poor memory performance, impaired learning capacity, and delayed psychomotor development due to its critical role in brain metabolism and neurotransmitter function. Similarly, iodine deficiency is widely recognized as one of the leading preventable causes of intellectual disability worldwide, as inadequate iodine intake can impair thyroid hormone production, which is essential for normal brain growth and neurological development. Zinc deficiency has also been linked to negative effects on cognitive functioning, including difficulties in learning, attention, and behavioral regulation. Because the developing brain is highly sensitive to nutrient availability, deficiencies in these essential micronutrients during critical periods of growth may result in long-lasting cognitive impairments and reduced educational achievement. Therefore, ensuring adequate micronutrient intake is crucial for supporting optimal cognitive performance and developmental outcomes in young children (Reynolds, 2001).

D. Long-Term Effects of Early Childhood Nutrition

Early childhood nutrition has profound and lasting effects on an individual's health, educational achievement, and socioeconomic well-being throughout life (Victora et al., 2008; Grantham-McGregor et al., 2007). Poor nutrition during the critical early years can lead to adverse outcomes, including lower educational attainment, reduced cognitive capacity, decreased workforce productivity, and an increased risk of chronic diseases such as obesity, diabetes, and cardiovascular disorders in adulthood (Black et al., 2013; Barker, 2004). Additionally, children who experience malnutrition are more likely to face social and economic disadvantages later in life, contributing to cycles of poverty and reduced opportunities (Hoddinott et al., 2013). In contrast, adequate nutrition during early childhood supports school readiness, enhances learning ability and academic success, and contributes to improved physical and cognitive development (Walker et al., 2011). These benefits often translate into greater economic productivity, higher earning potential, and a better overall quality of life in adulthood (Victora et al., 2008). Evidence from several longitudinal cohort studies demonstrates that nutritional interventions implemented during the first two years of life can yield significant long-term benefits, underscoring the importance of investing in early childhood nutrition as a strategy for promoting individual and societal development (Hoddinott et al., 2008; Gertler et al., 2014).

IV. DISCUSSION

The findings of this review reinforce the critical role of nutrition in determining child growth and cognitive development. Adequate nutrition during infancy and early childhood supports healthy physical development and optimal neurological functioning.

The evidence indicates that both macronutrient sufficiency and micronutrient adequacy are necessary for favorable developmental outcomes. Breastfeeding remains one of the most effective strategies for promoting healthy growth and cognitive performance. Furthermore, dietary diversity and nutrient-rich complementary foods are essential after six months of age.

Micronutrients, particularly iron, iodine, zinc, and vitamin A, emerged as significant contributors to developmental outcomes. Deficiencies in these nutrients can impair growth and cognitive function, emphasizing the need for targeted supplementation and food-fortification programs.

The review also highlights the long-term consequences of early nutritional deprivation. Stunted children are more likely to experience educational difficulties, reduced earning potential, and poorer health later in life. These findings underscore the importance of early intervention programs and comprehensive nutrition policies.

V. LIMITATIONS

Several limitations of this systematic review should be acknowledged when interpreting the findings. First, considerable variability existed among the included studies regarding research designs, sample sizes, assessment tools, and outcome measures, which may have affected the comparability of results and limited the ability to draw definitive conclusions. Second, differences in socioeconomic, cultural, and geographic contexts across study populations may have influenced nutritional practices, access to healthcare, and developmental outcomes, thereby affecting the generalizability of the findings. Third, the possibility of publication bias cannot be excluded, as studies reporting significant or positive associations are more likely to be published than those with null or negative results. Finally, although some studies provided longitudinal evidence, the availability of long-term follow-up data was limited in several cases, restricting the assessment of the sustained effects of early childhood nutrition on growth and cognitive development. Future research should employ standardized measurement tools, rigorous study designs, and long-term longitudinal approaches to better establish causal relationships and strengthen the evidence base regarding the impact of nutrition on child development.

VI. RECOMMENDATIONS

Based on the findings of this systematic review, several recommendations can be made to improve early childhood nutrition and support optimal growth and cognitive development. First, exclusive breastfeeding should be actively promoted during the first six months of life, as it provides essential nutrients and supports healthy physical and cognitive development. Second, nutritionally adequate complementary foods should be introduced at six months of age to meet the increasing nutritional needs of growing children while ensuring dietary diversity and sufficient nutrient intake. Third, micronutrient supplementation and food fortification programs should be strengthened, particularly for nutrients such as iron, iodine, zinc, and vitamin A, which are critical for growth and neurodevelopment. Fourth, efforts to improve maternal nutrition during pregnancy and lactation should be prioritized, as maternal nutritional status directly influences fetal growth and infant health outcomes. Fifth, community-based nutrition education initiatives should be implemented to enhance caregivers' knowledge of appropriate infant and young child feeding practices. Finally, governments and public health organizations should develop and strengthen policies aimed at improving food security, reducing malnutrition, and ensuring equitable access to nutritious foods for all children. Collectively, these strategies can contribute to better developmental outcomes and improved long-term health and well-being among children.

Table: 1 Early Childhood Nutrition and Its Impact on Growth and Cognitive Development (Walker et al., 2011; Hoddinott et al., 2013).

Nutritional Factor	Role in Early Childhood	Impact on Physical Growth	Impact on Cognitive Development
Adequate Energy Intake	Provides calories required for growth and daily activities	Supports normal weight gain and height growth	Enhances attention, learning capacity, and brain function
Protein	Essential for tissue building and repair	Promotes muscle development and overall body growth	Supports neurotransmitter synthesis and brain development
Iron	Required for hemoglobin formation and oxygen transport	Prevents anemia and growth retardation	Improves memory, concentration, and cognitive performance
Iodine	Necessary for thyroid hormone production	Supports normal growth and metabolism	Critical for brain development and intelligence quotient (IQ)
Zinc	Involved in cell growth and immune function	Enhances growth velocity and immune health	Improves neuropsychological function and learning ability
Vitamin A	Supports vision, immunity, and cell differentiation	Promotes healthy growth and development	Contributes to neurological development and visual processing
Vitamin D	Regulates calcium and phosphorus metabolism	Ensures proper bone growth and skeletal development	Supports neurodevelopment and cognitive function
Omega-3 Fatty Acids (DHA)	Structural component of brain tissue	Supports healthy growth and development	Enhances memory, problem-solving skills, and visual acuity
Breastfeeding	Provides balanced nutrients and bioactive compounds	Reduces risk of malnutrition and infections	Associated with improved cognitive outcomes and academic performance
Complementary Feeding	Supplies additional nutrients after 6 months	Prevents stunting and undernutrition	Supports continued brain growth and developmental milestones
Micronutrient Sufficiency	Prevents nutrient deficiencies	Maintains optimal growth patterns	Facilitates cognitive, behavioral, and emotional development
Balanced Diet	Ensures adequate intake of all essential nutrients	Promotes healthy physical growth and immunity	Improves learning, memory, and school readiness

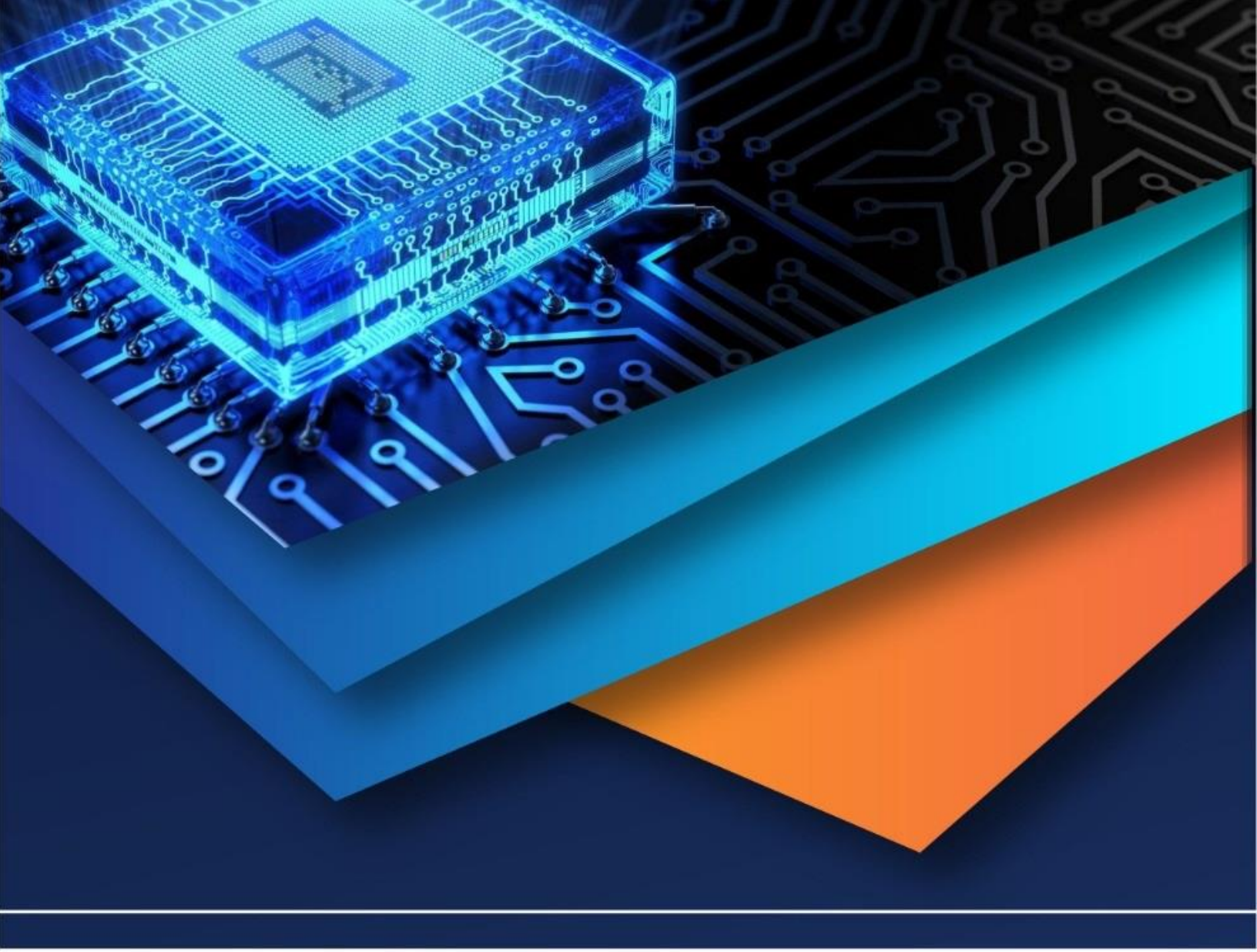
VII. CONCLUSION

Early childhood nutrition is a major determinant of both physical growth and cognitive development. The evidence reviewed demonstrates that adequate nutritional intake during the first years of life contributes significantly to healthy growth patterns, enhanced cognitive functioning, and improved long-term outcomes. Preventing malnutrition and addressing micronutrient deficiencies should remain a global public health priority. Investments in early childhood nutrition yield substantial benefits for individuals, communities, and national development.

REFERENCES

[1] Afifah, E. (2024). Determinants of suboptimal complementary feeding practices among children aged 6–24 months in Natuna. Jurnal Gizi dan Kesehatan, 16(1), 33–42.
[2] Anderson, J. W., Johnstone, B. M., & Remley, D. T. (1999). Breast-feeding and cognitive development: A meta-analysis. The American Journal of Clinical Nutrition, 70(4), 525–535.
[3] Armitage, A. E., & Moretti, D. (2019). The importance of iron status for young children in low- and middle-income countries: A narrative review. Pharmaceuticals, 12(2), 59. https://doi.org/10.3390/ph12020059
[4] Ayue, H. I. (0). Exploring the multifactorial predictors of stunting in children under five: A systematic review of the literature, 2015–2024. Systematic Reviews.
[5] Barker, D. J. P. (2004). The developmental origins of adult disease. Journal of the American College of Nutrition, 23(6 Suppl), 588S–595S.
[6] Belfort, M. B., Rifas-Shiman, S. L., Kleinman, K. P., Guthrie, L. B., Bellinger, D. C., Taveras, E. M., Gillman, M. W., & Oken, E. (2013). Infant feeding and childhood cognition at ages 3 and 7 years. JAMA Pediatrics, 167(9), 836–844.
[7] Bhatnagar, S., & Taneja, S. (2001). Zinc and cognitive development. British Journal of Nutrition, 85(S2), S139–S145.
[8] Black, M. M. (1998). Zinc deficiency and child development. The American Journal of Clinical Nutrition, 68(2), 464S–469S. https://doi.org/10.1093/ajcn/68.2.464s
[9] Black, M. M. (2003). Micronutrient deficiencies and cognitive functioning. The Journal of Nutrition, 133(11), 3927S–3931S.
[10] Black, M. M. (2008). Effects of vitamin B12 and folate deficiency on brain development in children. Food and Nutrition Bulletin, 29(2), S126–S131.
[11] Black, R. E., Victora, C. G., Walker, S. P., Bhutta, Z. A., Christian, P., de Onis, M., Ezzati, M., Grantham-McGregor, S., Katz, J., Martorell, R., & Uauy, R. (2013). Maternal and child undernutrition and overweight in low-income and middle-income countries. The Lancet, 382(9890), 427–451.
[12] Brkić, D. (2026). Relationship between nutrition, brain, cognition, learning, and behavior in school age children: Systematic evidence and future opportunities. Nutrition Reviews, Advance online publication.
[13] Centers for Disease Control and Prevention. (2024). Breastfeeding and infant growth standards: Growth chart training. U.S. Department of Health and Human Services. https://www.cdc.gov/growth-chart-training/hcp/using-growth-charts/who-breastfeeding.html
[14] Chen, Z., Yang, H., Wang, D., Sudfeld, C. R., Zhao, A., Xin, Y., Chen, J. C., Fawzi, W. W., Xing, Y., & Li, Z. (2022). Effect of oral iron supplementation on cognitive function among children and adolescents in low- and middle-income countries: A systematic review and meta-analysis. Nutrients, 14(24), 5332. https://doi.org/10.3390/nu14245332
[15] Cusick, S. E., & Georgieff, M. K. (2016). The role of nutrition in brain development: The golden opportunity of the "first 1000 days". The Journal of Pediatrics, 175, 16–21. https://doi.org/10.1016/j.jpeds.2016.05.013
[16] Cusick, S. E., & Georgieff, M. K. (2016). The role of nutrition in brain development: The golden opportunity of the first 1000 days. The Journal of Pediatrics, 175, 16–21.
[17] Dassie, G. A., Chala Fantaye, T., Charkos, T. G., Sento Erba, M., & Balcha Tolosa, F. (2024). Factors influencing concurrent wasting, stunting, and underweight among children under five who suffered from severe acute malnutrition in low- and middle-income countries: A systematic review. Frontiers in Nutrition, 11. https://doi.org/10.3389/fnut.2024.1452963
[18] Dewey, K. G. (2001). Nutrition, growth, and complementary feeding of the breastfed infant. Pediatric Clinics of North America, 48(1), 87–104. https://doi.org/10.1016/s0031-3955(05)70287-x
[19] Fewtrell, M., Bronsky, J., Campoy, C., Domellöf, M., Embleton, N., Fidler Mis, N., Hojsak, I., Hulst, J. M., Indrio, R., Lapillonne, A., & Mølgaard, C. (2017). Complementary feeding: A position paper by the European Society for Paediatric Gastroenterology, Hepatology, and Nutrition (ESPGHAN). Journal of Pediatric Gastroenterology and Nutrition, 64(1), 119–132. https://doi.org/10.1097/mpg.0000000000001454
[20] Georgieff, M. K. (2007). Nutrition and the developing brain: Nutrient priorities and measurement. The American Journal of Clinical Nutrition, 85(2), 614S–620S.
[21] Georgieff, M. K. (2011). Long-term brain and behavioral consequences of early iron deficiency. Nutrition Reviews, 69(Suppl. 1), S43–S48.
[22] Gertler, P., Heckman, J., Pinto, R., Zanolini, A., Vermeersch, C., Walker, S., Chang, S. M., & Grantham-McGregor, S. (2014). Labor market returns to an early childhood stimulation intervention in Jamaica. Science, 344(6187), 998–1001.
[23] Gila-Diaz, A., Arribas, S. M., & Ramiro-Cortijo, D. (2025). Breastfeeding: The multifaceted impact on child development and maternal well-being. Nutrients, 17(8), 1326. https://doi.org/10.3390/nu17081326
[24] Grantham-McGregor, S., Cheung, Y. B., Cueto, S., Glewwe, P., Richter, L., Strupp, B., & International Child Development Steering Group. (2007). Developmental potential in the first 5 years for children in developing countries. The Lancet, 369(9555), 60–70.
[25] Hermoso, M., Vucic, V., Vollhardt, C., Arsic, A., Roman-Viñas, B., Iglesia-Altaba, Iris., Gurinovic, M., & Koletzko, B. (2011). The effect of iron on cognitive development and function in infants, children and adolescents: A systematic review. Annals of Nutrition and Metabolism, 59(2-4), 154-165. https://doi.org/10.1159/000334490
[26] Hoddinott, J., Alderman, H., Behrman, J. R., Haddad, L., & Horton, S. (2013). The economic rationale for investing in stunting reduction. Maternal & Child Nutrition, 9(Suppl. 2), 69–82.

[27] Hoddinott, J., Maluccio, J. A., Behrman, J. R., Flores, R., & Martorell, R. (2008). Effect of a nutrition intervention during early childhood on economic productivity in Guatemalan adults. The Lancet, 371(9610), 411–416.
[28] Horta, B. L., de Mola, C. L., & Victora, C. G. (2015). Breastfeeding and intelligence: Systematic review and meta-analysis. World Health Organization.
[29] Imdad, A., & Bhutta, Z. A. (2011). Effect of preventive zinc supplementation on linear growth in children under 5 years of age in developing countries: a meta-analysis of studies for input to the lives saved tool. BMC Public Health, 11(Suppl 3), S22. https://doi.org/10.1186/1471-2458-11-s3-s22
[30] Innis, S. M. (2007). Dietary (n-3) fatty acids and brain development. The Journal of Nutrition, 137(4), 855–859.
[31] Isaacs, E. B., Fischl, B. R., Quinn, B. T., Chong, W. K., Gadian, D. G., & Lucas, A. (2010). Impact of breast milk on intelligence quotient, brain size, and white matter development. Pediatric Research, 67(4), 357–362.
[32] Kittisakmontri, K., Lanigan, J., Wells, J. C. K., & Fewtrell, M. (2020). The impact of dietary protein in complementary foods on infant growth and body composition in a population facing the double burden of malnutrition: Protocol for a multicenter, prospective cohort study. JMIR Research Protocols, 9(10), e18112. https://doi.org/10.2196/18112
[33] Kramer, M. S., & Kakuma, R. (2004). The optimal duration of exclusive breastfeeding: A systematic review. Advances in Experimental Medicine and Biology, 554, 63–77. https://doi.org/10.1007/978-1-4757-4242-8_7
[34] Krebs, N. F., Miller, L. V., & Michael Hambidge, K. (2014). Zinc deficiency in infants and children: a review of its complex and synergistic interactions. Paediatrics and International Child Health, 34(4), 279–288. https://doi.org/10.1179/2046905514y.000000151 Cited by: 238
[35] Mayo-Wilson, E., Imdad, A., Junior, J., Dean, S., & Bhutta, Z. A. (2014). Preventive zinc supplementation for children, and the effect of additional iron: a systematic review and meta-analysis. BMJ Open, 4(6), e004647. https://doi.org/10.1136/bmjopen-2013-004647
[36] Mazzocchi, A., et al. (2026). Sustainable complementary feeding in low-resource countries: Bridging global recommendations and local food systems. Frontiers in Sustainable Food Systems, 10, 1818978. https://doi.org/10.3389/fsufs.2026.1818978
[37] McCann, S., Perapoch Amadó, M., & Moore, S. E. (2020). The role of iron in brain development: A systematic review. Nutrients, 12(7), 2001. https://doi.org/10.3390/nu12072001
[38] McCarthy, E. K., Murray, D. M., & Kiely, M. E. (2021). Iron deficiency during the first 1000 days of life: Are we doing enough to protect the developing brain? Proceedings of the Nutrition Society, 81(1), 108-118. https://doi.org/10.1017/s0029665121002858
[39] Mulyani, A. T. (2025). Understanding Stunting: Impact, Causes, and Strategy to Accelerate Stunting Reduction—A Narrative Review. Global Health Perspectives.
[40] Nurliyana, A. R., Mohd Shariff, Z., Mohd Taib, M. N., Gan, W. Y., & Tan, K. A. (2016). Early nutrition, growth and cognitive development of infants from birth to 2 years in Malaysia: a study protocol. BMC Pediatrics, 16, Article 160. https://doi.org/10.1186/s12887-016-0700-0
[41] Nyarko, M. J., van Rooyen, D., & ten Ham-Baloyi, W. (2023). Preventing malnutrition within the first 1000 days of life in under-resourced communities: An integrative literature review. Journal of Child Health Care, 28(4), 898–913. https://doi.org/10.1177/13674935231166427
[42] Osendarp, S. J. M., Murray-Kolb, L. E., & Black, M. M. (2010). Case study on iron in mental development - in memory of John Beard (1947-2009). Nutrition Reviews, 68(Suppl 1), S48-S52. https://doi.org/10.1111/j.1753-4887.2010.00331.x
[43] Prado, E. L., & Dewey, K. G. (2014). Nutrition and brain development in early life. Nutrition Reviews, 72(4), 267–284.
[44] Rerksuppaphol, S., & Rerksuppaphol, L. (2018). Zinc supplementation enhances linear growth in school-aged children: A randomized controlled trial. Pediatric Reports, 9(4), 7294. https://doi.org/10.4081/pr.2017.7294
[45] Reynolds, A. (2001). Breastfeeding and brain development. Pediatric Clinics of North America, 48(1), 159–171.
[46] Suri, S. (2025). Editorial: The first 1000 days: Window of opportunity for child health and development. Frontiers in Public Health, 13.
[47] Vakilna, R., et al. (2021). Complementary feeding practices among children aged 6–23 months in Gujarat, India: Patterns, predictors and barriers. PLOS ONE, 16(12), e12932150. https://doi.org/10.1371/journal.pone.12932150
[48] Vassilakou, T. (2021). Childhood malnutrition: Time for action. Children, 8(2), 103. https://doi.org/10.3390/children8020103
[49] Victora, C. G., Adair, L., Fall, C., Hallal, P. C., Martorell, R., Richter, L., & Sachdev, H. S. (2008). Maternal and child undernutrition: Consequences for adult health and human capital. The Lancet, 371(9609), 340–357.
[50] Victora, C. G., Horta, B. L., de Mola, C. L., Quevedo, L., Pinheiro, R. T., Gigante, D. P., Gonçalves, H., & Barros, F. C. (2016). Association between breastfeeding and intelligence, educational attainment, and income at 30 years of age: A prospective birth cohort study from Brazil. The Lancet Global Health, 3(4), e199–e205.
[51] Vijayalakshmi, R., et al. (2025). Complementary feeding practices and their association with nutritional status of 6-23-month-old infants in Chennai, Tamil Nadu. Caspian Journal of Pediatrics, 11(1), e6.
[52] Walker, S. P., Wachs, T. D., Grantham-McGregor, S., Black, M. M., Nelson, C. A., Huffman, S. L., Baker-Henningham, H., Chang, S. M., Hamadani, J. D., Lozoff, B., Gardner, J. M., Powell, C. A., Rahman, A., & Richter, L. (2011). Inequality in early childhood: Risk and protective factors for early child development. The Lancet, 378(9799), 1325–1338.
[53] World Health Organization. (2025). Global nutrition targets 2030: Breastfeeding brief. World Health Organization. https://www.who.int/health-topics/breastfeeding
[54] Zeisel, S. H., & da Costa, K. A. (2009). Choline: An essential nutrient for public health. Nutrition Reviews, 67(11), 615–623.
[55] Zimmermann, M. B. (2011). The role of iodine in human growth and development. Seminars in Cell & Developmental Biology, 22(6), 645–652.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY