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The Role of Nutrition in Preventing Developmental and Cognitive Problems in Early Childhood: A Neuroscience Perspective

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ABSTRACT

Early childhood is a critical period for brain and cognitive development, which is strongly influenced by nutritional factors. This article aims to examine the role of nutrition in preventing developmental and cognitive problems in young children from a neuroscience perspective. Using the Systematic Literature Review (SLR) method, this study reviewed ten scientific articles from various reliable sources published between 2007 and 2025. The findings indicate that adequate nutritional intake—particularly iron, iodine, omega-3 fatty acids, and B-complex vitamins—has a significant impact on brain structure and function as well as children's cognitive abilities. Family conditions and dietary diversity also play an important role in neurological development. In addition, interactions between nutrition, physical activity, and gut microbiota emerge as relevant recent findings in supporting brain

health. This article concludes that early nutritional interventions should be a primary focus of child health and education policies and must be supported by multisectoral approaches to foster a healthy, intelligent, and productive generation.

Introduction

Early childhood is a highly critical phase in human development, as this period involves rapid brain growth and heightened vulnerability to environmental influences, including nutritional intake. Nutrition plays a crucial role in supporting growth and development in early childhood (Istiqomah et al., 2024). During this phase, a child's body grows at an accelerated rate, requiring adequate and balanced nutritional intake. Proper nutrition supports the formation of healthy body tissues and contributes to the development of various bodily systems, including the nervous and immune systems (Mayar & Astuti, 2021). Therefore, meeting appropriate nutritional needs from an early age is essential to support children's health and quality of life in the future. Nutrition not only influences physical growth but also has a significant impact on cognitive development and neurological function in children.

Deficiencies in essential nutrients such as iron, iodine, omega-3 fatty acids, and B-complex vitamins have been shown to be associated with impairments in cognitive development, attention, as well as delays in language and socio-emotional aspects (Walker et al., 2007). Recent

neuroscience research indicates that nutritional disturbances during early life can permanently alter brain structure and function, particularly in regions related to memory, concentration, and emotional regulation (Georgieff, 2022). In Indonesia, issues such as stunting and micronutrient deficiencies remain major challenges and directly affect children's readiness for learning at school age (Ministry of Health of the Republic of Indonesia, 2023). Therefore, a comprehensive understanding of the relationship between nutrition and cognitive development in early childhood is essential for designing appropriate intervention policies based on neuroscience research.

Neuroscience is a field of study that examines how the nervous system functions. In general, this aspect is often overlooked in educational practice, resulting in less varied learning experiences. Within the field of education, there is ongoing debate among researchers regarding neuroscience, particularly concerning the separation and integration of three elements—brain–mind, soul–body, and reason–emotion—which has yet to reach consensus (Susanti, 2021). Since neuroscience theories were introduced, especially those related to facts about brain development in children, numerous discoveries have helped psychologists conclude that early childhood represents a highly critical period, often referred to as the "golden age." This notion was articulated by a renowned psychologist, Gardner (2006), who stated that during the first five years of life, children typically achieve significant success in

learning various skills. Gardner proposed three explanations for the learning successes achieved by children during this period.

Understanding the interrelationship between nutrition and early childhood development is therefore crucial in supporting optimal growth. Awareness of the importance of adequate nutritional intake should be instilled from an early stage within families, educational settings, and communities. Through continuous efforts to ensure that children receive sufficient nutrition, it is expected that they will grow into healthy, intelligent, and productive individuals (Nasution et al., 2024). Consequently, further research on the effects of nutrition on the growth and development of early childhood is needed to generate more effective recommendations for improving children's quality of life in the future.

During this vital developmental period, parents and early childhood education (ECE) educators are expected to provide various forms of stimulation wisely. At this stage, children not only receive experiences but, more importantly, are prepared and stimulated to maximize the development of their intellectual capacities. Early experiences significantly influence brain development and learning processes. The more experiences children acquire, the more neurons (nerve cells—the primary cells that form the brain and nervous system) will develop.

Methods

This study employed the Systematic Literature Review (SLR)

method to systematically identify, evaluate, and synthesize research findings related to the contribution of nutrition in preventing developmental and cognitive problems in early childhood from a neuroscience perspective. The SLR method was selected because it enables the presentation of comprehensive, transparent, and structured scientific evidence derived from previous peer-reviewed studies, thereby ensuring a high level of reliability and accuracy (Kitchenham & Charters, 2007).

Data collection was conducted by searching for scientific articles obtained from both national and international databases. The national database used was **Garuda**, while the international databases included **PubMed, Scopus, and ScienceDirect**. The article search was limited to publications issued between **2018 and 2024** to ensure the relevance and currency of the scientific findings. Keywords used in the search included *nutrition*, *early childhood*, *cognitive development*, *brain development*, and *neuroscience*, in both Indonesian and English, with adjustments to terminology and the use of Boolean operators (AND, OR) appropriate to each database. Articles included in this review comprised empirical studies and systematic reviews that discussed the relationship between nutritional status—both macronutrients and micronutrients—and neurological function as well as cognitive abilities in children aged 0–5 years.

The selection and analysis process followed the Systematic

Literature Review flow based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The first stage was identification, which involved identifying all relevant articles through systematic searches across the selected databases using the specified keywords. At this stage, an initial pool of articles was obtained, compiled, and managed using reference management software to facilitate the screening process. The next stage was screening, which involved removing duplicate articles and conducting an initial selection based on titles and abstracts. This screening process aimed to ensure that retained articles were aligned with the research focus, namely the relationship between nutrition, brain development, and cognitive abilities in early childhood.

Articles that passed the screening stage proceeded to the eligibility stage, which involved an in-depth full-text review to assess compliance with the predefined inclusion and exclusion criteria. The inclusion criteria were: (1) articles discussing the relationship between nutritional status and neurological and cognitive development in early childhood; (2) studies involving children aged 0–5 years; (3) articles published in reputable journals that had undergone a peer-review process; and (4) articles available in full-text format. The exclusion criteria included articles not relevant to neuroscience-focused discussions, studies involving subjects outside the specified age range, and non-scientific publications such as opinion pieces, editorials, and popular reports.

The final stage was **inclusion**, in which articles meeting all criteria were selected for systematic analysis and synthesis. The included articles were analyzed by extracting key information, including study type, subject characteristics, types of nutrients examined, indicators of neurological and cognitive development, and main research findings. The extracted data were then synthesized narratively to identify patterns of findings, research gaps, and the implications of the reviewed studies for the development of nutritional interventions and early childhood health policies.

Through this approach, the study is expected to provide an in-depth, comprehensive, and evidence-based understanding of the effects of nutrition on brain development and cognitive abilities from early childhood, as well as to strengthen the scientific foundation for decision-making in nutritional intervention strategies and early childhood health policy development.

Result and Discussions

This section presents the results of the literature review regarding the contribution of nutrition in preventing developmental and cognitive problems in early childhood from a neuroscience perspective. Numerous studies have demonstrated a strong relationship between nutritional status in early life and the development of brain structure and function, which directly affects children's cognitive abilities and behavior. Through a systematic analysis of recent studies, this

discussion aims to explain how nutrition, family environment, and other supporting factors play a role in facilitating optimal neural development during this critical period of child growth. The following table compares the content and focus of ten selected articles analyzed in the table. This table is intended to highlight similarities and differences in the focus of each article related to the research topic.

No.	Author & Year	Article Title	Main Findings	Research Objectives
1	Georgieff (2022)	*Early life nutrition and brain development: breakthroughs, challenges and new horizons*	Early-life nutrition influences brain development and neurological function in children.	To review the relationship between early nutrition and child brain development.
2	Walker et al. (2007)	*Child development: Risk factors for adverse outcomes in developing countries*	Nutritional deficiencies are associated with impairments in cognitive and socio-emotional development.	To identify risk factors affecting child development in developing countries.

3	Ministry of Health of the Republic of Indonesia (2023)	*Indonesia Health Profile 2022*	Stunting and micronutrient deficiencies affect children's readiness for learning.	To provide national health data related to children's nutritional status.
4	Elvita et al. (2022)	*Analysis of the Family Environment on Early Childhood Nutritional Intake Affecting Neuroscience*	Dietary patterns and maternal knowledge significantly influence children's brain development.	To examine the role of the family environment in early childhood nutrition.
5	Samigullin et al. (2025)	*A central role of nutrition in cognitive function among primary school children: a cross-sectional analysis*	Nutrition affects cognitive function, emotional regulation, and overall brain health.	To review the relationship between nutrition and children's mental development.
6	Geertsema et al. (2025)	*Nutritional interventions to counteract the detrimental*	Early-life nutrition affects neural	To understand molecular and cellular mechanisms of

		consequences of early-life stress	development and complex behavior in adulthood.	early nutrition on brain development.
7	Theola & Andriastuti (2025)	*Neurodevelopmental Impairments as Long-term Effects of Iron Deficiency in Early Childhood: A Systematic Review*	Breastfeeding has a positive impact on infant brain structural development, especially in preterm infants.	To quantitatively analyze the effects of early diet on infant neurodevelopment.
8	Yeh et al. (2025)	*Relationship between dietary diversity, eating behavior, and cognitive performance in economically disadvantaged school children*	Children's dietary patterns are associated with brain morphology and cognitive performance.	To explore the relationship between dietary patterns, brain structure, and cognitive function.
9	Samigullin et al. (2025)	*A central role of nutrition in cognitive function among primary school*	Nutrition has a stronger association with	To emphasize the importance of nutrition in studies of children's

		children	cognitive function than other factors such as physical activity.	cognitive performance.
10	Zhang et al. (2025)	*Exercise, Diet, and Brain Health: From the Perspective of Gut Microbiota Regulation*	A complex relationship exists between exercise, gut microbiota, and brain health; moderate physical activity and a healthy diet enhance cognitive function and mood via gut microbiota modulation.	To examine the complex relationship between exercise, gut microbiota, and brain health.
11	Cusick & Georgieff (2016)	*The role of nutrition in brain development: the golden opportunity of the*	The first 1,000 days of life are a critical period during	To examine the role of nutrition during early life in child brain development.

		"first 1000 days"	which nutrient deficiencies can permanently affect brain structure and function.	
12	Prado & Dewey (2014)	*Nutrition and brain development in early life*	Micronutrient deficiencies such as iron, iodine, and zinc significantly affect cognitive and motor development.	To explain the relationship between early nutrition and brain development and cognitive function.
13	Black et al. (2013)	*Maternal and child undernutrition and overweight in low-income and middle-income countries*	Early-life undernutrition contributes to impaired cognitive development and long-term academic	To analyze the impact of maternal and child nutrition on long-term development and health.

			achievement .	
14	Benton (2010)	*The influence of dietary status on the cognitive performance of children*	Inadequate nutritional intake is associated with reduced attention, memory, and executive function.	To review the influence of nutritional status on children's cognitive performance.
15	Nyaradi et al. (2013)	*The role of nutrition in children's neurocognitive development, from pregnancy through childhood*	Healthy dietary patterns from pregnancy through childhood play an important role in brain structure and function.	To review long-term relationships between nutrition and neurocognitive development.

Based on the reviewed literature, there is strong consensus that nutrition during early life plays a crucial role in brain growth and cognitive development. Studies conducted by Georgieff (2022) and

Geertsema et al. (2025) emphasize that early nutritional adequacy affects not only brain structure but also neural function and complex behaviors in adulthood. The risks associated with nutritional deficiencies, as identified by Walker et al. (2007) and national data from the Ministry of Health of the Republic of Indonesia (2023), have serious implications for cognitive, socio-emotional development, and learning readiness, particularly in countries with lower socioeconomic conditions.

Furthermore, the influence of the family environment and children's dietary patterns, as reported by Elvita et al. (2022) and Yeh et al. (2025), indicates that maternal knowledge and dietary diversity significantly affect brain morphology and children's cognitive abilities. Samigullin et al. (2025) emphasized that nutrition has a stronger association with cognitive function compared to other factors such as physical activity. However, Zhang et al. (2025) introduced a novel perspective by linking exercise, gut microbiota, and brain health, suggesting that the interaction between a healthy diet and physical activity can enhance cognitive function and mood through complex biological mechanisms. Specifically, Theola and Andriastuti (2025) highlighted the importance of iron intake and breastfeeding in supporting brain structural development, particularly in preterm infants.

In conclusion, meeting adequate nutritional needs in early life is a

primary factor in supporting optimal brain development and cognitive abilities in children. Appropriate nutritional interventions, combined with a supportive family environment, have significant potential to prevent neurodevelopmental disorders and enhance children's learning capacities. Future research is recommended to further investigate molecular mechanisms and the interactions between nutrition, physical activity, and gut microbiota in relation to brain health, in order to develop more effective intervention strategies.

The application of the Systematic Literature Review (SLR) method in this study enabled a comprehensive and structured exploration of the relationship between early-life nutrition and child brain development. The review process began by identifying relevant scientific articles from credible sources, including empirical studies, government reports, and recent literature reviews published between 2007 and 2025. Each article was examined according to selection criteria focusing on nutrition, cognitive development, and neural development in children from early childhood to school age.

Data extracted from the selected articles included key findings related to nutritional intake, dietary patterns, family environmental factors, and nutritional interventions influencing brain development and cognitive abilities. The analysis involved grouping findings into major themes, such as the impact of nutritional deficiencies, the importance of breastfeeding, and the relationship between nutrition and

other variables such as physical activity and gut microbiota. This approach allowed for the integration of findings across different contexts and methodologies, resulting in a comprehensive understanding of the mechanisms and factors influencing brain development from a nutritional perspective.

The results of the literature review consistently demonstrate that early-life nutrition significantly influences brain development and cognitive function. Research by Georgieff (2022) and Geertsema et al. (2025) underscores the importance of early nutritional intake in shaping neurological development and future behavioral outcomes. Nutritional deficiencies, particularly iron and micronutrient deficiencies, identified by Walker et al. (2007) and the Ministry of Health of the Republic of Indonesia (2023), are major risk factors that hinder learning readiness and socio-emotional development.

Additionally, family environment and children's dietary patterns, as examined by Elvita et al. (2022) and Yeh et al. (2025), link maternal knowledge and dietary diversity to brain structure and cognitive performance. Samigullin et al. (2025) reaffirmed that nutrition has a stronger correlation with cognitive ability than factors such as physical activity. The findings of Zhang et al. (2025) further expand the discussion by revealing the complex relationship between exercise, gut microbiota, and brain health, offering new insights into how nutrition and lifestyle interact to support cognitive function.

The discussion reinforces the importance of early nutritional interventions in preventing neurodevelopmental disorders and enhancing children's learning abilities. A comprehensive approach integrating optimal nutrition, family education, and the promotion of physical activity and healthy lifestyles is essential to support holistic brain development. These findings also highlight the need for further research exploring molecular and cellular mechanisms underlying the effects of nutrition on neural development, as well as the potential modulation of gut microbiota as an innovative intervention strategy.

Based on this review, it is recommended that child health and education policies place greater emphasis on early nutritional interventions. Programs aimed at improving micronutrient and macronutrient intake—such as iron supplementation, support for exclusive breastfeeding, and nutrition education for mothers and families—should be strengthened and expanded, particularly in areas with high rates of stunting and malnutrition. Creating a family environment that promotes healthy and diverse dietary patterns is also crucial for enhancing brain development and cognitive function.

Additional practical implications include the integration of regular physical activity promotion and healthy lifestyle practices as part of a comprehensive approach to supporting brain health through gut microbiota modulation, as suggested by Zhang et al. (2025). Collaboration among healthcare professionals, educators, and

policymakers is essential to design cross-sectoral and sustainable intervention programs. Further research is also encouraged to explore the application of digital technologies in nutrition education and the development of community-based interventions tailored to local needs. Through these efforts, it is expected that a generation of children with optimal brain development will emerge, contributing to improved human resource quality in the future.

Conclusion

Based on this Systematic Literature Review, it can be concluded that adequate nutritional provision from an early age plays a crucial role in supporting brain development and children's cognitive abilities. Sufficient intake of both macronutrients and micronutrients—such as iron, iodine, and omega-3 fatty acids—has been proven to influence brain structure and function as well as children's behavioral outcomes in later life. Nutritional deficiencies during early life increase the risk of cognitive impairments, socio-emotional difficulties, and reduced learning readiness.

Beyond nutritional aspects, family environmental factors and dietary diversity also serve as highly significant supportive elements. This study emphasizes the importance of comprehensive and evidence-based nutritional interventions, including nutrition education for families and the promotion of healthy lifestyles, to enhance the quality of children's growth and development. These findings also provide a

foundational basis for designing future child health and education policies.

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