

Importance of childhood nutritional status in their cognitive development

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Abstract

The nutritional status of children is a priority issue for many national and international institutions. Despite efforts to improve their condition, there are still cases of malnutrition, due to excess and deficit of macro and micronutrients. Diseases associated with this condition, whether communicable or not, have a direct impact on the physical and psychological health of infants. This article presents the relationship between appropriate nutrition and optimal cognitive development during the early life stages. For this purpose, information was consulted from various sources such as SciELO, PubMed, Scopus, Hinari, university repositories, and reports from the Food and Agriculture Organization of the United Nations, the World Food Program and the World Health Organization. These sources state that malnutrition and hidden hunger in children is the cause of alterations in cognitive processes, since the daily diet provides the substances necessary for brain metabolic processes.

Keywords

Diet, Food, Nutrition, Cognition, Child.

Resumen

El estado nutricional de los niños es un tema prioritario para numerosas instituciones nacionales e internacionales. A pesar de los esfuerzos por mejorar su condición, aún persisten casos de malnutrición, tanto por exceso como por déficit de macro y micronutrientes. Las enfermedades asociadas a esta condición transmisibles o no, tienen un impacto directo en la salud física y psicológica de los infantes. Este artículo presenta la relación entre una nutrición adecuada y el desarrollo cognitivo óptimo durante las primeras etapas de la vida. Para ello, se consultó información de diversas fuentes como SciELO, PubMed, Scopus, Hinari, repositorios universitarios, e informes de la Organización de las Naciones Unidas para la Alimentación y la Agricultura, del Programa Mundial de Alimentos y de la Organización Mundial de la Salud. Estas fuentes afirman que la malnutrición y el hambre oculta en los niños son causas de alteraciones en los procesos cognitivos, ya que la dieta diaria provee las sustancias necesarias para los procesos metabólicos cerebrales.

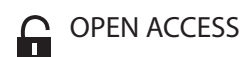
Palabras clave

Nutrición, Alimentación y Dieta, Cognición, Niño.

Introduction

Globally, there is enormous concern about the nutritional status of children, especially in middle and low-income countries. According to reports from the World Health Organization (WHO), eight million children under five years old present some degree of malnutrition, which is of significance because of its repercussions on health from the first years of life to adulthood.^{i,ii,iii}

Malnutrition is an abnormal condition caused by a deficit or excess of nutrients, either macronutrients or micronutrients, manifesting as loss (undernutrition), excessive weight gain (overweight and obesity), age-related short stature, and inadequate intake of vitamins and minerals (hidden hunger). It is multifactorial and includes socioeconomic, biological, and cultural factors.^{iii,iv,v}



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Proper nutrition is crucial to maintain homeostasis in brain functions, since nutrients act as cofactors or neurotransmitters, i.e., they are chemical substances necessary to perform cognitive activities such as information processing, memory, motor skills, and language, among other key elements of learning and academic performance.^{ii,iii,iv,v}

The study of this subject is relevant because the first stages of life are fundamental for brain development. The classification of cognitive development stages by Jean Piaget emphasized that children's learning process is qualitative and quantitative since, as they advance through the stages, their way of thinking is modified due to the assimilation and accommodation of the learning process.^{vi}

Therefore, it is essential to ensure an adequate diet from pregnancy, during breastfeeding, until the first five years of life, a crucial period to provide nutrients in appropriate quantity and prevent the different manifestations of malnutrition.ⁱⁱⁱ

This review aims to report on the relationship between adequate nutrition and cognitive development in early childhood. A documental search was conducted in scientific databases such as PubMed, Google Scholar, Research Gate, Cochrane, SciELO, Redalyc, and the National Library of Medicine. The search also included university repositories and official documents of the WHO, World Food Program (WFP), and the Food and Agriculture Organization of the United Nations (FAO). Articles published in Spanish, English, and Portuguese with publication dates of less than five years (2019-2023) were considered.

Discussion

Nutritional status of children

Proper nutrition in the first years of life is crucial for the development of children. However, worldwide, the production and consumption of foods that lack the necessary nutrients for optimal growth are predominant, which raises concerns about the high rates of malnutrition reported in the children population.^{i,ii,iii,iv,v}

In 2022, the WHO estimated that 149 million children under five years old were stunted, 45 million were wasted, and 37 million were overweight or obese, and that about half of all deaths of children under five were related to undernutrition.ⁱ

The United Nations Agenda 2030 (UN) and the WHO Global Nutrition Targets 2025 established targets for the health of children and mothers, recognizing that child nutri-

tion begins before pregnancy and continues through the first five years of life. These goals aim to reduce stunting, maternal anemia, overweight rate, low birth weight, and wasting, as well as to increase the breastfeeding rate up to six months of age.^{vii,viii}

Children are constantly exposed to unrestricted advertising of fast foods. This situation implies an increase in the frequent consumption of processed and ultra-processed foods, which are modified from their natural state to prolong their consumption time, change their consistency, and improve their taste at the expense of adding high contents of fat, sugar, salt or other additives.^{vii,ix}

According to the Food Systems Summit 2021 of the United Nations, in El Salvador, the diet is based mainly on bread, corn tortillas, sugary drinks, and sweet bread, with an increase in the consumption of simple carbohydrates, carbonated beverages, foods with excess fat and sodium, such as fast foods.^{vii}

In addition, the report mentions a lower consumption of fruits, vegetables, and foods of animal origin because the Salvadoran population is influenced by the mass media and globalization, which induces the incorporation of fast food into the daily diet. In addition, there is insufficient water consumption of less than two liters per day.^x

According to the United Nations Children's Fund (UNICEF), globally for 2019, one in three children under five years old is undernourished or overweight, and half of them present hidden hunger, which negatively affects their physical and cognitive development.^{viii} This was evidenced in El Salvador's National Health Survey 2021, which showed that children under two years old in urban areas mainly ingest packaged juices and carbonated beverages, while in rural areas, chocolate or coffee drinks predominate in that age group.^{xi}

This survey also reveals that in El Salvador, chronic malnutrition mainly affects children under five months old, living in rural areas (5.9 %) and that the percentage of stunting is also higher in these areas (11 %) compared to 9.3 % in urban areas. This contrasts with the percentage of children under five years old, who are overweight (8.3 %) and obese (3 %), predominantly in the urban areas.^{vii,xii}

Cerebral cortex and cognitive functions

Understanding the physiological processes involved in brain metabolism and cognitive functions is crucial for discerning the importance of maintaining a balanced

nutrient intake through a healthy diet. It helps in establishing the connection between proper nutrition and the cognitive processes.^{iii,xii,xiii}

The cerebral cortex is formed by millions of neurons and glial cells, which receive environmental stimuli, generating nerve impulses that cause sensory or motor responses. Neurotransmitters and chemical receptors are involved in nerve impulse transmission through the synaptic space.^{xiii}

The function of glial cells is to maintain brain homeostasis, and support and produce the myelin sheath, contributing to the transmission of nerve impulses to the central and peripheral nervous system to generate a response.^{xii,xiii}

Neurotransmitters are chemical messengers that send inhibitory or excitatory signals to neurons to trigger nerve impulses. Major neurotransmitters include acetylcholine, noradrenaline, gamma amino butyric acid (GABA), glutamate, serotonin, glycine, and histamine.^{xii,xiii}

This entire system is necessary for cognitive processes, which comprise the set of actions related to the intellectual activity of knowing and reasoning, including memory, perception, language, thought, and imagination, influenced both by the biopsychosocial environment and by the nutrition received, which provides essential micro and macronutrients for the synthesis of neurotransmitters and the energy necessary for brain metabolism.^{xiv,xv,xvi}

These cognitive processes are shaped in the brain through thousands of synapses, forming neural networks that store or discard information according to the child's needs. These neural networks begin to form in the first five years of life and last into adulthood.^{xvii,xviii,xix}

Jean Piaget described that cognitive development includes several stages and that learning, as well as the assimilation of information, is both qualitative and quantitative, i.e., accumulating knowledge and reorganizing it. The stages proposed by Piaget are: sensorimotor (0-2 years), preoperational (2-7 years), concrete operations (7-11 years), and formal operations (11 years and older).^{vi,xx}

Balanced diet and hidden hunger

The term diet refers to all prepared foods and beverages that people consume daily, whose preparation habits and practices are influenced by geographic location, culture, and socioeconomic status.^{xviii,xix}

Proper nutrition begins with good maternal nutrition during pregnancy and continues with breastfeeding, contrib-

uting to healthy growth, optimal cognitive development, and a strengthened immune system. Similarly, adequate nutrition in the first five years of life helps to avoid the risk of communicable and non-communicable diseases and the different expressions of malnutrition described above.^{xix,xx}

A balanced diet should consider the appropriate amount of food, with rations adjusted to age and metabolic needs, and the nutrients necessary to support the proper functioning of the body without causing harm while respecting the dietary habits according to the culture of each region. Transculturization has altered local diets.^{xx,xxi}

It is advisable to use a combination of foods that provide both macronutrients and micronutrients and to avoid processed or ultra-processed foods that contain high levels of fat, salt, or sugar, which make them more appealing, but increase the rates of obesity and heart disease, among other risks.^{xix,xx,xxi}

The Food and Nutrition Board of the United States suggests that the recommended daily intake for children from zero to eight years old should include carbohydrates, total fiber, lipids, linoleic acid, alpha-linolenic acid, proteins, as well as vitamins A, B, E, K, C, B6, B12, thiamine, riboflavin, niacin, folate, pantothenic acid, biotin, choline, and minerals such as calcium, iodine, iron, zinc, fluorine, magnesium, phosphorus, among others.^{xx,xxi}

Micronutrient deficiency is known as "Hidden Hunger". Micronutrients such as iron, vitamins A, D, B complex, zinc, and calcium are responsible for multiple functions in the body and both their deficiency and excess consumption can alter cognitive development and growth in childhood.^{xxii,xxiii}

The impact of hidden hunger during pregnancy is of particular concern, as it could affect the fetus and be reflected in the newborn's health up to five years of life. McCoy argues that hidden hunger at this stage of life has consequences on the functional capacity of the developing brain, which is crucial for the assimilation of information.^{xxii,xxiii}

Malnutrition and cognitive development

In the early stages of life, the brain undergoes accelerated development and maturation, where neural connections occur enabling children to adapt to their surrounding environment and to use the information assimilated. These connections are more evident in the stages of concrete and formal operations.^{xii,xiv,xxiv}

Brain metabolism involving neurons and glial cells requires cofactors to synthesize neurotransmitters and Adenosine Triphosphate (ATP), the main energy source for electrophysiological functions, obtained from glucose and oxygen.^{xxv,xxvi}

Research has shown that children with a balanced diet have better cognitive development. Breastfeeding alone is a necessary and sufficient source of nutrients, vitamins, carbohydrates, and other bioactives in appropriate amounts that provide the substrates required for infant development.^{xxvi,xxvii,xxviii}

Children who lack these nutrients may present deficits in analytical processes, classification of ideas and images, organization of ideas and symbols transmitted mainly through language, or the performance of everyday tasks such as playing, solving problems, and even learning a melody, among other activities.^{xx,xxii}

Martin *et al.* conducted studies on children with obesity to assess cognitive development and reported that compared to children of normal weight, they presented lower scores in mathematics, reading, and spelling; in addition, they detected decreased perceptual reasoning and memory reflected in emotional problems, lower motivation, and reduced participation in academic activities.^{xx,xxii}

Malnutrition also contributes to a decrease in the number of neurons and nerve connections, damage to the myelin sheath and dendritic branches, manifesting in a thin cerebral cortex, and slow brain growth, affecting motor function and memory. This damage may be irreversible if it persists beyond four years of age.^{iii,xxii}

Poor micronutrient intake is not physically visible, and it manifests itself in children's cognitive deficits, including grade repetition, shorter schooling, and poor performance in academic assessments, due to their essential role in the neurotransmitters synthesis and cofactors that promote biochemical reactions.^{xxiii,xxiv}

The brain demands a large amount of energy, mainly from glucose obtained from daily carbohydrate intake. However, carbohydrates with high sugar content and low nutritional value tend to decrease cognitive and psychomotor functions in children under five.^{xxv,xxvi,xxvii}

Neurotransmitters derived from protein metabolism are mainly obtained from the diet and are essential for cognitive functions. Glial cells are structurally composed of lipids and underline the importance of a healthy diet in adequate portions.^{xxiv,xxv,xxviii}

Neurotransmitters such as serotonin, adrenaline, and dopamine are synthesized from the amino acids tryptophan and

tyrosine, which are present in dairy products, red and white meats, nuts, and some vegetables. These compounds participate in cognitive processes such as learning, reasoning, and memory.^{xxix,xxx,xxxi}

Acetylcholine is related to memory and neurodevelopment; it is synthesized from the amino acid L-tyrosine, obtained from the daily diet. In addition, its synthesis depends on vitamin B12 and folate. Deficiency of pyridoxal phosphate, thiamine pyrophosphate, and vitamin B12 leads to marked neurological dysfunction.^{xxxii,xxxiii}

Two-thirds of the neurons in the cerebral cortex use glutamic acid as a neurotransmitter and contain zinc in their synaptic vesicles. Zinc deficiency has been linked to cognitive delay in children since these neurons are responsible for long-term memory and the learning process.^{xxxiv,xxxv}

Iron is a necessary cofactor for several enzymatic reactions, given that it intervenes in the conduction of the nervous impulse. It is a required nutrient in the diet of children under five years old, where most neuronal connections are built.^{xxxvi,xxxvii}

Docosahexaenoic acid (DHA) is a phospholipid that is part of the cell membrane and is involved in the transmission of nerve impulses, neuronal growth, learning processes, neurogenesis, memory and visual function. It is mainly found in breast milk, fish and seafood, soybeans and nuts.^{xxxvi,xxxvii,xxxviii}

Iodine present in fish, seafood, and dairy products is essential for thyroid hormone synthesis. These hormones are crucial for the development and proper functioning of the brain. Iodine deficiency leads to intellectual deficits. It is recommended to fortify salt with iodine.^{xxxvii,xxxix}

It is worth noting that although a balanced diet is a determining factor in the cognitive development of children, physical exercise and the environmental conditions in which they develop also play a significant role.^{xl,xli}

In cases of obese children, cognitive impairment is associated with neuroinflammation and neurodegeneration. Adipose tissue releases adipokines such as leptin and interleukin 6, which have proinflammatory functions, causing chronic inflammation. This inflammation leads to a weakening of the blood-brain barrier and may cause damage at the microglial level.^{xlii,xliii}

The insulin resistance present in obesity, combined with the leptin effect, decreases the function of this hormone, altering synaptic plasticity. Research in children with obesity has shown difficulties in sustained attention, memory, and other motor skills.^{xliii,xliv}

Conclusion

There is a scientific consensus that connects proper nutrition to optimal cognitive development in the early stages of life. During this period, children assimilate and process the information they receive from their environment, which enables higher development. On the contrary, malnourished children have high rates of school repetition, school dropout, or low schooling.

For this reason, it is necessary to ensure the intake of an appropriate diet, balancing macro and micronutrients. Lack of this balance results in cognitive deficits at early age and may even cause irreversible brain damage. The mother's prenatal diet and exclusive breastfeeding until six months of life are essential, followed by the progressive introduction of foods with all the necessary nutrients.

In contrast, excessive consumption of processed and ultra-processed food containing excess sodium, fat, and sugars, contributes negatively to children's neurodevelopment. These products generate nutritional imbalances and do not provide essential substrates for brain development.

It is essential to provide nutritional guidance at home and school since adults are directly responsible for children's nutrition. Likewise, there must be permanent nutritional surveillance, allowing the evaluation of the child in all areas of his life and ensuring adequate cognitive development, providing more possibilities for a better future.

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