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The Role of Nutrients in Child's Brain Development

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Abstract

Early childhood is a basic stage for the child's later life. During this period the brain development and the foundations for cognitive development and social-emotional skills, is laid. Nutrition plays a key role in optimal brain function. When a child is adequately fed, the basis for smooth brain function is created. Nutritional deficiencies may affect the child's cognitive skills and behavior. Since rapid brain development occurs during the early years, this period may be particularly sensitive to deficiencies in the diet. Modern data shows that diet seems to be one of the most important growth and maturation factors in the brain both in infancy and childhood. In particular, fatty acids play a central role in brain tissue, iron deficiency causes disturbances in attention, memory and behavior, and is closely linked to lower cognitive indices. Long-term studies have shown that children with iron deficiency have lower school performance. In addition, zinc, as well as iodine and vitamins D and B12 deficiencies are likely to adversely affect brain function and memory. An inadequate diet usually causes multiple deficiencies of micronutrients with short-term and long-term effects on the functioning of the child's brain.

Key words: Brain development, early childhood, nutrition, nutrients, fatty acids, vitamins

1. Introduction

The human brain is a self-adjusting organ, the result of co-operative hereditary and environmental influences. Research has shown that the structure of the fine texture of the brain -the formation of neural pathways or "neural networks"- is guided by environmental stimuli, natural and social (Katsiou-Zafrana, 2018; Bhatnagar & Taneja, 2001).

Cognitive development is affected by many factors, including nutrition. A big bulk of bibliographical references indicates the correlation between healthy nutrition and optimal brain function. Nutrients provide structural elements which play a critical role in cell multiplication, DNA composition and the neurotransmitter and hormone metabolism, as they are vital components of enzyme systems in the brain (Nyaradi, Li, Hickling, Foster, Oddy, 2013; Fenech, 2013; De Souza, Fernandes, do Carmo, 2011).

Every child is entitled to optimal cognitive, social, emotional and behavioral development. The cognitive, social and emotional parts of the brain continue to develop throughout the child's life. However, the growth and development trajectory of the brain is heterogenous in the course of time. A large part of the ultimate structure and capacity of the brain is shaped early in life, before the age of 3 years. Among the factors that influence early brain development is the provision of optimal nutrition (Cusick & Georgieff, 2016).

Throughout the first 3 years of a child's life, nutrition plays an important role in the child's health and physical growth. This is a critical period for brain formation, which will serve as the foundation for the development of cognitive, motor and socio-emotional skills throughout life.

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Nutrient inadequacy during this period can endanger the structural development of the brain (Nurliyana, MohdShariff, MohdTaib, Gan, Tan, 2016). Although all nutrients are necessary for the development and function of the brain, research has indicated that essential fatty acids, iron, zinc, iodine, vitamins B12 and D are primarily important in early childhood (Prado & Dewey, 2014).

The present study is based on the bibliographical review and research influences that sought a link between nutrition during early childhood and children's cognitive development in their later life.

2. Micronutrient influences and cognitive development in early years

Nutrients are vital for the development and function of the organism. In periods of rapid growth, there is a great need for provision of nutrients, necessary for the development of the brain. Nutrient inadequacy, however, can endanger the structural development of the brain, as it is likely to cause serious and permanent damage. This is because nutrients can influence the anatomy of the neurons by reducing their multiplication or diversity (Nurliyana, Mohd Shariff, Mohd Taib, Gan, Tan, 2016; Benton, 2008). Recent findings have established that the point of time, the duration and the severity of nutrient inadequacies have a different impact on brain development and subsequent cognitive and emotional procedures (Black, 2018).

2.1. Essential fatty acids

The term essential fatty acids refers to those polyunsaturated fatty acids that must be provided by foods because these cannot be synthesized in the body, yet are necessary for health (Kaur, Chugh & Gupta, 2014). The brain is a rich in lipids organ. Essential fatty acids are its vital structural components from which it has been shaped, and without them, brain cells cannot function to the optimum degree. The provision of fatty acids is of primary importance for the functioning of the nerve tissue. The n-3 docosahexaenoic acid (DHA) and the n-6 fatty acids are the basic polyunsaturated fatty acids of a long chain, playing a central functioning role in the optimal development of the brain; consequently, they can be vital for its function (Vollet, Ghassabian, Sundaram, Chahal, Yeung, 2017; De Souza, Fernandes, do Carmo, 2011).

The accumulation of DHA in the brain is being processed during intrauterine and neonatal period up to the age of 3 years and the high accumulation levels in the brain are retained through life (Lauritzen et al., 2016).

The enrichment of diet with fatty acids has a positive impact on the child's learning skills, memory, language progress and cognitive competence in general (Øyenet al., 2018; Willatts, 2018). More specifically, the hippocampus, the frontal lobes and the basal ganglia of the brain are the fundamental areas of cognitive function affected by DHA. The accumulation of n-3 fatty acid within the cell membranes contributes to enhanced information processing, and thus, to enhanced problem solving, while it has been associated with heightened attention of children and improved cognition (Vollet, Ghassabian, Sundaram, Chahal, Yeung, 2017).

The insufficient intake of n-3 fatty acid reduces DHA in the brain, leading to brain damage or abnormal brain disorder (Willatts, 2018). Additionally, inadequacy or imbalance of fatty acid intake is likely to lead to neuro-developmental disorders, such as Attention Deficit Disorder – Hyperactivity Disorder (ADHD), dyslexia and autism spectrum disorder (Agostoni et al., 2017; Richardson & Montgomery, 2005).

2.2. Zinc

Zinc deficiency appears to be a major problem worldwide, affecting 40% of the global population. Zinc is a vital nutrient for the brain, with important structural and functional roles. Zinc is a cofactor for more than 200 enzymes that regulate diverse metabolic activities in the body, including protein and DNA synthesis. It also plays a role in neurogenesis, maturation and migration of neurons as well as in synapse formation. Zinc is also found in high concentrations in synaptic vesicles of hippocampal neurons, which are centrally involved in learning and memory (Nyaradi, Li, Hickling, Foster, Oddy, 2013). Early development, when cell activity is the highest, may be particularly sensitive to zinc deficiency. Zinc deficiency can interfere with multiple organ systems, especially when it occurs during childhood, when nutritional demands are high. It has been associated with reduced neuronal growth and brain volume leading to possible retardation of cognitive function. Additionally, zinc levels are associated with reading skills and school progress (Al Mamum & Ghani, 2017).

In particular, zinc deficiency can trigger aggressive and antisocialdis position (Piao, Cong, Lu, Feng, Ge, 2017), behavior (attention span, temperament, recreation activities), rough and fine mobility as well as social skills. (Cogia & Sachdev, 2012). To conclude, zinc deficiency leads to poor learning, attention and memory capacity (Cusick & Georgieff, 2016).

2.3. Iron

Iron is an essential nutrient during all stages of human development. It has particular importance for children because of its critical impact on their development. Iron is vital for the normal anatomical development of the fetal brain. Iron deficiency in early childhood is the most common micronutrient deficiency and can lead to irreversible damage to brain structure and cognitive function, regardless of therapies with iron supplements (Cerami, 2017). The potential mechanisms apply to the impact of iron deficiency on neurometabolism, myelinosis and the functioning of neurotransmitters, especially the hippocampus, during brain development. Research has shown that iron deficiency can lead to delayed motor development by ten months of age, delayed cognitive processing by ten years of age, altered recognition, memory and executive functions at nineteen years of age and poorer emotional health in the mid-twenties (Mudd et al., 2018; Cusick & Georgieff, 2016).

Iron deficiency, in combination with intake of pharmaceuticals -which has proved to be unsatisfactory- as well as adopting western type eating habits, are all associated with ADHD (Millichap & Yee, 2012; Panahandeh, Vatani, Safavi, Khoshdel, 2017).

2.4. Iodine

Iodine is an essential trace element for the function of the organism. It is essential for the biosynthesis of thyroid hormones, necessary for normal increase, development and functioning of the metabolism throughout life. Iodine deficiency can cause irreversible brain damage and mental retardation, while it is responsible for 10 – 15 IQ unit loss of the population worldwide. The reason is that iodine is the basic element the thyroid needs for thyroid hormone composition. Thyroid hormones play a determining role in early development process, especially that of the brain (WHO, 2007; Ghassabian & Trasande, 2018; Delange, 2001).

Research has indicated that the most severe form of brain damage resulting from iodine deficiency is cretinism, characterized by severe and irreversible alterations in brain development and by mental retardation (Yeatman & Charlton, 2013).

Iodine deficiency during pregnancy is seen as an important issue of public health that needs attention, as it reflects on the cognitive and motor development of the children, which can later affect their school progress (Bath, Steer, Golding, Emmett, Rayman, 2013; Murcia et al., 2017).

2.5. Vitamin B12

Vitamin B12 plays a vital role in normal brain development and function. Myelin production is an essential component of brain development from gestation to childhood and, to a great extent, it is associated with the development of the nervous system and the subsequent cognitive function. Vitamin B12 also serves as a cofactor in numerous catalytic reactions in the human body, which are required for the neurotransmitter synthesis and functioning. Vitamin B12 deficiency may cause pernicious anemia with effects on cognitive development, while its total inadequacy is likely to lead to neuropathy, through degeneration of fibres, and irreversible brain damage (Winje et al., 2018; Dror & Allen, 2008).

2.6. Vitamin D

Vitamin D deficiency is regarded as one of the most common nutritional deficiencies, and it is usually an undiagnosed medical condition worldwide. Vitamin D is produced mainly in the skin after exposure to ultraviolet radiation and less than 10% of it is provided from dietary sources. Human studies have shown that the poor state of vitamin D during gestation is related to adverse neuropsychiatric outcomes including schizophrenia and child autism. Recent studies have shown a connection between vitamin D status of the mother in early pregnancy and delayed neurocognitive development, including language impairment, mental development and psychomotor development in early childhood. Advanced neuro-imaging techniques can detect unique alterations in the developing brain of a young child, which can often relate to vitamin D deficiency (Chowdhury et al., 2017).

High levels of maternal vitamin D in early pregnancy can protect against disturbing behavior, especially ADHD-like symptoms at preschool age (Daraki et al., 2018). According to clinical trials carried out on premature infants, the timely administration of vitamin D supplements did not significantly improve cognitive development. Nonetheless, further research needs to be done so as the dosage of vitamin D supplement to be determined (Salas et al., 2018).

3. Conclusions

The elasticity of the brain is the means nature uses to protect the brain from external influences, allowing for its adaptation to environmental effects. Yet, it is all dependent on the time, the duration and the severity of the influence. Healthy nutrition, with adequate quantities of essential micronutrients, proteins and calories, provided in the appropriate time period, can ensure the smooth development of the brain. Significant congenital malformations, such as hydrocephaly, mental retardation and behavior problems are in some cases prevented with a balanced diet.

The majority of the studies that have explored the connection between nutrition and cognitive development, focus on isolated micronutrient components, including n-3 fatty acids, zinc, iron and iodine. Observation studies indicate that these micronutrient components play a vital role in child cognitive development. The deficiency of nutrients must be regarded as a public health issue of the utmost importance, as long-term effects can be prevented throughout children's school life. Also, parents, as they act as models for their children, are called upon to educate and strengthen the adoption of healthy dietary habits, by ensuring the availability and accessibility of food.

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