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Micronutrients of Importance in the First 1000 Days of Children's Cognitive Development for Sustainable Educational and Career Development

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Abstract

The paper reviewed the micronutrients that are required for cognitive development in the first 1000 days of life which refers to the period from conception of a child to the second birthday. Cognitive development refers to the growth and progression of children's ability to learn, reason, think and solve problems. During this period, the brain undergoes rapid development that is dependent on adequate nutrition, particularly micronutrients which include iron, iodine, zinc, folates, Vitamin B_{12} and Vitamin A among other dietary components. Micronutrients are crucial for children's cognitive development because they give structural and functional advantages to the brain and central nervous system during their formative years. The deficiency or inadequate consumption of these micronutrients especially during the critical stage of brain formation, could lead to structural and functional damage to the brain and delayed or non-acquisition of cognitive competencies needed for future educational and career successes. Brain deformation arising from micronutrient deficiency may be reversible or permanent. Micronutrient deficiencies could be prevented through adequate consumption of micronutrients during pregnancy, exclusive breastfeeding in the first six months of life and introduction of adequate complementary feeding with varieties and fortified foods after six months with continued breastfeeding for 2 years of the child's life and good nutrition knowledge of mothers through Nutrition Education. It is recommended that pregnant women should be exposed to knowledge of adequate infant and childhood nutrition, care and practices that promote micronutrient intake for mothers and children so that they intentionally consume meals high in vitamins and minerals.

Keywords: Micronutrients; Children; First 1000 days; Cognitive development; Nutrient deficiency.

Introduction

Early childhood nutrition plays a critical role in shaping the child's cognitive development. the first 1000 years of an individual begin at conception and run through the second birthday of the person. During this period, the brain goes through the fastest growth and development which forms the foundation for its reaching its optimum development. This optimum development is dependent on the consumption of micronutrients and others. dietary components. Micronutrients are vitamins and minerals needed in very small quantities in the human body to ensure optimal growth, development, disease prevention and well-being (Partnership for Child Development (PCD), 2019; Centre for Disease Control and Prevention (CDCP), 2018). Some of these micronutrients may be produced in the body while others are found in foods. Iron, iodine, zinc, calcium vitamin A, and B vitamins are not produced in the human body, therefore must be consumed through food (CDCP, 2018). Studies have shown that these nutrients affect brain growth and neurodevelopment both during the prenatal stage of life and during childhood (Benton, 2008). They also act as coenzymes or form structural parts of the enzymes required for metabolic activities and therefore need to be in regular supply to the brain (Swaminathan et al., 2013).

It has been established that at this formative period of 1000 days of a child's life, nutrient deficiency or inadequacy can have a long-term effect on health and wellbeing. Folic acid, vitamin A, iron and iodine have been reported to be the most important micronutrients for the foetus (Bird (2016), as they aid in the proliferation of the cells of the hippocampus, the left temporal lobe and the prefrontal cortex parts of the brain. These parts of the brain are responsible for encoding and retrieval of memories; acquisition and understanding of language, as well as higher-order cognitive functioning such as problem-solving (Benton, 2012). These attributes are essential for smooth learning, educational development and career success.

The global prevalence of deficiency in at least one of three micronutrients has been estimated to be 56% (372 million) among preschool-aged children and 69% (12 billion) among non-pregnant women of reproductive age (Stevens et al., 2022). According to their study, three-quarters of preschool-aged children with micronutrient deficiencies live in East Asia, South Asia and Sub-Saharan Africa. Deficiency of micronutrients interferes with early brain development in two ways; by limiting the formation of myelin sheaths, dendrites and synapses and by altering the tissue levels of neurotransmitters such as dopamine and serotonin. These result in structural and functional changes in the neurons. This shows that the deficiencies of specific micronutrients have a detrimental impact on children's cognitive processes and functions, resulting in a negative shift in the intelligence quotient (IQ) potential of children (Khor and Misra, 2012). It is therefore imperative to note that from conception, the consumption of adequate micronutrient-rich foods should be a priority for pregnant mothers and children under two years of age to ensure that the components of the brain are all developed to their full potential to reduce cases of learning difficulties in schools arising from low cognitive potentials and capacities of the children.

Concept of Cognitive Development

Cognition, according to Nyaradi, Li, Hickling, Foster and Oddy (2015) represents a complex set of higher mental functions of the brain such as attention, memory, thinking, learning and perception. Cognition, just like every other aspect of the human functional domains, progresses in capabilities of functioning, as individuals' brains develop across lifespan. Brain development starts at conception and continues across middle childhood and into the adult years. It begins with the formation of brain cells, followed by cell migration and differentiation, and the development of synapses to enable cells to communicate with one another (Black, 2008). Siegler (2019), described cognitive development as the advancement in mental processes such as perceiving objects and events in the environment, acting skillfully on objects to obtain goals, understanding and producing language, problem-solving, reasoning, creating, conceptualizing, categorizing, remembering and planning. It involves changes in the way humans think and process information received from the environment. Lam and Lawlis (2016) explained that an adequate micronutrient supply is a necessary stimulation required by the brain, as their deficiencies have been linked to impaired cognition in children.

The first 1000 days (that is, from conception to 2 years of age) according to Prado et al. (2017) are a critical period for cognitive development as it can have long-term effects on brain architecture and cognitive ability. This is when neurons and myelin are formed at a rapid rate to shape the foundation for future cognitive health and function. The myelination of the brain as stated by Winje et al. (2018) is of importance for multiple brain systems and is highly related to neurodevelopment and subsequent cognitive functioning. According to Nyaradi et al. (2015) cognitive development at this time predicts an individual's school achievement in the later years. Academic achievement on the other hand is of significant concern because it is important for future personal health, wealth and well-being.

Micronutrients Deficiencies (MNDs) and Children's Cognitive Development

In the first 1000 days beginning from conception to two years of age, micronutrients play critical and significant roles in both body growth and the cognitive development of children which may determine their learning abilities, educational development and future career in adulthood. During this period, which is critical as the brain undergoes rapid growth and development, adequate intake of all the essential nutrition is required to support this growth and development process. The nourishment of the foetus during gestation and the infant after birth is the sole responsibility of the mother through feeding during pregnancy and breastfeeding/complementary feeding after birth. These micronutrients include iron, iodine, folic acid, zinc, vitamin A and the B complex vitamins. Micronutrient deficiencies (MNDs) are commonly associated with chronic hunger and specific dietary deficits (PCD, 2019). It was reported by Khor and Misra (2012) to be generally correlated with overall undernutrition, particularly in poor households where poverty limits the quantity and quality of dietary intake. Iron, iodine, folate, vitamin A, and zinc deficiencies are the most widespread MNDs, and all are common contributors to poor growth, intellectual impairments, perinatal complications, and increased risk of morbidity and mortality (Khor & Misra, 2012). Brain growth is very rapid during the first 1000 days of life and micronutrient deficiencies at this stage can alter the pattern of central nervous system development and hence, interfere with the acquisition of cognitive skills (Black, 2008). According to Thompson and Nelson (2001), the structural and functional development of the human brain starts at conception with the formation of the neural tubes, followed by the generation, proliferation, migration and differentiation of the neurons; after which the formation of myelin and synapses begin at the last trimester. Myelin is the protective fatty tissue which facilitates the exchange of nerve impulses; therefore, as stated by Black (2008), any impediment to the myelination of the brain cells prenatally or during infancy could lead to delayed acquisition of cognitive skills. During gestation, micronutrients, are transferred from the mother to the foetus through the placenta, therefore the requirements of the foetus is factored in the recommended intakes of the pregnant mother, while infants obtain their micronutrient requirements through breastmilk, and/or natural and fortified complementary foods.

Specific Micronutrients and Cognitive Development

Iron is necessary for haemoglobin formation, which carries oxygen in red blood cells to the brain and all other parts of the body (Centre for Disease Control (CDC), 2019). It is responsible for the proper development of the brain cells that produce myelin (Khor and Misra (2012). It, therefore, aids myelination and development of various parts of the brain, which occur rapidly from the last trimester of pregnancy to about 2 years of the life of the child (Cerami, 2017). Iron is also associated with the enzymes necessary for synthesizing neurotransmitters, production of energy and brain regulation (Nyaradi et al., 2015). Eighty per cent of the iron present in a full-term born baby is accumulated during the third trimester of pregnancy, this may be the reason why preterm babies are usually deficient in total body iron (American Academy of Pediatrics, 2010). Different recommendations have been made for an increase in the iron requirement of pregnant mothers. This explains why iron supplements are essential for mothers attending Ante-natal Clinics during pregnancy in Nigerian Primary Health Care Clinics as standard practice. Children obtain iron from breast milk and or infant formula, heme iron (animal food sources), and non-heme iron obtained from plant food sources (Carter et al., 2011). Breastmilk is a poor source of iron (35 mg/L) however, Domello, et al., (2014) explained that the iron in breastmilk is enough for the neonates because there are sufficient stores of iron in the body of newborns which usually lasts for about 4-6 months of life (Bothwell, 2000). However, as babies grow older, the iron stores deplete, warranting a daily iron supplementation from four months for the full-term infant (CDC, 2019a).

Iron deficiency is a major cause of anaemia in addition to malaria, injuries and parasite infestations. Iron deficiency during fetal development and the first 2 years of life is associated with poor growth and decreases in cognitive development (Cerami, 2017). Several observational studies reported by Bryan et al. (2004) found that children who experienced iron deficiency anaemia before age two continued to demonstrate lower academic performance during their school-age years, even after the anaemia had been treated. In a similar study in Michigan, USA on infants between 9-10 months, Carter et al. (2011) observed that infants who had iron deficiency anaemia performed less than children without iron deficiency anaemia on cognitive tests of object permanence and recognition memory. Carter et al. (2011) in another review of the findings of thirteen studies across Europe, Asia and Africa, concluded that infants with iron deficiency anaemia showed persistently lower cognitive test scores than normal infants. These studies have shown that iron is an essential nutrient in brain development to ensure that children do not grow up with learning difficulties which could hamper their educational development,

Iodine is another one of the most important minerals required by a fetus for brain and cognitive development (CDCP, 2018). The production of the thyroid hormones (Thyronine T3 and Thyroxine T4) that facilitate the maturation of the central nervous system for faster transmission of nerve impulses from the brain to the parts of the body is dependent on iodine. According to John, Black and Nelson (2017), The thyroid gland requires about 60 µg of iodine per day to produce an adequate supply of these hormones. Studies have established the link between poor dietary intake of iodine and incidences of cognitive retardation (WHO 2020[b]). John et al. (2017) observed that mild to moderate deficiency of iodine is associated with cognitive delays which can lead to academic setbacks while severe deficiency can lead to intellectual disability. Prado et al. (2017) reported a similar study in China which revealed that children whose mothers lived in iodine-deficient areas had 12.5 points lower in IQ tests, compared to those whose mothers were living in iodine-sufficient locations. Therefore, iodine is a vital micronutrient to ensure optimal brain growth and development which is a pre-requisite for the attainment of academic success.

Zinc is a mineral that promotes immunity, resistance to infection, and proper growth and development of the nervous system (CDC, 2018). The role of zinc in brain development and function is the formation of neurons, migration, and synapse generation (John et al., 2017; Khodashenas et al., 2015). Zinc aids learning and memory by modulating the intracellular and intercellular neuronal signalling of the hippocampus (Warthon-Medina et al., (2015). Learning and memory are important characteristics needed for intellectual and academic success in school, so the deficiency of zinc in these early stages of life of children could affect attention leading to memory loss and ultimately impairing the ability to learn. Warthon-Medina et al. (2015) reported a study in which zinc supplements were given to children from 12 to 35 months; a follow-up on the children at 7–9 years of age showed significant improvements in intellectual function scores among the group that received zinc supplement, compared with the placebo control group. Benton (2008) also reported that a study of Egyptian infants showed that low zinc status was associated with poor attention.

Folate or folic acid, also known as vitamin B_9 or folacin are naturally occurring in foods or artificially incorporated in vitamin supplements. Folic acid is crucial for proper brain functioning; it plays an important role in mental health and the production of the body's genetic material, DNA and RNA. According to CDC (2018), folic acid is essential in the earliest days of brain and spinal cord development. Studies reported by Campoy et al. (2015) showed improved neurodevelopment in infants of folate-supplemented mothers. This implies that folates are indispensable for rapid cell growth and proliferation during brain development. Bird (2016) observed that if pregnant women are folate deficient in the first 3-5 weeks of pregnancy, their fetus is at risk of Neural Tube Defects (NTDS). NTDs are a result of incomplete closure of the neural tube commonly manifesting in the forms of *spina bifida*, (a condition in which a portion of the spinal cord and the surrounding structures develop outside instead of inside the body) and *anencephaly* (a condition in which the brain and skull bones do not form properly and results in parts of the brain being absent) (Stanford Children Health, 2020). Therefore, foliate is essential to prevent NTDs.

Vitamin B_{12} or cobalamin like iron, plays an important role in neural myelination, synaptogenesis, and neurotransmitter synthesis, with potential effects on cognitive development and ultimate cognitive functioning of children (Venkatramanan et al., 2016). Infants need vitamin B12 for supporting brain development and producing healthy red blood cells. Folates (folic acid) and vitamin B_{12} are often considered as a pair so deficiencies in one vitamin may alter the metabolism of the other (Mahmood, 20140). Pacholok (2014) observed that the deficiency of Vitamin B_{12} in infants and children is not easily diagnosed because the signs and symptoms often mimic those of autism spectrum disorders such as obsessive-compulsive behaviours, and difficulty with speech, language, writing and comprehension. When accurate treatment is not initiated early enough, the children are at risk of irreversible brain damage leading to retarded cognitive and language development (Pacholok, 2014). Poor vitamin B_{12} status is common among young children in low and middle-income countries (Kvestad et al., 2015), which unfortunately includes Nigeria. In a cohort study among North Indian infants, Kvestad et al., (2015) reported that marginal vitamin B_{12} status was associated with lower scores on the mental development index of the Bayley Scales of Infant and Toddler Development. In another study by Benton 2012, a 14-month-old baby with severe brain atrophy as a result of vitamin B_{12} deficiency was found to have normal brain waves after six weeks of supplementation. However, a follow-up observation at 2 years of age showed that cognitive and language development remained seriously retarded. This suggests that Vitamin B_{12} deficiency in infancy could have negative lasting consequences on the academic success of children

Vitamin A or Retinol is necessary for healthy eyesight and immune system functions (CDC, 2018). It is also very key during foetal growth and development and particularly crucial during the development of the central nervous system (Ransom et al., 2014). It plays a critical role in visual perception, hence deficiency of vitamin A is the leading cause of childhood blindness in developing countries (Benton, 2012). Deficient children are at an increased risk of appetite loss, eye problems, lower resistance to infection, iron deficiency anaemia, growth failure and death (Centers for Disease Control and Prevention, 2018). Old and recent studies have linked vitamin A to cognitive performance in children. Among these studies is that of Ali et al. (2017) were is was established that children who received prenatal and childhood vitamin A supplementation had significantly better performance in reading, spelling, and math computation compared with the control group. Vitamin A has also been directly linked to the proper absorption of iron, its metabolism and storage in the body (Gropper and Smith,2013, Ip et.al., 2017)). Indicating that these two vitamins are dependent on each other to function optimally.

Prevention and Intervention Programmes for Childhood Micronutrient Deficiency

Micronutrient deficiency is a global public health issue, especially in developing countries of the world. UNICEF (2018) identified the strategies to prevent and treat micronutrient deficiencies in women and children to include dietary diversification, food fortification, supplementation, Nutrition Education of women of childbearing age and prevention and treatment of infectious diseases, and deworming. The promotion and support of exclusive breastfeeding (Scherbaum, 2016) and adequate complementary feeding plus immunization of children in the first year against childhood killer diseases is also a major strategy to prevent micronutrient deficiencies in infants and children.

Dietary diversification in this context involves getting all micronutrients by consuming a variety of foods from multiple sources (both plant and animal food sources) and these foods should be sufficient in quality and quantity (Nair et al., 2016; WHO 2020[a]). Dietary diversification is a long-term strategy aimed at changing household diet through social and behaviour change activities, increased production of nutrient-rich foods and improved access to diverse foods. It is a nutrition intervention strategy targeted at a wider population to prevent micronutrient deficiency at the household level. This strategy if properly applied will help ensure sustainable micronutrient intake by both the pregnant mothers and infants after birth.

Food fortification has been identified by the World Health Organization (WHO), the Copenhagen Consensus and the Food and Agriculture Organization (FAO) as one of the top four strategies for decreasing micronutrient malnutrition at the global level National Institute of Health, 2020). It involves deliberately adding essential vitamins and minerals to foods during processing. to improve the nutritional quality of the food supply and provide a public health benefit with minimal risk to health (WHO & FAO, 2006). T Salt, staple cereals such as wheat, corn, rice, sugar, vegetable oils, bouillon cubes, and other condiments are commonly fortified foods available in the markets, (National Institute of Health, 2020; (Anjorin et al., 2019)) especially in Nigeria. Salt is fortified with iodine, oils and sugar with vitamin A, bouillon cubes/powders with iron and cereals with the B Complex vitamins. This is so because these foods are staples and commonly consumed in all households, therefore a good vehicle to make these micronutrients available to all. According to CDC (2018), fortification of salt with iodine has been one of the most successful nutrition interventions to date as 71% of global households have access to iodized salt.

Micronutrient supplementation is the term used to describe the provision of relatively large doses of micronutrients, in the form of pills, capsules or syrups. It has the advantage of being capable of supplying an optimal amount of a specific nutrient or nutrients, in its highly absorbable form, and is the fastest way to control deficiency in individuals or population groups that have been identified as being deficient (WHO & FAO, 2006). Standardized doses of these micronutrients are available for pregnant mothers, infants, young children and adults which when taken as recommended will prevent micronutrient deficiency throughout the lifecycle. The supplements are available in sometimes in the form of multivitamins and minerals or as individual vitamins and minerals.

The provision of Nutrition Education to pregnant women is also another intervention strategy to prevent these micronutrient deficiencies and ensure adequate consumption in the first 1000 years.

Contento, 2016 observed that it is a combination of educational strategies, at the individual, institutional, community, and policy levels, accompanied by environmental supports, designed to facilitate the voluntary adoption of healthy feeding habits. The Nutrition Education programmes on adequate micronutrient consumption should be properly planned and implemented effectively by trained nutrition experts for the objectives of the Education and intended behaviour change targeted at the increased consumption of micronutrient-rich foods to be met. Exclusive breastfeeding and adequate complementary food intake together with the continuation of breastfeeding till the child is two years old have been proven to ensure optimal growth and brain development (Scherbaum 2016; UNICEF 2018; Anjorin et. et., 2019; Stevens et.al.,2022) Breastmilk is a crucial food for children's health and development during this critical window. It provides all of the vitamins and minerals that children need to grow and thrive in the first 6 months of life, and continues to be a pivotal part of their diet up to the age of 2 or beyond (UNICEF, 2018). WHO (2020) therefore recommends early initiation of breastfeeding within one hour of birth, exclusive breastfeeding of infants for 6 months after birth and continuous breastfeeding till 23 months of age, as children and adolescents who were breastfed as babies, according to WHO (2020) are likely to perform better on intelligence tests and have higher school attendance.

The importance of adequate consumption of micronutrients especially, iron, iodine, zinc, and vitamins A, and B Complex- folic acid and cyanocobalamin are all rudiments to ensuring effective cognitive development which makes learning easier and the subsequent academic success which enhances sustainable educational pursuit and career progression at workplaces. The link between adequate micronutrient intake in the first 1000 years to the cognitive development of the brain cells and its subsequent effect on the attention span of infants, and learning in the preschool years have been established in literature over the years (Partnership for Child Development. 2019).

Conclusion

Children within the first 1000 days of life depend on the mothers' personal nutrition and infant feeding practices, to get their daily supply of micronutrients. Micronutrients are of critical importance in the cognitive development of children as they provide structural and functional cognitive development benefits to the brain and the central nervous system during the formative periods of life. Micronutrient deficiencies often come with far-reaching consequences, particularly in brain development and functions. While some of the effects could be remedied through supplementation and/or food fortification, some of the effects result in a lifetime cognitive disability, which makes it difficult for the affected children to reach their potential educationally and attain their career goals. From the foregoing, the consumption of these micronutrients (iron, iodine, zinc, vitamin A, folate, and vitamin B_{12}) is essential to the optimum performance of their functions both in the brain and other parts of the body. The growth and development of the brain, which is the bedrock or the organ of the body that is related to learning, memory and the intellect should be preserved. The deficiency of any of the above-mentioned micronutrients in the first 1000 days of life will adversely affect the academic performance of the individual both in the formative and later years of life.

Recommendations

It is therefore recommended that:

1. Women who have plans of having children should start early (before conception takes place) to consciously take foods that are rich in vitamins and minerals.
2. Nutrition Experts should be employed in Antenatal clinics to educate women attending these clinics on the importance of micronutrients in the growth and cognitive development both at the foetal and childhood stage.
3. Modules on meal planning by these employed Nutrition Experts for pregnant and young children under two years should be planned and taught to the women in the Maternal and Child clinics.
4. Micronutrient supplementation should be encouraged during pregnancy and lactation. Government at all levels and private sector food producers should scale up the fortification of processed foods so that most cereal products will contain sufficient quantities of micronutrients, as the staple food of Nigerians are cereal and their products.

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