Niger J Paediatr 2022; 49 (1): 14 – 16

ORIGINAL

Asindi A Asindi
Torty Chimaeze

Zinc function in childhood brain

DOI:http://dx.doi.org/10.4314/njp.v49i1.3

Accepted: 14th January 2022

Torty Chimaeze (✉)
Neurology unit,
Department of Paediatrics,
University of Calabar
Teaching Hospital, Calabar
Email: drchimatorty@gmail.com
chimaezetorty@unical.edu.ng

Asindi A Asindi
Department of Paediatrics,
University of Calabar,
Calabar, Nigeria.

Abstract: Zinc is essential in the metabolic activities in the body including protein, DNA and RNA synthesis. It plays a role in neurogenesis, maturation, and migration of neurons and in synapse formation.Zinc is high in the hippocampal neurons which is involved in learning and memory.

Deficiency of zinc during pregnancy has been related to many congenital abnormalities of the foetal nervous system. Furthermore insufficient levels of zinc in children is associated with lowered learning ability, apathy, lethargy and mental retardation. Maternal deficiency of zinc during lactation has been associated with impairment of infant brain development.

Zinc status in mother and child can be assessed by measurement of zinc in plasma; zinc deficiency can be corrected with appropriate diet and zinc supplements.

Red meat, poultry items, oysters, cashew nuts and almonds are rich sources of zinc.

Introduction

Zinc is necessary for the activity of over 300 enzymes that aid in metabolism, digestion, nerve function and many other processes.[1]This mineral is fundamental to DNA synthesis and protein production.[2] Human body growth and development rely on zinc because of its role in cell growth and division. [3] Zinc plays an important role in axonal and synaptic transmission and is necessary for nucleic acid metabolism, brain growth and phosphorylation.

Zinc is also needed to support senses of taste and smell. Because one of the enzymes crucial for proper taste and smell is dependent on this nutrient, a zinc deficiency can therefore reduce the ability to taste or smell.[4] Zinc deficiency therefore can lead to loss of appetite and growth retardation. In severe cases, it can result in hair loss, skin impairment, diarrhoea and delayed sexual maturation. In addition, zinc is critical for the development and function of immune cells.[5] Zinc deficiency in older children can be corrected through diet and supplements.

The main focus of this review is on the importance of zinc in the development of the brain and cognitive functions in children. It examines some deleterious neurological consequences associated with zinc deficiencies in children.

In the central nervous system (CNS), zinc is second only to iron in trace metal abundance. This micronutrient is a biofactor that plays essential roles in the central nervous system across the lifespan from early foetal brain development through childhood maintenance to brain functions in adults.[6]

Zinc Neurobiology and neurophysiology

Zinc is essential for normal development of the central nervous system and is required for the formation and function of a variety of proteins, enzymes, hormones, and growth factors that direct stem cell proliferation and differentiation during neurodevelopment. Stem cells and neuronal progenitor cells play important roles in the developing brain by giving rise to the neural tube, the first brain structure to form during gestation, and eventually to the neural crest by way of asymmetric proliferation and migration.[6-8] These neuronal stem cells then differentiate into mature neurons, forming synaptic connections throughout the developing brain. Zinc balance is not only important for neural tube formation and neuronal pruning, but it also governs the process of stem cell proliferation and neurogenesis in the CNS during development.[6]

Zinc acts on glutamate receptors and other voltage-gated ion channels in the brain. It also modulates synapses (a property known as synaptic plasticity). Both of these effects contribute significantly to learning and memory. The highest concentrations of zinc in humans are found in the hippocampus and in the choroid layer of the retina which is part of the brain. All pieces of information are processed by the hippocampi before being stored in the cerebrum hence the hippocampus plays a major role in memory and knowledge and wisdom. Zinc deficiency affects short-term memory more than long-term.

Neurologic impact of zinc deficiency

Since zinc is needed for key enzymes in the developing brain such as DNA polymerase, a critical enzyme in DNA synthesis, hence acute Zinc deficiency impairs brain function in humans.[9] Zinc deficiency in experimental animals during early brain development causes malformations, whereas deficiency later in brain development causes microscopic abnormalities and impairs subsequent functions. A limited number of studies suggest that similar phenomena can occur in humans.
Because zinc is so important to cognitive function, zinc supplementation has also been successful in improving the symptoms of ADHD. Studies show a zinc supplement improves focus and reduces impulsivity in children with ADHD.[10]

Laboratory assessment of zinc deficiency

Zinc status in human subjects can be assessed by measurement of zinc in plasma, erythrocytes, neutrophils, lymphocytes, and hair. Available data indicate that zinc in neutrophils and the assay of activity of alkaline phosphatase in neutrophils may be the best tools for the diagnosis of zinc deficiency. Measurement of zinc in the plasma is simple and readily available in many laboratories. Plasma (or serum) zinc concentration is the most widely used biomarker to determine zinc status.
According to Mayo Clinic Laboratories, serum zinc the normal reference range is 0.60-1.20 mcg/mL for children under age 10, and 0.66-1.10 mcg/mL for children 10 years and above including adults.[11]

Nutritional Sources of Zinc
Foods highest in zinc include: [12]

- Shellfish: Oysters, crab, mussels, lobster and clams
- Meat: Beef, pork, lamb and bison
- Poultry: Turkey and chicken
- Fish: Flounder, sardines, salmon and sole
- Legumes: Chickpeas, lentils, black beans, kidney beans, etc.
- Nuts and seeds: Pumpkin seeds, cashews, hemp seeds, etc.
- Dairy products: Milk, yogurt and cheese
- Eggs
- Whole grains: Oats, quinoa, brown rice, etc.
- Certain vegetables: Mushrooms, peas, asparagus and beet greens

The following shows the recommended daily allowance of zinc, based on a person's age and sex: [12]

Age	Male	Female
0–6 months	2 mg	2 mg
7–12 months	3 mg	3 mg
1–3 years	3 mg	3 mg
4–8 years	5 mg	5 mg
9–13 years	8 mg	8 mg
14–18 years	11 mg	9 mg
19 years and over	11 mg	8 mg

Hambidge et al[13] reviewed the effects of inadequately treated maternal acrodermatitis enteropathica on offspring. Some of their infants had brain malformations. Related to these observations, reports from Turkey suggested that low maternal Zn nutrition increased the occurrence of foetal anencephaly.[14]
Pregnant and breastfeeding women should consume 11 and 12 mg per day, respectively.[15] During pregnancy and breastfeeding, a higher intake of zinc is necessary, because newborns and infants up to 6 months obtain zinc through breast milk.
Zinc deficiency can be corrected with appropriate diet and zinc supplements. Plasma zinc concentrations normally respond to zinc supplementation, especially in subjects with a low or moderately low baseline but the neurological deficit caused may not be reversed in children.

Conclusion

Zinc, an essential micronutrient has many critical effects for brain development in childhood and brain function. It is essential for normal brain development in the child as it is required for the formation and function of a variety of proteins, enzymes, hormones, and growth factors that direct stem cell proliferation and differentiation during neurodevelopment.
Zinc deficiency is usually due to inadequate dietary intake of major sources including lean meat, shellfish, dairy products and nuts. Zinc deficiency can restrict brain development, impair cognitive function and has been linked to congenital malformations.

Adequate Zinc intake in diet is paramount, however, when necessary zinc supplementation maternal/infancy/ childhood may be a crucial intervention to prevent congenital malformations, improve child growth and brain development for optimal brain function and eventual attainment of the full potential of the child.

References

1. Zastrow ML, Pecoraro VL. Designing Hydrolytic Zinc Metalloenzymes. *Biochemistry 2014; 53: 957−978.*
2. Roohani N, Hurrell R, Kelishadi R, Schulin R. Zinc and its importance for human health: An integrative review. *J Res Med Sci 2013; 18: 144-57.*
3. Liu E, Pimpin L , Shulkin M , Kranz S, Duggan C.P, Mozaffarian D, Fawzi WW. Effect of Zinc Supplementation on Growth Outcomes in Children under 5 Years of Age. *Nutrients 2018; 10: 377-399.*
4. Lyckholm LJ, Heddinger SP, Parker G, Coyne PJ, Ramakrishnan V, Smith TJ. J Pain Palliat. *Care Pharmacother 2012 ; 26(2): 111–114*
5. Prasard AS. Zinc in Human Health: Effect of Zinc on Immune Cells. *Mol Med 2008;14 (5-6):353-357*
6. Gower-Winter S, Levenson CW. Zinc in the central nervous system: From molecules to behaviour Biofactors. *2012; 38 (3): 186–193. doi:10.1002/biof.1012.*
7. Chudasama Y, Wright KS, Murray EA. Hippocampal lesions in rhesus monkeys disrupt emotional responses but not reinforcer devaluation effects. Biol. *Psychiatry. 2008; 63:1084–1091.*
8. Goeldner C, Reiss D, Wichmann J, Meziane H, Kieffer BL, Ouagazzal AM. Nociceptin receptor impairs recognition memory via interaction with NMDA receptor-dependent mitogen-activated protein kinase/extracellular signal-regulated kinase signaling in the hippocampus. *J Neurosci. 2008; 28:2190–2198*
9. Duncan JR, Hurley LS. Thymidine kinase and DNA polymerase activity in normal and zinc deficient developing rat embryos. *Exp. Biol. Med. 1978;159:39–43*
10. OzgurYorbik, M. FatihOzdag, Abdullah Olgun, M. Guney-Senol, SemaiBek, Serif Akman. Potential effects of zinc on information processing in boys with attention deficit hyperactivity disorder. Progress in Neuro-Psychopharmacology *&Biological Psychiatry 2008; 32: 662–667.*
11. Mayo Clinic laboratories. Test Catalogue https://www.mayocliniclabs.com/test-catalog/Clinical+and+Interpretive/8620
12. Institute of Medicine, Food and Nutrition Board.Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. Washington, DC: National Academy Press, 2001.
13. Hambidge KM, Neldner KH, Walravens PA. Zinc, acrodermatitis enteropathica and congenital malformation. *Lancet 1975; 1: 577-578*
14. Cavdar AO, Bahçeci M, Akar N, Erten J, Bahçeci G, Babacan E, Arcasoy A, Yavuz H. Zinc status in pregnancy and the occurrence of anencephaly in Turkey. *J Trace Elem Electrolytes Health Dis. 1988; 2 (1): 9-14.*
15. Institute of Medicine (US) Panel on Micronutrients. Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. Washington (DC): National Academies Press (US); 2001. 12, Zinc. Available from: https://www.ncbi.nlm.nih.gov/books/NBK222317/