Journal of Scientific and Technical Research
13 (2) 2023, 60-65
http://www.publishingindia.com/jstr

Impact of Micronutrient Deficiency on Cognitive Development in Children

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Abstract: Micronutrients refer to the minute quantities of essential vitamins and minerals crucial for the body's proper functioning. Despite their small amounts, these nutrients play a pivotal role in supporting various bodily functions. Deficiencies in any of these micronutrients can lead to severe, and in some cases, life-threatening illnesses. Their functions include aiding in the synthesis of hormones, enzymes, and other essential chemicals necessary for normal growth and development. Globally, iron, vitamin A, and iodine deficiencies are the most prevalent, especially in young children and expectant mothers. Micronutrient deficiencies disproportionately affect counties with low and moderate incomes. The different facets of nutrition in rural and urban India, with a focus on the importance of nutrients, particularly in the context of childhood development. With an emphasis on how children are more vulnerable to malnutrition as a result of insufficient nutritional intake, recurrent illnesses, and unequal food distribution, it emphasises the seven types of nutrients and their significance in maintaining life. It emphasises how undernutrition stunts a child's growth both physically and mentally, especially in rural India where it mostly affects children's cognitive health and learning capacities. Furthermore, the text delves into micronutrients, their role in biochemical processes, and their connection to major public health issues like anaemia and iodine deficiency disorders. It emphasizes the importance of addressing undernutrition, which contributes to 45% of fatalities in children under five, according to the World Health Organization (WHO). It also touches on necessity for early intervention to develop healthy behaviours that can help manage illnesses like diabetes mellitus, as well as the long-term effects of childhood influences on lifestyle preferences. It also tackles the common problem of anaemia caused by iron deficiency and looks on ways to increase iron absorption and bioavailability with the goal of improving public health outcomes worldwide. The influence of undernutrition and micronutrient deficiencies on children's mental health is also discussed in the text, with a focus on the connection between inadequate nutrition and emotional, behavioural, and cognitive problems. It emphasises how important it is to comprehend this relationship in order to create therapies that will improve children's well-being and cognitive development.Lastly, the article discusses the economic ramifications of the "double burden" of malnutrition, which occurs when undernutrition coexists with overweight or obesity. It asks decision-makers and interested parties to give priority to programmes that treat both forms of malnutrition in order to lessen the detrimental effects they have on people and communities. An overview of the complex problems relating to development, health, and nutrition is given in the abstract, with special attention to children in India.

Keywords: EChild development, Cognitive development, Iodine, Iron, Malnutrition, Micronutrient deficiency, Omega-3 fatty acid, Vitamin D.

Abbreviations: DDS – Dietary Diversity Score, BMI – Body Mass Index, IDA - Iron Deficiency-Related Anemia, ICDS - Integrated Child Development Services, LBW - Low Birth Weight

I. Introduction

A nutrient is an ingredient that both nourishes and is necessary for development. It is possible to identify seven different types of nutrients: mineral, vitamin, fiber, carbohydrate, protein, fat, and water. Each category is essential to the body's healthy operation. Micronutrients are essential in biochemical processes, while macronutrients provide energy. Water is one of the most crucial nutrients, a means for transportation, and helps in maintaining the temperature of the body. Children, particularly those residing in rural areas of India, are vulnerable to malnutrition due to insufficient dietary intake, frequent illnesses, inadequate care, and uneven food distribution within the family. Repeated infections weaken the body and lead to a deficiency of crucial nutrients, thereby diminishing immunological capacity to fend off diseases. This results in stunted growth among children, negatively impacting their future learning abilities as well as their mental and physical development [25]. Undernutrition significantly affects children's brain and cognitive development, playing a crucial role in determining maternal and child

health. Micronutrients, including minerals and vitamins, are essential for regulating both endocrine and exocrine secretions, thereby controlling various physiological processes [9]. "Cognition" refers to the mental processes required for acquiring and understanding information. These encompass various cognitive functions such as knowledge, reasoning, problem-solving, recall, and thought. The combined conscious and unconscious processes involved in thinking, perceiving, and reasoning are collectively known as cognitive processes. Major public health issues include anaemia (iron deficiency disease), iodine deficiency disorders (IDD), damaging the eye. Undernutrition is a factor in 45% of fatalities in children under the age of five, according to the WHO [2]. Childhood influences shape lifestyle preferences that stick with people throughout adulthood. As a result, interference to promote good lifestyles pattern in the early stages of life. Low understanding of good eating patterncan help in overcoming the diabetes mellitus. Therefore, it's critical to develop a complete comprehensive diabetes education programme to encourage good life and eating pattern decisions so that the procedure of diabetes mellitus could be prevented. In India, the general population, educators, doctors, and parents of children with type 1 diabetes are among those who lack understanding about controlling the condition. Children's mental health is significantly impacted by undernutrition and a lack of certain micronutrients. Poor nutrition can cause emotional upheavals, behavioural issues, and cognitive decline [18]. For the best possible brain development and function, micronutrients including iron, iodine, zinc, and vitamin D are essential. These micronutrient deficiencies are linked to a higher incidence of mental health issues in children. For the purpose of creating effective therapies to advance children's well-being and general cognitive development, it is essential to comprehend the connection between malnutrition, micronutrient deficiency, and mental health

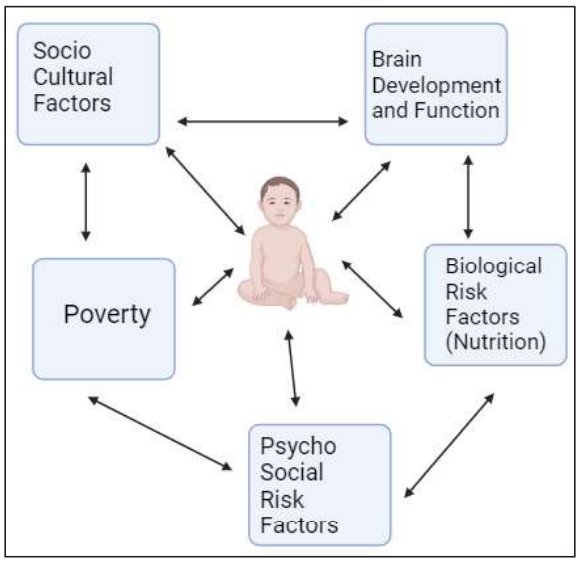

Fig. 1: The Theoretical Framework Regarding the Influence of Nutrition on Cognitive Development

II. Iodine and Cognitive Development in Children

Iodine deficiency is the largest avoidable cause of depletion in cognitive functioning in the world since there is a direct correlation between it and cognitive development during pregnancy, and this correlation may be avoided by public health initiatives [28]. Congenital Hypothyroidism presents with symptoms such as stunted growth, primitive reflexes, diplegia, mental retardation, visual impairments, facial deformities, and visual impairements. In myxodematous cretinism, there are additional symptoms such as dry skin, irregular ECG patterns, severe development retardation, and primitive reflexes and pyramidal signals. Postnatal iodine deficit can cause thyroid dysfunction in the child, which can result in hypothyroidism. There have been conflicting findings from observational studies comparing kids with and without goitres; some have found cognitive abnormalities in kids with goitres, while others have not. The possibility that varying degrees of hypothyroidism can result in a goitre is one reason for the ambiguity. Numerous randomised studies have been carried out to investigate the effects of iodine supplementation on children's cognitive performance who live in iodine-deficient areas. But the results haven't always produced trustworthy conclusions. Children who received iodine in utero before the third trimester performed better on a psychomotor performance measure than children who received iodine later in pregnancy or at the age of two years old, according to a recent longitudinal follow-up of school-age children who all received iodine [27].

III. Iron and Cognitive Development Relation

The most widespread dietary deficiency on a global scale is insufficient iron. According to World Health Organization (WHO) estimates, as many as 5 billion individuals lack sufficient iron, contributing to 2 billion cases of anemia worldwide. The stages characterized by rapid growth and increased nutritional needs, such as puberty, pregnancy, and the age range of 6 to 24 months, pose the greatest risk for iron deficiency. The production of haemoglobin requires iron. Reduced oxygen carrying capacity brought on by an iron shortage can affect development, growth, and immunity. Iron deficiency is only the cause of 50% of anaemia. The remaining portion results from sickle cell disease, HIV, malaria, vitamin A insufficiency, vitamin B-12 and folate deficits, and other inherited anaemia. Numerous observational studies have revealed that even after receiving treatment for their anaemia, children who suffered from anaemia at a young age continued to do worse academically [2]. Memory, attention, cognitive function, physical skills, emotional and psychological behaviour are all impacted by iron deficiency. The processes are connected to long-term alterations in GABA and dopamine metabolism, as well as hippocampal function and structure, myelinization, and function. Two commonly observed neurobehavioral conditions in children include attention deficit hyperactive disorder (ADHD) and autism spectrum disorder (ASD) [21]. Recent

research has examined the connection between these conditions and iron deficiency. γ-aminobutyric acid (GABA) and glutamate homeostasis are impacted by changes in iron levels in the brain. These alterations result in emotional and psychological issues in addition to deficiencies in learning and memory as well as physical skills. ADHD symptoms are caused by an imbalance between excitatory and inhibitory neurotransmitters, such as GABA [4].

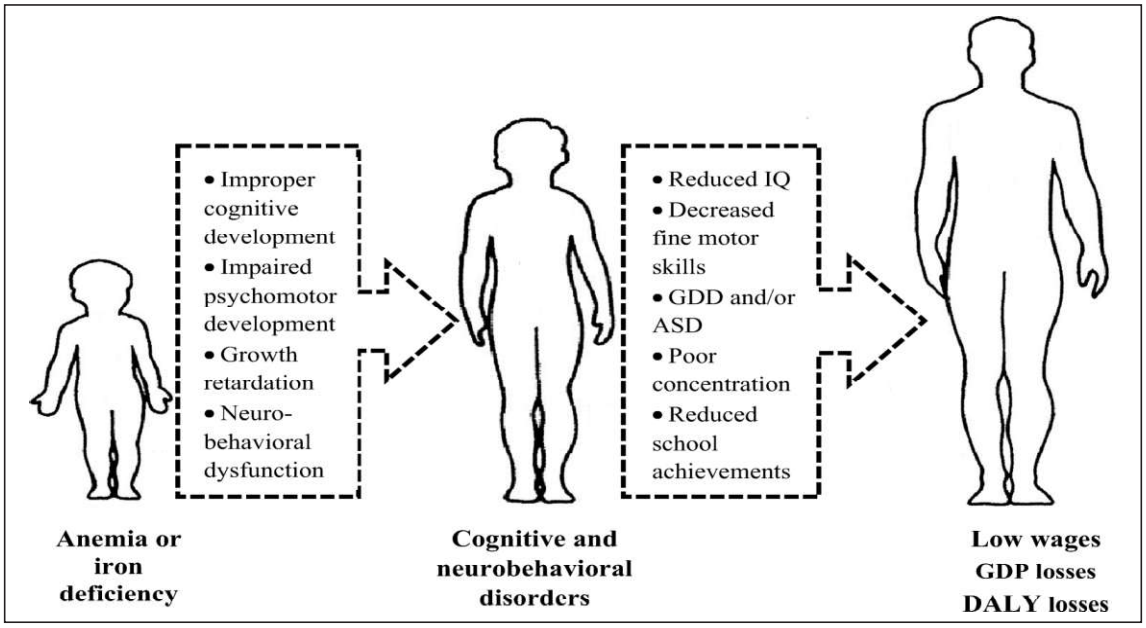

Fig. 2: How Childhood Iron Deficiency Anaemia May Result in Wage Loss in Adulthood (L. Pivina, Y. Semenova, M. D. Doşa, M. Dauletyarova, and G. Bjørklund, 2019)

IV. Zinc and Cognitive Development Relation

Zinc, the fourth most abundant intracellular metal and a biologically essential trace element, is crucial for the functioning of over 200 enzymes and proteins. Periods of rapid growth, such as during pregnancy, infancy, and adolescence, are particularly vulnerable to insufficient dietary zinc. Inadequate zinc during these stages can result in either temporary or persistent developmental issues. Zinc plays a vital role in various brain activities, including neurotransmitter function, hormone and growth factor transit, receptor binding, and DNA and protein synthesis during critical phases of brain growth. It is indispensable for brain maturation and mental function. The insufficient intake of zinc poses a notable public health challenge. The examination of zinc deficiency effects has been a focal point in randomized trials of zinc supplementation in populations with zinc deficiency. However, commonly used biological indicators like hair and plasma zinc may not perfectly reflect functional impairment due to zinc deficiency [6].

V. Vitamin B-12 and Cognitive Development Relation

Since animal products are the only source of vitamin B-12, children who avoid them as well as babies who are breastfed by women who consume insufficient amounts of these products run the danger of being deficient in the vitamin. Even in affluent nations, the elderly commonly face vitamin B-12 deficiency, often attributed due to their lowered capacity to absorb vitamin. Consequently, many studies exploring the correlation between vitamin B-12 deficiency and cognitive function have focused on older individuals, revealing associations with neurobehavioral abnormalities and dementia. Limited research exists on the relationship between vitamin B-12 insufficiency and children's cognitive functioning, primarily confined to case studies involving infants born to vegan mothers or mothers with pernicious anemia, a condition impeding the absorption of vitamin B-12 [7]. These infants may experience delays in reaching developmental milestones. Two observational studies have been undertaken on children with B-12 deficiency. In the initial study, offspring of omnivorous mothers in The Netherlands exhibited delayed language and motor development when compared to children of macrobiotic mothers. Despite their current diet providing nearly the recommended daily intake of vitamin B-12, at the age of 12, these children scored lower than the omnivores on standardized tests, including the Digit Span, Block Design, and Raven's Progressive Matrices, and displayed elevated levels of methylmalonic acid [2]. The second investigation included school-aged participants from Guatemala. Beyond academic challenges, such as diminished academic performance, lower teacher assessments, heightened attentional problems, and increased delinquent behavior, children experiencing vitamin B-12 deficiency also exhibited reduced reaction times on neuropsychological tests measuring

perception, memory, and reasoning. These observational studies suggest an association between low vitamin B-12 levels and compromised cognitive function, yet additional research is needed to validate these findings through intervention trials.

VI. Omega-3 and Cognitive Development in Children

Eicosapentaenoic acid (EPA) and Docosahexaenoic acid (DHA) represent essential long-chain omega-3 polyunsaturated fatty acids (PUFA) vital for enhancing behavior and cognitive functions in school-age children.The worldwide health impact of mental and neurological disorders in humans has exceeded the combined burden of cancer and cardiovascular disease. Simultaneously, there has been a substantial reduction in the presence of omega-3 polyunsaturated fatty acids (PUFAs) in the Western diet over the past few decades. There is a belief that inadequacy in n-3 polyunsaturated fatty acids (PUFAs) can have adverse effects on cognitive brain development, although this theory is backed by clinical evidence that is somewhat conflicting. Conversely, supplementing with n-3 PUFAs may yield positive effects [7]. Additionally, information derived from both animal and clinical studies suggests that n-3 polyunsaturated fatty acids (PUFA) could serve as a potential treatment for cognitive impairment associated with neurodegenerative conditions such as Alzheimer's disease (AD) and the normal aging process. An expanding body of research indicates that functional deficiencies or imbalances in specific highly unsaturated fatty acids (HUFA) from the omega-3 and omega-6 series might be implicated in various developmental and psychiatric disorders, including autism, depression, bipolar disorder, dyslexia, dyspraxia, ADHD, and the schizophrenia spectrum. Preliminary research suggests that omega-3 HUFA might also be beneficial for addressing behavioral and learning challenges in children with conditions like dyslexia, ADHD, and related disorders. The primary characteristics of many of these disorders may appear in less severe manifestations as part of normal variations in behavior, mood, and cognitive functions. According to reports, omega-3 fatty acids play a role in enhancing cognitive development and learning, particularly in relation to reference memory. They support the flexibility of neuron membranes, facilitate synaptogenesis, and play a role in synaptic transmission. Additionally, they might influence the activity of the nervous system [26].

Table I: Role of Micronutrient in Cognition

Micronutrient	*Role in Cognition*	*Reference Range*
IODINE	Neurological cretinism includes retardation	90 - 150 mcg
IRON	concentration, intellectual status, memory, and learning skills	22 - 134 µg/dl
VITAMIN B12	neural damage and brain atrophy, psychomotor function, and brain development	330 - 1185 ng/L
ZINC	attention, activity, neuropsychological behavior and motor development	0.72 - 1.15 µg/mL
OMEGA 3 FATTY ACID	Attention deficit, autism, major depressive disorder	2000 mg of EPA and DHA

(L. Pivina, Y. Semenova, M. D. Doşa, M. Dauletyarova, and G. Bjørklund, 2019)

VII. Conclusion

After an examination of the available literature and statistics for this article, it has been concluded that despite the implementation of various strategies to minimize child malnutrition, the majority of recipients still require assistance. Consequently, there is a need for additional local efforts to support these beneficiaries. It is recommended to reorganize the assistance in alignment with seasonal food items to fulfill the nutritional needs of children across various food categories, groups, and Dietary Diversity Score (DDS). Given the close relationship between education and health, schools are identified as optimal locations for health education initiatives. Considering the high prevalence of VDD in the population, it is crucial to implement effective public health interventions, such as food fortification, to address these deficiencies. However, it is acknowledged that fortification alone may not be sufficient to tackle widespread nutritional deficiencies. Although fortification can offer advantages, interventions based on evidence are regarded as the most efficacious approach for promoting the adoption of healthy behaviors. Regrettably, there is a scarcity of published preventive interventions and strategies rooted in behavioral theory and empirical research. This research addresses a significant void in the current understanding, providing insights into potential themes and strategies for conveying preventive messages to children and adolescents within educational settings. This involves advocating for clear and well-supported textual information through educational videos and interactive activities.

References

[1] B. P. Singh, and M. Sharma, "Nutritional status of school going children in India: A review," *International Journal of Medical Research & Health Sciences*, vol. 10, no. 10, pp. 130-38, 2021.

[2] U. Venkatesh et al., "Micronutrient's deficiency in India: A systematic review and meta-analysis," *Journal of Nutritional Science*, vol. 10, p. e110, 2021.

[3] T. Rawal et al., "How to promote a healthy lifestyle among school children: Development of an intervention module (i-PROMISe)," *Public Health in Practice*, vol. 3, p. 100262, 2022.

[4] P. S. Rakesh et al., "Anemia among school children in Ernakulam district, Kerala, India," *Indian Journal of Hematology and Blood Transfusion*, vol. 35, pp. 114-118, 2019.

[5] M. Verma et al., "Nutrition status of school children in Punjab, India: Findings from school health surveys," *Journal of Tropical Pediatrics*, vol. 67, no. 1, fmaa068, 2021.

[6] S. Awasthi et al., "Prevalence of specific micronutrient deficiencies in urban school going children and adolescence of India: A multicenter cross-sectional study," *Plos One*, vol. 17, no. 5, p. e0267003, 2022.

[7] R. D. Jurakulovna, "Analysis of distribution of vitamins, macro and micro elements deficiency among children and adolescents in Samarkand region, according to clinical symptoms," *Eurasian Research Bulletin*, vo. 17, pp. 229-235, 2023.

[8] A. Pal et al., "Under nutrition and associated factors among children aged 5-10 years in West Bengal, India: A community-based cross-sectional study," *Egyptian Pediatric Association Gazette*, vol. 69, pp. 1-12, 2021.

[9] P. De, and N. Chattopadhyay, "Effects of malnutrition on child development: Evidence from a backward district of India," *Clinical Epidemiology and Global Health*, vol. 7, no. 3, pp. 439-445, 2019.

[10] A. Singh, "Childhood malnutrition in India," *Perspective of Recent Advances in Acute Diarrhea*, 2020.

[11] R. Mandlik et al., "Determinants of vitamin D status in Indian school-children," *Indian Journal of Endocrinology and Metabolism*, vol. 22, no. 2, p. 244, 2018.

[12] E. Chheda et al., "Effect of oral nutrition supplement on growth in preschool children - A systems physiology-based in silico analysis: Effect of ONS on growth in preschool children," *Indian Journal of Child Health*, pp. 204-213, 2022.

[13] S. Kumar et al., "Iron deficiency anemia: A comprehensive review on iron absorption, bioavailability and emerging food fortification approaches," *Trends in Food Science & Technology*, vol. 99, pp. 58-75, 2020.

[14] S. Grantham-McGregor, and J. Smith, "The effect of malnutrition and micronutrient deficiency on children's mental health," *Mental Health and Illness of Children and Adolescents*, pp. 375-393, 2020.

[15] S. Srivastava, and S. Kumar, "Does socio-economic inequality exist in micro-nutrients supplementation among children aged 6-59 months in India? Evidence from National Family Health Survey 2005-06 and 2015-16," *BMC Public Health*, vol. 21, no. 1, pp. 1-12, 2021.

[16] J. J. Muros et al., "Assessing the dietary intake of calcium, magnesium, iron, zinc and copper in institutionalised children and adolescents from Guatemala contribution of nutritional supplements," *Journal of Trace Elements in Medicine and Biology*, vol. 53, pp. 91-97, 2019.

[17] R. Nugent et al., "Economic effects of the double burden of malnutrition," *The Lancet*, vol. 395, no. 10218, pp. 156-164, 2020.

[18] Muhd. Shahid et al., "Prevalence of child malnutrition and household socioeconomic deprivation: A case study of marginalized district in Punjab, Pakistan," *PloS One*, vol. 17, no. 3, p. e0263470, 2022.

[19] S. Murarkar et al., "Prevalence and determinants of undernutrition among under-five children residing in urban slums and rural area, Maharashtra, India: A community-based cross-sectional study," *BMC Public Health*, vol. 20, no. 1, pp. 1-9, 2020.

[20] R. Mandlik et al., "Occurrence of infections in school children subsequent to supplementation with vitamin D-calcium or zinc: A randomized, double-blind, place bo-controlled trial," *Nutrition Research and Practice*, vol. 14, no. 2, pp. 117-126, 2020.

[21] L. Pivina et al., "Iron deficiency, cognitive functions, and neurobehavioral disorders in children," *Journal of Molecular Neuroscience*, vol. 68, pp. 1-10, 2019.

[22] E. Tam et al., "Micronutrient supplementation and fortification interventions on health and development outcomes among children under-five in low-and middle-income countries: A systematic review and meta-analysis," *Nutrients*, vol. 12, no. 2, p. 289, 2020.

[23] K. Vikram, and N. Chindarkar, "Bridging the gaps in cognitive achievement in India: The crucial role of the integrated child development services in early childhood," *World Development*, vol. 127, p. 104697, 2020.

[24] D. Khanna et al., "Oral nutritional supplementation improves growth in children at malnutrition risk and with picky eating behaviors," *Nutrients*, vol. 13, no. 10, p. 3590, 2021.

[25] A. R. Lakshminarayanan et al., "Malnutrition detection using convolutional neural network," in *2021 Seventh*

International conference on Bio Signals, Images, and Instrumentation (ICBSII), IEEE, 2021.

[26] S. J. M. Osendarp, "The role of omega-3 fatty acids in child development," *Oléagineux, Corps Gras, Lipides*, vol. 18, no. 6, pp. 307-313, 2011.

[27] H. Choudhry, and Md. Nasrullah, "Iodine consumption and cognitive performance: Confirmation of adequate consumption," *Food Science & Nutrition,* vol. 6, no .6, pp. 1341-1351, 2018.

[28] K. Bougma et al., "Iodine and mental development of children 5 years old and under: A systematic review and meta-analysis," *Nutrients*, vol. 5, no. 4, pp. 1384-1416, 2013.