Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol. 14, Issue 15s (2025)
https://www.jneonatalsurg.com

OPEN ACCESS

Anemia In Children: A Persistent Global Challenge

Dr. Ambika P L[1], Dr. Lavanya.B[2], Dr. A.N. Uma[*3]

[1]Assistant Professor, Pathology, School of Allied Health Sciences, Sri Balaji Vidyapeeth (Deemed to be University), Puducherry.

[2]Assistant Professor, Department of Community Medicine, Sri Sathya Sai Medical College and Research Institute, Chennai

[*3]Professor of Medical Genetics, Principal of School of Allied Heath Sciences, Sri Balaji Vidyapeeth (Deemed to be University), Puducherry.

***Corresponding Author:**

A.N. Uma

Professor of Medical Genetics, School of Allied Health Sciences,Mahatma Gandhi Medical College and Research Institute Sri Balaji Vidyapeeth, Puducherry.

Email ID: uma@mgmcri.ac.in

Cite this paper as: Dr. Ambika P L, Dr. Lavanya.B, Dr. A.N. Uma, (2025) Anemia In Children: A Persistent Global Challenge. *Journal of Neonatal Surgery*, 14 (15s), 1920-1927.

ABSTRACT

Anemia is a widespread hematological disorder defined by a reduction in the number of circulating red blood cells (RBCs) or a decrease in the hemoglobin concentration below established age- and sex-specific thresholds. This condition impairs the oxygen-carrying capacity of blood, which in turn affects tissue oxygenation and cellular metabolism. Among vulnerable populations, particularly children under five years of age, anemia represents a significant public health concern with far-reaching consequences. According to the World Health Organization (WHO), more than 40% of children in this age group globally are anemic, underscoring the critical scale and urgency of the problem [1].

The etiology of anemia in children is complex and multifactorial. Nutritional deficiencies—most notably of iron, but also of folate, vitamin B12, and vitamin A—are among the leading causes. However, other contributors include inherited hemoglobin disorders (hemoglobinopathies), chronic infections (such as malaria and tuberculosis), inflammatory and autoimmune diseases, and certain genetic or congenital conditions that impair hematopoiesis. Socioeconomic factors such as poverty, food insecurity, poor access to healthcare, and inadequate maternal education further compound the risk, particularly in low- and middle-income countries.

The consequences of anemia in children extend beyond hematological parameters. It adversely affects cognitive and motor development, academic performance, immune function, and overall physical growth. Severe or prolonged anemia during critical stages of development may lead to irreversible deficits, placing affected children at a disadvantage throughout life. Moreover, the burden of anemia contributes to increased healthcare utilization, reduced productivity, and higher morbidity and mortality rates, making it not only a medical concern but also a socioeconomic one.

Given its broad implications, a comprehensive understanding of the epidemiology, etiology, clinical manifestations, diagnostic approaches, and management strategies of anemia in children is essential for effective intervention. This review explores these multidimensional aspects of childhood anemia, aiming to inform clinicians, researchers, and public health practitioners about the key factors driving the condition and the necessary steps for its prevention and treatment. Ultimately, addressing the burden of anemia requires a concerted global effort focused on improving nutrition, strengthening health systems, promoting maternal and child health, and reducing inequalities in healthcare access and education.

Keywords: *Anemia in children, iron deficiency, pediatric health, hemoglobinopathy*

1. INTRODUCTION

Anemia, a condition marked by a reduction in the number of red blood cells (RBCs) or a diminished concentration of hemoglobin, represents one of the most widespread and persistent global health challenges, especially in low- and middle-income countries. Among vulnerable groups, children under the age of five are particularly affected, making pediatric anemia a major public health concern. According to the World Health Organization (WHO), more than 40% of children under five worldwide are anemic, with the highest prevalence rates recorded in sub-Saharan Africa, South Asia, and parts of Latin

America. The implications of anemia in early childhood are far-reaching and profound, with negative impacts on cognitive development, physical growth, immune function, and school performance. These outcomes not only compromise individual health and potential but also perpetuate cycles of poverty and inequality at the community and national levels.

The burden of anemia in children is rooted in a complex interplay of factors, ranging from nutritional deficiencies and infectious diseases to genetic disorders and chronic conditions. Iron deficiency remains the most common cause, often due to inadequate dietary intake, poor absorption, or increased iron requirements during periods of rapid growth. However, anemia in children is not solely attributed to iron deficiency; other micronutrient deficiencies—such as folate, vitamin B12, and vitamin A—can also contribute to hematological impairments. Beyond nutrition, the role of infections, such as malaria, helminthiasis, and chronic inflammatory diseases, cannot be overlooked, especially in endemic regions. Furthermore, hereditary conditions like sickle cell disease, thalassemia, and other hemoglobinopathies significantly contribute to the overall prevalence of pediatric anemia, particularly in specific geographic populations.

Understanding anemia in children thus necessitates a multidimensional perspective that encompasses biological, environmental, social, and economic factors. For example, in impoverished settings, limited access to diverse food sources, poor sanitation, and inadequate healthcare infrastructure exacerbate the risk and severity of anemia. In contrast, in more developed contexts, underlying chronic diseases, low birth weight, and inherited blood disorders often play a larger role. These variations in etiology underscore the importance of region-specific data and tailored interventions that address the root causes of anemia within specific populations.

Clinically, anemia in children may present with a wide range of symptoms, from subtle signs such as fatigue, irritability, and pallor to more severe manifestations including tachycardia, developmental delays, and impaired learning. In many cases, mild to moderate anemia may go unnoticed due to its non-specific presentation, leading to delayed diagnosis and intervention. The chronic nature of anemia and its ability to silently impair multiple physiological systems make early detection and effective management crucial for improving health outcomes. Diagnosis typically involves laboratory testing, including complete blood count (CBC), reticulocyte count, serum ferritin, and peripheral blood smear analysis. However, in low-resource settings, access to diagnostic tools may be limited, underscoring the need for simplified screening strategies and community-based health initiatives.

Management of pediatric anemia requires a comprehensive approach that targets both the underlying cause and the resultant physiological deficits. Nutritional interventions, particularly iron supplementation and food fortification, have shown significant success in reducing anemia prevalence when properly implemented. In regions where parasitic infections are prevalent, deworming programs and malaria prevention measures are critical components of anemia control. For children with genetic forms of anemia, early diagnosis and supportive care, including transfusions, hydroxyurea therapy, and genetic counseling, are essential. Equally important are public health strategies that strengthen healthcare systems, enhance maternal and child health services, and promote health education at the community level.

Efforts to address pediatric anemia must also recognize the broader socio-economic and political contexts in which the condition arises. Factors such as poverty, food insecurity, limited education, and gender inequality contribute to the persistence of anemia across generations. Investing in early childhood health, particularly by addressing anemia, can yield long-term benefits in human capital development, economic productivity, and social well-being. International initiatives, including those led by the WHO, UNICEF, and national governments, have made notable strides in combatting anemia, yet much work remains to be done to achieve sustainable progress and equity in child health.

This review article aims to explore the multifaceted dimensions of anemia in children by examining its epidemiology, etiology, clinical features, diagnostic challenges, and current management strategies. Through an integrative understanding of the causes and consequences of pediatric anemia, this review seeks to highlight the urgency of targeted interventions and evidence-based policies that can effectively reduce the burden of this preventable condition. Ultimately, addressing anemia in children is not only a medical imperative but also a moral and developmental priority that can significantly improve the lives of millions of children worldwide.

2. PREVALENCE OF ANEMIA IN CHILDREN

Anemia is a common health complication with varying prevalence throughout the world due to regions and socioeconomic factors. The World Health Organization claims nearly 58.4 million children under five years of age suffer from anemia across the globe. For instance, one study conducted in India revealed that 58.6% of children ranging from 6 to 59 months old suffered from anemia. Similarly, one systematic review and meta-analysis provided evidence for the prevalence of anemia in children under five years of age in Africa, which is at 47.5% south of the Sahara.

Anemia impacts various dimensions of children's health and development, including:

• Cognitive Development: A leading cause of anemia is iron deficiency which, in many cases, disrupts cognitive ability with adverse effects on learning, memory, and concentration[4].

• Physical Growth: Anemia tends to slow down growth and physical development, resulting in under-growth and delay in

attaining motor skills.[5].

• Immune Response: Anemia tends to weaken the immune system, causing children to be more prone to infections, as well as worsening the illness.[6]

• School Performance: Anemia is known to affect the performance in class with negative academic achievement and increase the rate of school dropout.[7]

3. GRASPING THE FUNDAMENTALS

Disks enriched with hemoglobin, known as red blood cells or RBCs, aid in the transportation of oxygen in our bodies. RBCs hold on to oxygen from lungs and carry it to be utilized by organs and tissues in the body. A reduction in self-sufficient and healthy RBCs negatively impacts the body's ability to produce sufficient amount of hemoglobin and leads to anemia. Symptoms of anemia can aggravate into more severe conditions such as weariness, feeling weak, having difficulty in breathing, and paleness of skin. (8)

4. THE DEVELOPMENT OF ANEMIA: A MULTIDIMENSIONAL APPROACH

Anemia arises through various interlinked mechanisms, and understanding its development requires a holistic view of these contributing factors. These mechanisms fall into three major categories: impaired red blood cell (RBC) production, increased destruction of RBCs, and blood loss.

Impaired red blood cell production is commonly associated with nutritional deficiencies, particularly iron, vitamin B12, and folate. Iron is essential for hemoglobin synthesis, and deficiencies typically arise due to inadequate intake, poor absorption, or increased physiological demands such as during infancy, adolescence, or pregnancy. Vitamin B12 and folate are critical for DNA synthesis and the maturation of red blood cells. Their deficiency can result in megaloblastic anemia, a condition characterized by the presence of large, immature, and dysfunctional RBCs. Beyond nutrient deficiencies, certain bone marrow disorders, including aplastic anemia and leukemia, can significantly impair the body's ability to produce sufficient RBCs. Chronic diseases such as kidney disorders, autoimmune conditions, and endocrine dysfunctions may also suppress bone marrow activity or interfere with erythropoietin production, leading to what is termed anemia of chronic disease.

The second pathway to anemia involves increased destruction of red blood cells. Hemolytic anemias, whether hereditary—such as sickle cell disease and thalassemia—or acquired through autoimmune processes or drug-induced hemolysis, result in a shortened lifespan of RBCs. In these cases, the body cannot produce new cells fast enough to compensate for the loss, leading to a net reduction in circulating red blood cells.

Blood loss, both acute and chronic, is another significant contributor to anemia. Acute hemorrhage from trauma or surgical procedures can lead to sudden, severe anemia. Chronic blood loss, on the other hand, is often more insidious and may result from gastrointestinal bleeding (due to ulcers, parasitic infections, or inflammatory bowel disease) or heavy menstrual bleeding. Over time, such persistent blood loss can deplete the body's iron stores, leading to iron deficiency anemia.

In pediatric populations, anemia is influenced by a combination of nutritional, genetic, infectious, and chronic disease-related factors. Iron deficiency remains the most prevalent cause of anemia in children worldwide. This is largely due to rapid growth during early childhood and adolescence, which increases the body's demand for iron. Inadequate intake of iron-rich foods—such as red meat, legumes, and fortified cereals—further exacerbates this issue. Children who consume a diet low in other micronutrients, including vitamin B12 and folic acid, are also at risk. Malabsorption syndromes like celiac disease and Crohn's disease can hinder the absorption of these vital nutrients.

Genetic conditions, including sickle cell anemia, thalassemia, and hereditary spherocytosis, significantly impact the quantity and quality of RBCs. These disorders often result in chronic anemia and require ongoing management through medication, transfusions, or bone marrow transplants. Infections such as malaria, HIV, and tuberculosis can directly or indirectly suppress red cell production through inflammation or by affecting the bone marrow's functionality.

Myelodysplastic syndromes and malignancies such as leukemia also impair RBC production and are critical considerations in pediatric anemia, although they are less common. These conditions typically present with other systemic symptoms and require specialized medical intervention.

The management and prevention of anemia, especially in children, require a multifaceted approach. Nutritional strategies play a foundational role—consuming both heme iron (from animal sources) and non-heme iron (from plant-based sources) is essential. Vitamin C enhances the absorption of non-heme iron, making foods like citrus fruits, tomatoes, and bell peppers valuable dietary additions. Fortified foods such as cereals and bread, along with iron supplements when necessary, help restore depleted iron levels.

Raising awareness in communities about the importance of a balanced diet and routine health screenings is crucial. In cases of anemia stemming from chronic illnesses, managing the underlying condition is key. Regular monitoring through blood tests allows for early detection and prompt intervention, which is especially important in children to prevent long-term

developmental consequences.

Ultimately, addressing anemia through improved nutrition, education, healthcare access, and early medical intervention can significantly enhance overall health outcomes and quality of life, particularly in vulnerable pediatric populations.

Table 1: Mechanisms by which vitamin deficiencies can play roles in the development of anaemia

Vitamin deficiency	Possible role in anaemia through:
Vitamin A	Mobilization affected by iron storage Impaired erythropoiesis, Increased susceptibility to infection
Folic acid	Impaired DNA synthesis, leading to ineffective erythropoiesis
Vitamin B12	Impaired metabolism of folate, leading to ineffective erythropoiesis
Riboflavin	Impaired iron mobilization, globin production, leading to impaired erythropoiesis Reduced intestinal absorptive capacity
Vitamin C	Reduced absorption, mobilization of iron from stores, Impaired folate metabolism Oxidant damage to erythrocytes, leading to Haemolysis, Capillary haemorrhaging, leading to blood loss
Vitamin E	Oxidant damage to erythrocytes, leading to haemolysis
Vitamin B6	Impaired haem synthesis, leading to impaired erythropoiesis

5. LATEST ADVANCEMENTS

Anemia Phone, a technological innovation created by a diverse team of researchers at Cornell University, is designed to provide a precise, rapid, and cost-effective assessment of iron deficiency. This technology has been officially handed over to the Indian Council of Medical Research, a governmental body in India, for incorporation into its initiatives aimed at addressing anemia, as well as promoting women's health and maternal and child health across the nation. The implementation of Anemia Phone will facilitate swift screening and diagnosis of iron deficiency at the point of care throughout India. Iron deficiency is the primary contributor to anemia, a medical condition characterized by an insufficient number of healthy red blood cells to transport oxygen effectively, impacting one in four individuals. This technology was developed and validated in the laboratories of the Joan Klein Jacobs Center for Precision Nutrition and Health within the College of Human Ecology. The formal transfer of this technology to India occurred at no financial cost on November 7 2024.

Iron deficiency accounts for only 10–40% of all cases of anemia in India, while other factors such as deficiencies in micronutrients, hemoglobinopathies, anemia related to chronic illnesses, and anemia of unknown origin make up the remainder. Consequently, according to current guidelines, 60-90% of individuals with anemia may be subjected to unnecessary iron supplementation. This not only leaves the underlying causes of their anemia unaddressed but also subjects them to the adverse effects of oral iron therapy, which can include distressing gastrointestinal issues and alterations in gut microbiota, potentially leading to compromised gut immunity and recurrent diarrhea. Furthermore, the guidelines suggest that iron tablets should be taken after meals, a recommendation that is misguided.

REFERENCES

[1] World Health Organization (WHO). (2021). Anemia. [Online]. Available from: https://www.who.int/news-room/fact-sheets/detail/anaemia

[2] National Family Health Survey (NFHS-5). (2020). India Health Survey. [Online]. Available from: https://rchiips.org/nfhs/

[3] De Benoist B, McLean E, Egli I, Cogswell M. Worldwide prevalence of anemia: WHO global database on anemia. World Health Stat Annu. 62(1):113-144.

[4] Lozoff B, Brittenham GM, Viteri FE, Woolridge MW. Iron deficiency microcytosis and behavior problems in a longitudinal study of infants. Pediatrics. 87(3):380-387.

[5] Grantham-McGregor S, Powell CA, Fletcher PE, et al. Nutritional supplementation, psychosocial stimulation, and cognitive development of stunted children: the Jamaican study. Lancet. 338:132-138.

[6] Chandra RK. Nutrition, immunity, and infection: mechanisms of interaction. Clin Microbiol Rev. 4(1):296-318.

[7] Grantham-McGregor S, Powell CA, Walker SP, Chang SM. (1994). Iron deficiency is associated with increased prevalence of infection and parasite infestation in preschool children. Am J Clin Nutr. 60(1):408-413.

[8] Zimmermann MB, Stoltzfus RJ. Iron deficiency. Lancet. 2009; 373(9660):518-528.

[9] Cook JT, Grantham-McGregor SM. Anemia among young children and its consequences. Adv Pediatr. 2007;54:33-56.

[10] Global and Regional Results. Geneva: Administrative Committee on Coordination/Subcommittee on Nutrition, 1992.

[11] Iron Deficiency: Indicators for Assessment and Strategies for Prevention. Geneva: World Health Organization, 1997.

[12] Lee GR. The anemia of chronic disease. Semin. Hematol. 1983; 20: 61±80.

[13] Fairbanks VF. Iron in medicine and nutrition. In: Shils ME, Olson JA, Shike M, eds. Modern Nutrition in Health and Disease. Philadelphia: Lea and Febiger, 1994; 185±213.

[14] Viteri FE. Iron supplementation for the control of iron deficiency in populations at risk. Nutr. Rev. 1997; 55: 195± 209.

[15] DeMaeyer E, Adiels-Tegman M. The prevalence of anaemia in the world. Rapp. Trimest. Statist. Sanit. Mond. 1985; 38: 302±16.

[16] International Nutritional Anemia Consultative Group (INACG). Iron De®ciency in Women. Washington, DC: The Nutrition Foundation, 1981.

[17] Rossiter CE. Maternal mortality. Br. J. Obstet. Gynaecol. 1985; 5 (Suppl.): 100±15.

[18] Dallman PR. Iron. In: Brown ML, ed. Present Knowledge in Nutrition. Washington, DC: International Life Sciences Institute/Nutrition Foundation, 1990; 241±50.

[19] Christian P. Antenatal iron supplementation as a child survival strategy. Am. J. Clin. Nutr. 1998; 68: 403±4.

[20] Sommer A. Nutritional Blindness. New York: Oxford University Press, 1982.

[21] Humphrey JH, West KP, Sommer A. Vitamin A deficiency and attributable mortality among under-5-year-olds. Bull. World Health Org. 1992; 70: 225±32

[22] Falkingham M, Abdelhamid A, Curtis P, Fairweather-Tait S, Dye L, Hooper L. The effects of oral iron supplementation on cognition in older children and adults: a systematic review and meta-analysis. Nutrition journal. 2010;9(1):1–16. pmid:20100340

[23] Chen Z, Yang H, Wang D, Sudfeld CR, Zhao A, Xin Y, et al. Effect of Oral Iron Supplementation on Cognitive Function among Children and Adolescents in Low-and Middle-Income Countries: A Systematic Review and Meta-Analysis. Nutrients. 2022;14(24):5332. pmid:36558491

[24] Lam LF, Lawlis TR. Feeding the brain–The effects of micronutrient interventions on cognitive performance among school-aged children: A systematic review of randomized controlled trials. Clinical Nutrition. 2017;36(4):1007–14. pmid:27395329

[25] Taras H. Nutrition and student performance at school. Journal of school health. 2005;75(6):199–213. pmid:16014126

[26] Samson KL, Fischer JA, Roche ML. Iron status, anemia, and iron interventions and their associations with cognitive and academic performance in adolescents: a systematic review. Nutrients. 2022;14(1):224. pmid:35011099

[27] Jáuregui-Lobera I. Iron deficiency and cognitive functions. Neuropsychiatric disease and treatment. 2014:2087–95. pmid:25419131

[28] WHO. Guideline: intermittent iron supplementation in preschool and school-age children: Geneva: World

Health Organization; 2011.

[29] Gera T, Sachdev H, Nestel P, Sachdev SS. Effect of iron supplementation on haemoglobin response in children: systematic review of randomised controlled trials. Journal of pediatric gastroenterology and nutrition. 2007;44(4):468–86. pmid:17414146

[30] Gera T, Sachdev H. Effect of iron supplementation on incidence of infectious illness in children: systematic review. Bmj. 2002;325(7373):1142. pmid:12433763

[31] Page MJ, Moher D, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. BMJ. 2021;372:n160. pmid:33781993

[32] Pocock SJ, Smith M, Baghurst P. Environmental lead and children's intelligence: a systematic review of the epidemiological evidence. Bmj. 1994;309(6963):1189–97. pmid:7987149

[33] Lanphear BP, Dietrich K, Auinger P, Cox C. Cognitive deficits associated with blood lead concentrations< 10 microg/dL in US children and adolescents. Public health reports. 2000;115(6):521.

[34] Canfield RL, Henderson CR Jr, Cory-Slechta DA, Cox C, Jusko TA, Lanphear BP. Intellectual impairment in children with blood lead concentrations below 10 μg per deciliter. New England journal of medicine. 2003;348(16):1517–26.

[35] Bellinger DC. Interpreting the literature on lead and child development: the neglected role of the "experimental system". Neurotoxicology and Teratology. 1995;17(3):201–12.

[36] Lefebvre C, Glanville J, Briscoe S, Featherstone R, Littlewood A, Marshall C, et al. Searching for and selecting studies. In: Higgins J, Thomas J, Chandler J, Cumpston M, Li T, Page M, et al., editors. Cochrane Handbook for systematic reviews of interventions. Version 6.3: John Wiley & Sons; 2022. p. 67–107.

[37] Wan X, Wang W, Liu J, Tong T. Estimating the sample mean and standard deviation from the sample size, median, range and/or interquartile range. BMC medical research methodology. 2014;14(1):1–13. pmid:25524443

[38] Higgins JP, Eldridge S, Li T. Including variants on randomized trials. In: Higgins J, Thomas J, Chandler J, Cumpston M, Li T, Page M, et al., editors. Cochrane handbook for systematic reviews of interventions. Version 6.3: John Wiley & Sons; 2022. p. 569–93.

[39] Fageer MNA, Hussein MD, Fagiri MNA, Osman M. 1239 Randomized controlled trial on the effect of weekly iron/folic acid supplementation on anemia and school performance among school children in rural Sudan. BMJ Publishing Group Ltd; 2021.

[40] Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Annals of internal medicine. 2009;151(4):264–9. pmid:19622511

[41] Lynn R, Harland EP. A positive effect of iron supplementation on the IQs of iron deficient children. Personality and Individual Differences. 1998;24(6):883–5.

[42] Buzina-Suboticanec K, Buzina R, Stavljenic A, Tadinac-Babic M, Juhovic-Markus V. Effects of iron supplementation on iron nutrition status and cognitive functions in children. Food and Nutrition Bulletin. 1998;19(4):298–306.

[43] Baumgartner J, Smuts CM, Malan L, Kvalsvig J, van Stuijvenberg ME, Hurrell RF, et al. Effects of iron and n-3 fatty acid supplementation, alone and in combination, on cognition in school children: a randomized, double-blind, placebo-controlled intervention in South Africa. The American journal of clinical nutrition. 2012;96(6):1327–38. pmid:23097272

[44] Sen A, Kanani SJ. Impact of iron-folic acid supplementation on cognitive abilities of school girls in Vadodara. Indian pediatrics. 2009;46(2). pmid:19242031

[45] Sungthong R, Mo-Suwan L, Chongsuvivatwong V, Geater AF. Once-weekly and 5-days a week iron supplementation differentially affect cognitive function but not school performance in Thai children. The Journal of Nutrition. 2004;134(9):2349–54. pmid:15333727

[46] Soemantri A, Pollitt E, Kim I. Iron deficiency anemia and educational achievement. The American Journal of Clinical Nutrition. 1985;42(6):1221–8. pmid:4072957

[47] Soemantri A. Preliminary findings on iron supplementation and learning achievement of rural Indonesian children. The American Journal of Clinical Nutrition. 1989;50(3):698–702. pmid:2773847

[48] Pollitt E, Hathiral P, Kotchabhakdi NJ, Missell L, Valyasevi A. Iron deficiency and educational achievement in Thailand. The American journal of clinical nutrition. 1989;50(3):687–97. pmid:2773846

[49] Pollitt E. Iron deficiency and educational deficiency. Nutrition Reviews. 1997;55(4):133–40. pmid:9197133

[50] Kashyap P, Gopaldas T. Impact of hematinic supplementation on cognitive function in underprivileged school girls (8–15 yrs of age). Nutrition Research. 1987;7(11):1117–26.

[51] Gopaldas T, Kale M, Bhardwaj P. Prophylactic iron supplementation for underprivileged school boys. II. Impact on selected tests of cognitive function. Indian pediatrics. 1985;22(10):737–43.

[52] Seshadri S, Hirode K, Naik P, Malhotra S. Behavioural responses of young anaemic Indian children to iron-folic acid supplements. Br J Nutr. 1982;48(2):233–40. pmid:7115656

[53] Ayoya MA, Spiekermann-Brouwer GM, Traoré AK, Garza C. Effect on school attendance and performance of iron and multiple micronutrients as adjunct to drug treatment of Schistosoma-infected anemic schoolchildren. Food and nutrition bulletin. 2012;33(4):235–41. pmid:23424889

[54] Ayoya MA, Spiekermann-Brouwer GM, Traoré AK, Stoltzfus RJ, Habicht J-P, Garza C. Multiple micronutrients including iron are not more effective than iron alone for improving hemoglobin and iron status of Malian school children. The Journal of nutrition. 2009;139(10):1972–9. pmid:19675104

[55] Sungthong R, Mo-Suwan L, Chongsuvivatwong V, Geater AF. Once weekly is superior to daily iron supplementation on height gain but not on hematological improvement among schoolchildren in Thailand. The Journal of nutrition. 2002;132(3):418–22. pmid:11880565

[56] Hathirat P, Valyasevi A, Kotchabhakdi NJ, Rojroongwasinkul N, Pollitt E. Effects of an iron supplementation trial on the Fe status of Thai schoolchildren. British Journal of Nutrition. 1992;68(1):245–52. pmid:1390607

[57] Malan L, Baumgartner J, Calder PC, Zimmermann MB, Smuts CM. n–3 Long-chain PUFAs reduce respiratory morbidity caused by iron supplementation in iron-deficient South African schoolchildren: a randomized, double-blind, placebo-controlled intervention. The American journal of clinical nutrition. 2014;101(3):668–79. pmid:25733652

[58] Chwang L, Soemantri A, Pollitt E. Iron supplementation and physical growth of rural Indonesian children. The American journal of clinical nutrition. 1988;47(3):496–501. pmid:3348161

[59] Stevens GA, Paciorek CJ, Flores-Urrutia MC, Borghi E, Namaste S, Wirth JP, et al. National, regional, and global estimates of anaemia by severity in women and children for 2000–19: a pooled analysis of population-representative data. The Lancet Global Health. 2022;10(5):e627–e39. pmid:35427520

[60] Quadri P, Fragiacomo C, Pezzati R, Zanda E, Forloni G, Tettamanti M, et al. Homocysteine, folate, and vitamin B-12 in mild cognitive impairment, Alzheimer disease, and vascular dementia. The American journal of clinical nutrition. 2004;80(1):114–22. pmid:15213037

[61] Tucker KL, Qiao N, Scott T, Rosenberg I, Spiro A 3rd. High homocysteine and low B vitamins predict cognitive decline in aging men: the Veterans Affairs Normative Aging Study. Am J Clin Nutr. 2005;82(3):627–35. Epub 2005/09/13. pmid:16155277.

[62] Ramos MI, Allen LH, Mungas DM, Jagust WJ, Haan MN, Green R, et al. Low folate status is associated with impaired cognitive function and dementia in the Sacramento Area Latino Study on Aging. The American journal of clinical nutrition. 2005;82(6):1346–52. pmid:16332669

[63] Levine M, Morita K, Pollard H. Enhancement of norepinephrine biosynthesis by ascorbic acid in cultured bovine chromaffin cells. J Biol Chem. 1985;260(24):12942–7. Epub 1985/10/25. pmid:3932336.

[64] Majewska MD, Bell JA. Ascorbic acid protects neurons from injury induced by glutamate and NMDA. Neuroreport. 1990;1(3–4):194–6. Epub 1990/11/01. pmid:1983355.

[65] Kruszewski M. Labile iron pool: the main determinant of cellular response to oxidative stress. Mutation Research/Fundamental and Molecular Mechanisms of Mutagenesis. 2003;531(1–2):81–92. pmid:14637247

[66] Domellöf M. Benefits and harms of iron supplementation in iron-deficient and iron-sufficient children. Importance of Growth for Health and Development. 65: Karger Publishers; 2010. p. 153–65.

[67] 61.Kim J, Wessling-Resnick M. Iron and mechanisms of emotional behavior. J Nutr Biochem. 2014;25(11):1101–7. pmid:25154570

[68] Nieoullon A. Dopamine and the regulation of cognition and attention. Prog Neurobiol. 2002;67(1):53–83. pmid:12126656

[69] Carlson ES, Tkac I, Magid R, O'Connor MB, Andrews NC, Schallert T, et al. Iron is essential for neuron development and memory function in mouse hippocampus. The Journal of nutrition. 2009;139(4):672–9. pmid:19211831

[70] Fretham SJ, Carlson ES, Georgieff MK. The role of iron in learning and memory. Advances in Nutrition.

2011;2(2):112–21. pmid:22332040

[71] Peng P, Kievit RA. The development of academic achievement and cognitive abilities: A bidirectional perspective. Child Development Perspectives. 2020;14(1):15–20. pmid:35909387

[72] Youdim MB, Ben-Shachar D, Yehuda S. Putative biological mechanisms of the effect of iron deficiency on brain biochemistry and behavior. The American journal of clinical nutrition. 1989;50(3):607–17. pmid:2773840

[73] Low MSY, Speedy J, Styles CE, De-Regil LM, Pasricha SR. Daily iron supplementation for improving anaemia, iron status and health in menstruating women. Cochrane Database of Systematic Reviews. 2016;(4). pmid:27087396