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Impact of Early Nutrition on Cognitive Development in Children; A systematic review

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Abstract

Background:

The brain of children requires all essential nutrients in adequate amounts. Adequate and balanced nutrients are essential for development and functioning of the brain. Cognitive development (CD) in early life often predicts the later achievements in life. Therefore, nutrition has a vital role in shaping CD across the lifespan from infancy to older age. Furthermore, nutritional requirements vary potentially based on several aspects including age of the individual.

Aim:

To assess the effect of nutrition on cognition in pediatrics by reviewing the research reported on such subjects.

Methods:

Exploration of electronic databases was done to get eligible articles and through the implementation of various terms for the search process. Eligible articles were original, English, and Full-text, concerned with the correlation and/or impact of nutrition on CD among the pediatric population.

Results:

Ten studies agreed with the criteria and were enrolled with 2416 children included in the studies with age range of six months to 12 years. The studies encompassed different designs. The findings were presented in a proper manner.

Conclusion:

Good and balanced nutrition is essential for proper CD in children, as CD is associated with their nutritional status. Proper CD is associated with adequate and balanced nourishment and vice versa.

Keywords: Cognitive development, Pediatrics, Impact, Nutrition.

Introduction:

Malnutrition is defined as the imbalance between the nutrient requirement of individuals and their nutrient consumption and encompasses conditions of undernutrition and over-nutrition **[1]**. Undernutrition occurs due to inadequate intake of protein, minerals, vitamins, or energy **[1]**, and it is a global problem hindering the development of young pediatrics **[2, 3]**. Undernutrition can cause several issues for young children, such as stunting, emaciation, and wasting **[1]**. Undernutrition can also result in impaired development and reduced functional capacity **[4]**.

The brain of humans, especially children, requires all nutrients, including carbohydrates, proteins, fats, minerals, vitamins, and water, to form and maintain its structure. Hence, adequate nutrition is crucial for the progression and functioning of the brain **[5, 6]**. Cognitive development (CD) in early life often predicts later life achievements **[7, 8]**. The CD is a complex and multi-faceted group of mental abilities. In pediatrics, this event tracks the progression of various areas such as memory, problem-solving, reasoning, knowledge representation, and learning **[9]**.

Nutrition has a vital role in shaping CD across the lifespan from infancy to older age **[10].** Nutritional requirements for individuals vary potentially based on several variables such as age, physical activity, height, weight, genetic and metabolic conditions **[10]**. In early childhood, sufficient nutrition enhances the formation of neural connections and supports cognitive functions such as memory, attention and problem-solving skills **[10]**.

A previous review focused on the first thousand days of life discovered the important role of macronutrients such as protein in optimizing brain development **[11]**. However, public policy often doesn't include preschool-age children despite the importance of the second 1000 days of life in the behavior and CD of children **[12]**. So, this review was carried out to identify the impact of children's nutrition on their cognition till 12 years of age.

Method and search procedure:

The PRISMA statement **[13]** was adopted as the guidance for writing this review. An exploration of electronic databases was done to search for eligible articles; such databases included PubMed, Science Direct, Google Scholar, and Scopus. The search procedure was done using various terms in various combinations to get all possible related research, including "Children, Pediatrics, Impact, Effect, Correlation, Association, Nutrition, Status, Malnutrition, Cognition, Cognitive Development, Cognitive abilities, and Cognitive performance." All the obtained titles were revised precisely to avoid missing significant research.

Eligibility criteria:

The findings were first checked for duplication to exclude duplicate articles, then checked for the study population and excluded articles conducted on the adult population. Also, studies focused on the relationship between nutrition and other items, such as physical activity or physical growth, were excluded. To include studies over ten years, articles published from 2016 to 2025 were eligible and considered for further refining steps. Study protocols were excluded, and non-original articles were, whereas original articles were considered for further steps of refining and were then checked for language. English articles were enrolled and considered eligible. Articles from any region of the world and those of any design were also eligible. Articles available for full text were included, whereas those providing abstracts only were excluded. The scheme of inclusion is illustrated in figure 1.

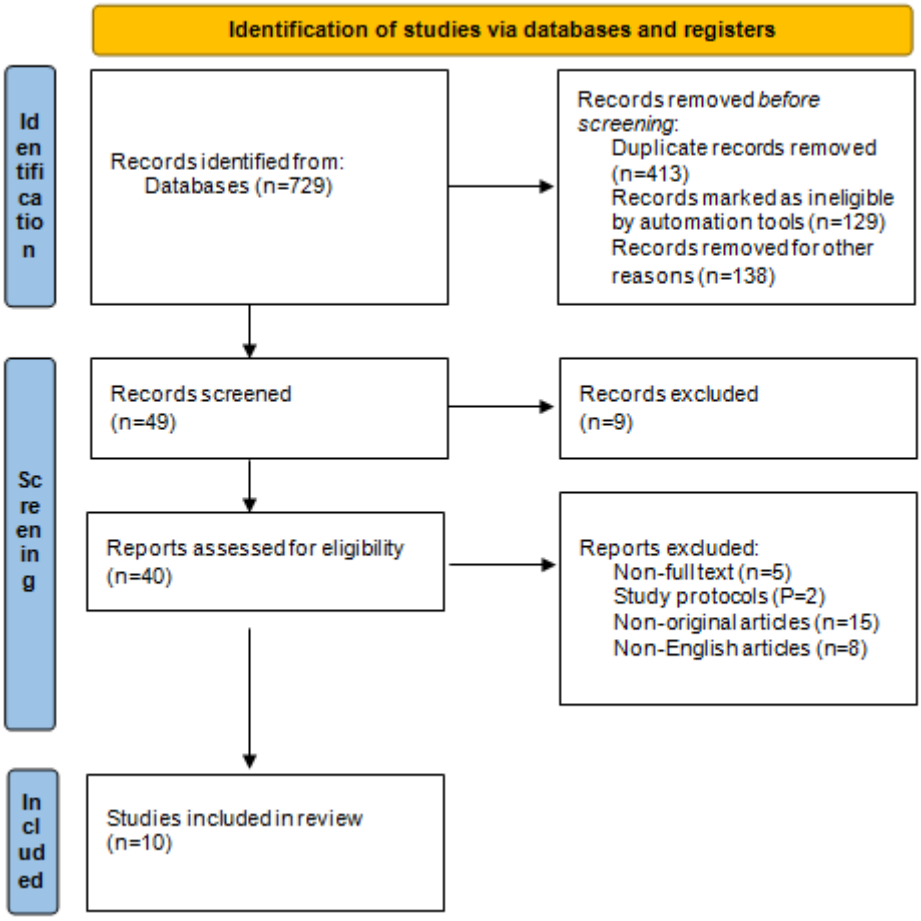

Fig1: Scheme of inclusion

Data review, extraction, and analysis:

Each enrolled article was revised for abstract to determine the data required for extraction. The data was extracted by reviewing the full-text research and using an excel sheet for extraction of data. A pre-designed table was used to summarize the data under major four titles to facilitate the understanding of the data.

Results:

This work enrolled ten articles that agreed with our criteria **[14-23] (table 1).** Most of the studies were cross-sectional **[15, 18-23]**, whereas the remaining three studies included observational **[14]**, retrospective **[16]**, or trial **[17]**. The total number of children was 2416 subjects with an age range of six months to 12 years; there were seven studies that categorized pediatrics into many groups. Two studies categorized subjects into three groups based on nutrition level **[14, 21]**; another two studies reported the proportion of acute malnutrition among the subjects (6.4%) **[15]** and the proportion of malnutrition (8.2%) **[23]**. One study reported the proportions of normal nutrition (27.8%) and abnormal one (72.2%) **[16]**. One research study enrolled malnourished subjects and categorized them into control and intervention, whose mothers received an educational intervention for 12 months to identify the impact of educating mothers on malnutrition and cognition improvement **[17]**. One research categorized subjects based on region into rural and urban categories **[19]**.

The findings of the studies were highly heterogeneous due to the varied objectives of each enrolled research; therefore, we could present the findings of the studies as follows:

Regarding the levels of CD, normal CD was 72.2% **[16]**, 69.36% had moderate CD **[18]**, high average (25.9%), superior (2.4%) and very superior (1.2%) **[20]**, and 88.6% had good cognitive performance **[23]**.

Regarding the studies that categorized nutrition levels, one study reported the best CD regarding four domains and the overall cognition scores for well-nourished subjects, whereas intermediate scores were detected for moderately nourished and the lowest scores were detected for those with severe malnutrition. Such scores of CD were improved after six months considerably ($P<0.05$) in each category with considerable variations in CD based on the nutritional status($P<0.01$), where severe malnutrition scored the least improvement **[14]**. The other study that involved three categories of nutrition reported cognition based on IQ, and it was revealed that there was no correlation between cognitive performance (IQ) and nutritional status ($P=0.2$); however, IQ was higher among subjects from the urban region ($P=0.005$) and lower for those consuming food cooked with margarine ($P=0.002$) **[21]**.

One study compared the correlation of CD with nutrition in rural and urban region revealed that cognition was considerably higher in urban region and regarding visual processing, pattern reasoning, and school performance ($P<0.001$), where cognitive function and school performance were linked with nutritional status **[19]**.

Positive correlation was reported between CD and nutritional status in one study **[18]**. Gross motor ($P=0.01$), fine motor ($P=0.047$) and problem-solving skill developments ($P=0.047$) were associated with nutritional status **[15]**. Also, the CD was associated with nutrition (RR 2.591, $P=0.01$) **[16]**.

Patterns of food influenced cognition; verbal and general cognitive abilities and cognitive functions were negatively associated with snacky patterns. Neurodevelopmental scales displayed no association with Western or Mediterranean patterns **[22]**. Cognitive function and school performance were negatively linked with stunting ($P<0.001$) **[19]**. Stunting was an indicator of malnutrition in one study and considerably affected CD ($P=0.005$) **[23]**. Cognitive function had no association with BMI ($P=0.2$) or hemoglobin level ($P=0.1$) **[20]**.

The nutrition educational intervention of mothers revealed that such intervention resulted in improved CD ($P<0.001$) **[17]**.

Table 1: Summary of the extracted information

Author and Publication year	Design	Size, groups, and Age of the subjects	Results and main findings
Rafi et al 2024 [14]	Observational	-N=100 *Well-nourished=40 *Moderate=35 *Severely malnourished=25 -Age: 3-5Y	*At baseline, those who were well-nourished had the highest mean scores regarding all domains and the overall Cognitive Score. *The moderate group displayed intermediate scores, while the severe category had the lowest ones. *After six months, all categories displayed improvement, with the good category having the greatest overall gains. *Considerable improvements within each category were detected (P <0.05), with potential variations in CD based on nutritional status (P< 0.01). *The severe category experienced the least improvement.
Ghimire 2023 [15]	Cross-sectional	-N=347 *Acute malnutrition=6.4% -Age: 6-24 months	*There was a considerable relationship of nutritional status with ≥16month subjects in gross motor progression (P=0.01), fine motor development (P=0.047) and problem-solving skill progression (P=0.047).
Pangestuti et al 2023 [16]	Retrospective	-N=79 *Normal nutrition=27.8% *Abnormal=72.2% -Age: 5-6 Y	*CD was normal among 72.2% and abnormal among 27.8% *There was a significant relation between CD and nutritional status, with an RR of 2.591 (RR 2.591, P=0.01).
Ansuya et al 2023 [17]	Randomized controlled trial	-N=253 malnourished children *Control=126 *Intervention=127 whose mothers received education for12 months -Age:3-5 Y	*52% of intervention category pediatrics had average CD scores on the pre-test, and in control, the average CD of the children was 44.4%. *The CD of pediatrics in the intervention category improved compared to the control (P< 0.001).
Badrialaily et al. 2022 [18]	Cross-sectional	-N=62 -Age:4-6 Y	*The rates of CD were 30.64% poor and 69.36% moderate. *A positive correlation was found between nutritional status and CD.

Kabero et al 2021 [19]	Comparative cross-sectional	-N=178 primary school *Urban=90 *Rural=88 -Age: *Urban:8.7±11 Y *Rural:8.8±1 Y	*The mean of cognitive scores of urban pediatrics was higher (P<0 .001) as compared to rural. *The urban mean cognitive scores were higher for pattern reasoning and visual processing with (P < 0.001). *School performance was higher (*P* < .001) for urban. *Stunting (*P* < .001) negatively predicted cognitive function scores and school performance. *Cognitive function and school performance of the pediatrics were linked with their nutritional status.
Rosali et al 2021 [20]	Cross-sectional	-N=85 -Age:9-12 Y	*Cognition function levels included extremely low (10.6%), borderline (9.4%), low average (12.9%), average (37.6%), high average (25.9%), superior (2.4%), and very superior (1.2%). *The correlations between cognitive function and other factors included correlations with BMI (P=0.2) and hemoglobin level (P=0.1).
Abdel-Rahman et al 2017 [21]	Cross-sectional	-N=288 *Under nutrition=35 *Normal=229 *Over nutrition=24 -Age:4-<7 Y	*No considerable correlation was found between cognitive performance based on IQ and nutritional status (P=0.2). *IQ score was considerably higher among those from urban regions (P=0.005). *Mean IQ score was markedly lower among pediatrics whose mothers use margarine in food (P=0.002).
Leventakou et al 2016 [22]	Cross-sectional	-N=804 preschool -Age: mean=4.2 Y	*The 'Snacky' pattern was negatively associated with the verbal ability, general cognitive ability, and cognitive functions of the posterior. *The 'Western' and the 'Mediterranean' patterns were not linked with pediatric neurodevelopmental scales.
Onifade et al 2016 [23]	Cross-sectional	-N=220 *Malnutrition=8.2% -Age: 5Y	* 88.6 % had good cognitive performance, while 11.4% had fair and 5.5 % had poor performance. *Stunting as an indicator of malnutrition was found to have a significant association with cognitive development (P=0.005).

Cognitive development; CD, RR; Relative risk, BMI; Body mass index, IQ; Intelligence quotient.

Discussion:

The first 1000 days of life are an essential brain development duration in which sufficient nutrition is vital for optimal CD and growth **[24, 25]**. This period has been identified as a sensitive duration in which pediatrics are most sensitive to behavioral and cognitive deficits **[1]**. The early life of children shapes their health and development, including CD **[26]**. Therefore, this review was carried out to identify the effect of nutrition on CD in children.

The rates of CD levels were reported in only four out of ten studies in this work; the findings reflect inadequate CD as 72.2% had normal CD, 88.6% had a good performance, 69.36% had moderate CD, and only a few proportions had high average to very superior CD as reported in the four studies. The consequences of improper CD include poor school performance, reduced attention, and difficulties communicating with others **[10]**. One of the included studies in this review declared that cognitive function and school performance were linked with nutritional status **[19]**. In addition to the impact of inadequate nutrition on children in reduced school performance, improper nutrition is also more likely to lead to lower academic achievements **[27]**. Nonetheless, one research in this analysis revealed no association between IQ and nutritional status of children **[21]**.

Malnourished pediatrics often complain of delays in memory, language development, attention, and problem-solving skills. These cognitive impairments can restrict academic performance and limit future opportunities **[27]**. In our review, one study revealed that the best CD regarding the development of language, memory, motor coordination, and problem-solving skills for well-nourished children, and the level of CD was reduced with reduced nourishment status. Additionally, the improvement of subjects in CD was dependent on the baseline nutritional status, where well-nourished subjects persisted better CD development, whereas moderate and severely malnourished children experienced lower and the least improvement, respectively, after six months **[14]**.

In one study, it was demonstrated that stunted children had a 7% reduction in optimal CD compared with not stunted ones **[9]**. Another study showed that early-onset persistent stunting was linked with lower CD in subjects at 5 years of age **[28]**. Two studies in our analysis reported stunting; one of them revealed that stunting was an indication of malnutrition, and it considerably influenced CD **[23]**. The other study revealed that stunting negatively correlated with cognitive function and school performance **[19]**. The later findings can be explained as stunting, which is an indicator of malnutrition **[23]**; hence, stunting is associated negatively with cognition. Also, school performance is associated with cognition **[19]**; hence, stunting is negatively associated with school performance.

Iron is necessary for neurological pathway development in the brain that affects the brain functions **[6, 29, 30]**. Iron deficiency or anemia can adversely affects the overall CD and intelligence, especially if it occurs in early childhood **[6, 30, 31]**. However, one study in this work assessed the relation between cognitive function and hemoglobin level revealed no considerable relation **[20]**.

In a previous review, it was revealed that high fish consumption had beneficial impacts on the cognitive outcomes of nourished pediatrics **[1]**. One of the enrolled studies revealed that the food pattern affected cognition; snacks were adversely associated with cognition of children. However, Mediterranean pattern which involves high seafood and fish consumption displayed no association with neurodevelopmental scales **[22]**.

This review also found that CD **[16, 18]** and different aspects of CD **[15]** were associated with nutritional status. In a previous review enrolled, 12 trials assessed the effects of food and micronutrient interventions on cognition of undernourished and nourished children aged 2-6 years; eight studies reported considerable positive impacts on cognition outcomes **[1]**. A review included 41 articles concerned with children and teenagers deduced strong correlations between determinants of a child's early nutritional status and motor and CD in infancy and through the preschool years, persisting to adolescence/young adulthood **[32]**. Another systematic review, published early in 2016, enrolled 12 studies and deduced that healthy diets in early childhood were associated with better cognitive outcomes among young pediatrics. However, it was revealed that there was a paucity of literature and variability in the quality and type of measures applied, which highlighted the requirement for more rigorous research **[26]**. Such variability and paucity of literature are similar findings in the included studies revealing persistent issues in research and literature concerned with nutrition and its impact on the cognition of children.

Nutrition interventions have gained a great focus, especially in middle and low-income nations, where malnutrition is highly common **[33]**. Parental education has been recognized to have an essential role in improving the nutrition of children. It was discovered that parents with higher education were more likely to provide more balanced diets **[34]**. Also, parental training regarding pediatric nutrition is a necessary contributor to long-term developmental gains **[35]**. One of the enrolled research studies in this review assessed the impact of nutritional educational intervention on mothers, and it revealed improvement in CD due to improvement in the nutrition of children, which was initially improved due to the improved nutritional education of mothers **[17]**.

Conclusion:

Good and balanced nutrition is essential for proper CD in children as CD is associated with their nutritional status; proper CD is associated with adequate and balanced nourishment and vice versa. Additionally, well-nourished children are more prone to continue proper CD over time in contrast to those with undernourishment. Additionally, the severity of undernutrition affects the CD degree. The CD was influenced by several factors, such as resident region, nutrition education of the mother, and food pattern. Such factors also affect the nutrition status and hence CD. Improving the nutritional education of mothers can improve the nutritional status of children and, hence, their CD.

Limitations, strengths, and recommendations:

The limitations of this study include the enrollment of studies of weak evidence due to the heterogeneity of the studies in designs, objectives, variables, and, hence, outcomes. However, such limitation seems to be a significant issue, as was also reported in a previous analysis. However, this analysis provides recent data on the impact of pediatric nutrition on their cognition. Therefore, we recommend establishing further research with a larger sample size and with stronger evidence.

References:

1-Roberts M, Tolar-Peterson T, Reynolds A, Wall C, Reeder N, Rico Mendez G. The effects of nutritional interventions on the cognitive development of preschool-age children: a systematic review. Nutrients. 2022 Jan 26;14(3):532.

2-Cusick, S.E.; Georgieff, M.K. The Role of Nutrition in Brain Development: The Golden Opportunity of the “First 1000 Days”. J. Pediatr. **2016**, 175, 16–21.

3-Black, R.E.; Victora, C.G.; Walker, S.P.; Bhutta, Z.A.; Christian, P.; de Onis, M.; Ezzati, M.; Grantham-McGregor, S.; Katz, J.; Martorell, R.; et al. Maternal and Child

Nutrition Study Group. Maternal and Child Undernutrition and Overweight in Low-Income and Middle-Income Countries. Lancet **2013**, 382, 427–451.
4-Martins, V.J.B.; Toledo Florêncio, T.M.M.; Grillo, L.P.; do Carmo P Franco, M.; Martins, P.A.; Clemente, A.P.G.; Santos, C.D.L.; de Fatima A Vieira, M.; Sawaya, A.L. Long-Lasting Effects of Undernutrition. Int. J. Environ. Res. Public Health **2011**, 8, 1817–1846.
5-Bourre, J.M. Effects of Nutrients (in Food) on the Structure and Function of the Nervous System: Update on Dietary Requirements for Brain. Part 1: Micronutrients. J. Nutr. Health Aging **2006**, 10, 377–385.
6-Monk, C.; Georgieff, M.K.; Osterholm, E.A. Research Review: Maternal Prenatal Distress and Poor Nutrition—Mutually Influencing Risk Factors Affecting Infant Neurocognitive Development: Maternal Prenatal Distress and Poor Nutrition. J. Child. Psychol. Psychiatry **2013**, 54, 115–130.
7-Welsh, J.A.; Nix, R.L.; Blair, C.; Bierman, K.L.; Nelson, K.E. The Development of Cognitive Skills and Gains in Academic School Readiness for Children from Low-Income Families. J. Educ. Psychol. **2010**, 102, 43–53.
8-Grantham-McGregor, S.; Cheung, Y.B.; Cueto, S.; Glewwe, P.; Richter, L.; Strupp, B. Developmental Potential in the First 5 Years for Children in Developing Countries. Lancet **2007**, 369, 60–70.
9-Ekholuenetale M, Barrow A, Ekholuenetale CE, Tudeme G. Impact of stunting on early childhood cognitive development in Benin: evidence from Demographic and Health Survey. Egyptian Pediatric Association Gazette. 2020 Dec;68:1-1.
10-Penchyna Nieto MR. The impact of nutrition on people's cognitive development, *J. Nutrition and Food Processing;* 2024:7(9).
11-Cusick, S.E.; Georgieff, M.K. The Role of Nutrition in Brain Development: The Golden Opportunity of the "First 1000 Days". J. Pediatr. **2016**, 175, 16–21.
12-Brown, T.T.; Jernigan, T.L. Brain Development during the Preschool Years. Neuropsychol. Rev. **2012**, 22, 313–333.
13- Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71.
14-Rafi SM, Reddy RG, Gurajala CS. IMPACT OF EARLY CHILDHOOD NUTRITION ON COGNITIVE DEVELOPMENT: AN OBSERVATIONAL STUDY. International Journal of Medicine and Public Health; 2024:14(2):702-707.
15- Ghimire J. The nutritional status and cognitive & motor development of children in Nepal. J Public Health Policy Plan. 2023;7(4):183.
16- Pangestuti D, Akbar S, Ayu MS. THE INFLUENCE OF NUTRITIONAL STATUS ON COGNITIVE DEVELOPMENT PRE-SCHOOL AGE CHILDREN. MORFAI JOURNAL; 2023:3(1):98-103.
17- Ansuya, Nayak BS, Unnikrishnan B, Shashidhara YN, Mundkur SC. Effect of nutrition intervention on cognitive development among malnourished preschool children: randomized controlled trial. Scientific Reports. 2023 Jun 30;13(1):10636.
18-Badrialaily, Mohd Nor ND. A Measuring Relationship of Children Nutritional Status Toward Cognitive Development in Aceh. Jurnal Pendidikan Awal Kanak-kanak Kebangsaan. 2022 Dec 30;11(2):55-61.
19- Kabero TH, Bosha T, Feleke FW, Haile Weldegebreal D, Stoecker B. Nutritional Status and Its Association with Cognitive Function among School Aged Children at Soddo Town and Soddo Zuriya District, Southern Ethiopia: Institution Based Comparative Study. Global Pediatric Health. 2021 Jun;8:23337941611028198.

20- Rosli NH, Kamarudin KS, Hamzah Y, Yusof HM. Correlation Between Nutritional Status, Cognitive Function and Daytime Sleepiness of Schoolchildren in Terengganu, Malaysia. Jurnal Gizi dan Pangan. 2021 Nov 29;16(3):189-98.
21- Abdel-Rahman TA, Kamal NN, El-Dessouki KH, AbdAllah AA. Assessment of nutritional status and cognitive development of preschool children at minia governorate, Egypt. Canadian Journal of Clinical Nutrition. 2017 Jan 1;5(1):7294.
22- Leventakou V, Roumeliotaki T, Sarri K, Koutra K, Kampouri M, Kyriklaki A, Vassilaki M, Kogevinas M, Chatzi L. Dietary patterns in early childhood and child cognitive and psychomotor development: the Rhea mother–child cohort study in Crete. British Journal of Nutrition. 2016 Apr;115(8):1431-7.
23- Onifade OM, Otegbayo JA, Akinyemi JO, Oyedele TA, Akinlade AR. Nutritional status as a determinant of cognitive development among preschool children in South-Western Nigeria. British Food Journal. 2016 Jul 4;118(7):1568-78.
24- Lenroot, R.K.; Giedd, J.N. Brain Development in Children and Adolescents: Insights from Anatomical Magnetic Resonance Imaging. Neurosci. Biobehav. Rev. **2006**, 30, 718–729.
25- Bryan, J.; Osendarp, S.; Hughes, D.; Calvaresi, E.; Baghurst, K.; van Klinken, J.-W. Nutrients for Cognitive Development in School-Aged Children. Nutr. Rev. **2004**, 62, 295–306.
26- Tandon PS, Tovar A, Jayasuriya AT, Welker E, Schober DJ, Copeland K, Dev DA, Murriel AL, Amso D, Ward DS. The relationship between physical activity and diet and young children's cognitive development: A systematic review. Preventive medicine reports. 2016 Jun 1;3:379-90.
27- Muriithi Wanjiku G. The Impact of Malnutrition on Child Development: Understanding Long-Term Health and Cognitive Outcomes; 2024:3(2):41-44.
28- Alam MA, Richard SA, Fahim SM, Mahfuz M, Nahar B, Das S, Shrestha B, Koshy B, Mduma E, Seidman JC, Murray-Kolb LE. Impact of early-onset persistent stunting on cognitive development at 5 years of age: Results from a multi-country cohort study. PloS one. 2020 Jan 24;15(1):e0227839.
29- Muñoz, P.; Humeres, A. Iron Deficiency on Neuronal Function. Biometals **2012**, 25, 825–835.
30- Youdim, M.B.; Yehuda, S. The Neurochemical Basis of Cognitive Deficits Induced by Brain Iron Deficiency: Involvement of Dopamine-Opiate System. Cell. Mol. Biol. **2000**, 46, 491–500.
31- McCann, S.; Perapoch Amadó, M.; Moore, S.E. The Role of Iron in Brain Development: A Systematic Review. Nutrients **2020**, 12, 2001.
32- DiGirolamo AM, Ochaeta L, Flores RM. Early childhood nutrition and cognitive functioning in childhood and adolescence. Food and Nutrition Bulletin. 2020 Jun;41(1_suppl):S31-40.
33- Skouteris H, Green R, Chung A, Bergmeier H, Amir LH, Baidwan SK, Chater AM, Chamberlain C, Emond R, Gibbons K, Gooey M. Nurturing children's development through healthy eating and active living: Time for policies to support effective interventions in the context of responsive emotional support and early learning. Health & social care in the community. 2022 Nov;30(6):e6719-29.
34- Shonkoff JP, Richter L, Van Der Gaag J, Bhutta ZA. An integrated scientific framework for child survival and early childhood development. Pediatrics. 2012 Feb 1;129(2):e460-72.
35-Aslanovich AR. Nutrition and Early Development: A Framework for Thriving Children. Journal of Medical Genetics and Clinical Biology. 2024:1(12):77-83.