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A Review on the Influence of Nutritional Status on Cognition Performance of School Going Children

Khushnuma[1], Jauhar Azeem[2], Huma Naqeeb[1], Zarafshan Zeb[3], Najma Mehboob[3], Bilal[3], Ayesha Bibi[1]

[1]Department of Human Nutrition and Dietetics, Women University Mardan, KP, Pakistan.
[2]Department of Biochemistry, Hazara University, Mansehra, KP, Pakistan
[3]Department of Human Nutrition, The University of Agriculture, Peshawar, KP, Pakistan.

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Corresponding Author: Ayesha Bibi, Department of Human Nutrition and Dietetics, Women University Mardan, KP, Pakistan.
Email: drayeshabbb@wumardan.edu.pk

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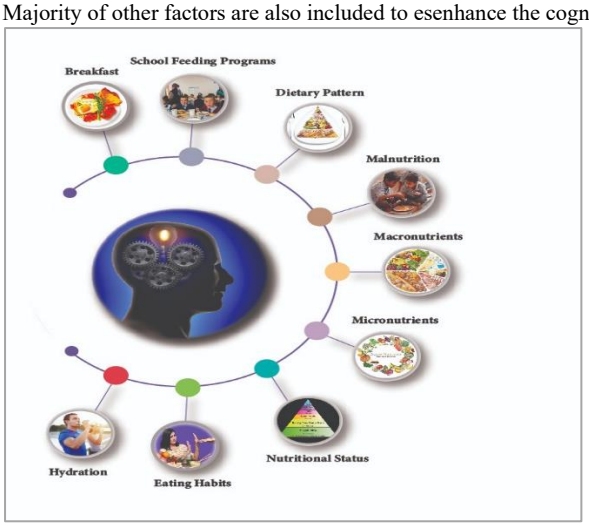
ABSTRACT

Most of the children have poor nutritional status all over the world, which affect the children life in different ways. One of the impacts is nutritional status which influences the cognitive performance of school going children. The aim of this review was to determine the influence of nutritional status on the cognitive performance of school going children. Study was searched from the databases (google scholar, PubMed, sciHub). Studies with cognitive performance of school going children at the age between 5 and 14 were cited for the review. The aim of the review is to find how diet affects the cognitive performance of children and to identify how diet is associated with school performance. The review evaluated that diet high in nutrition, micro nutrients, intake of fructose, soluble fiber, total fiber, leafy vegetables, breakfast, breakfast high in macro nutrients composition, school feeding programs can positively associated with cognitive function. Poor nutrition status, nutrition deficiencies, malnutrition, stunting wasting are negatively associated with cognitive function. There is no significant association between dietary fats with cognitive function. Adequate intake of macronutrients (Carbohydrates, proteins, fats) and micronutrients (vitamins and minerals) can help in cognitive function. Majority of other factors are also included to esenhance the cognitive performance.



Graphical abstracts of a review on the influence of nutritional status on cognition performance of school going children

INTRODUCTION

Cognitive function is the ability to gather and use knowledge in order to respond to environmental demands; this process involves a variety of abilities, including those related to attention, memory, thinking, perception, problem-solving, creativity, and language use (Kabro *et al*., 2021). These abilities have reportedly been found to have an important role in predicting academic success (Marinoni *et al*., 2022). For higher and outstanding academic performance, children, especially those of school age, need adequate cognition (Apprey *et al*., 2022). Due to its high prevalence, cognitive impairment triggers major challenges to global public

health (Tiantian Zhang *et al*., 2023: Vella-Broderick & Gilowska 2022: Dohmen *et al*., 2023). During the first three years of life, a child's cognitive development is particularly sensitive. Since children spend the majority of this time at home, the home environment is considered to be one of the variables in the environment that has the greatest impact on a child's cognitive development (Jing Han *et al*., 2023).

Nutrition plays an essential role in cognitive ability, growth, and brain development (Stein *et al*., 2023). Early in life, nutrition is essential to supporting healthy brain development, and it has long-lasting and frequently irreversible consequences for a person's cognitive development and long-term mental health (Kadosh *et al*., 2021). For optimal growth in children, proper nutrition is essential. The issue of malnutrition is brought on by a child not receiving enough food with good nutrition, which is required for the child's growth and development since school-going children are affected by mental retardation, poor memory, and bad academic performance (Neelam & Chokarvoty 2023). Low-quality meals may also negatively affect children's academic performance. Poor nutrition can affect the brain and cognitive functions that are rapidly growing (Naveed *et al*., 2019). Early poverty is often linked to cognitive function deficits, poorer academic achievement, and low scores on standardized tests (Taylor *et al*., 2020).

Studies of children with protein and calorie malnutrition have tended to draw the conclusion that severe malnutrition causes both immediate and long-term cognitive and Behavioural issues (Benton, 2014). The cognitive functions that decline with ageing can also be affected by a micronutrient deficit (Szot *et al*., 2022). Lower cognitive functioning is found in children and adolescents who are overweight or obese (Esteban-Cornejo *et al*., 2020). Nutritional deficits can affect learning, therefore it's important for families to feed their kids properly so they can do well in school. Students may not be able to perform to their full potential at their individual schools if they do not take enough of certain essential nutrients, such as calcium, potassium, and vitamin C (Abiodun & Deborah 2023).

A person's intellect level and their capacity to retain information at school are both influenced by their nutritional status; therefore, someone with an adequate nutritional status will be able to pick up concepts better and have success in school. Protein, lipids, carbs, vitamins, minerals, and water are all necessary for the human brain's structural formation and maintenance. Therefore, proper nutrition is important for the growth and operation of the brain. However, it has been found that some micronutrients, including long-chain polyunsaturated fatty acids (LC-PUFAs), choline, iodine, zinc, folate, and B12, are particularly important for cognitive development. (Roberts *et al.*, 2022).

Carbohydrates, lipids, and proteins, collectively known as macronutrients, provide the nutrients needed for optimum performance. Physical activity and brain function are both affected by inadequate nutrition. Simple carbohydrates (sugars) are consistently linked to lowered global cognition, whereas complex carbohydrates are linked to successful brain ageing and enhanced short- and long-term memory (Muth & Park 2021). Children that consume more than 46 g of high-fiber grain products per day see improvements in cognitive domains like visual perception and visuospatial thinking (Dalile *et al*., 2022).

As glucose is the brain's primary energy source, it is necessary for it to function. Many human studies demonstrate that glucose ingestion improves cognitive performance in healthy individuals as well as in people with memory deficiencies and those with poor glucose management, as compared to placebo or skipping breakfast. Rarely is glucose ingested as part of an usual diet; instead, it comes from foods that include carbs, which are then converted to glucose, providing the brain and other organs with the energy they require. Using the well-known classification of carbohydrates known as the glycemic index, multiple studies demonstrate that the rate of glucose release might have an impact on cognitive function (Philippou & Constantinou 2014).

Amino acids often make up proteins. Twelve amino acids are produced by the body itself, while the remaining eight (essential) amino acids must be obtained from dietary intake. All of the required amino acids are present in a diet high in quality protein. Foods high in protein include meat, milk, and other dairy products, as well as eggs. While grains, beans, and peas all contain protein, they may be deficient in a number of important amino acids. A relatively high-protein diet should have a good impact on brain functioning and cognition because the majority of neurotransmitters in the brain are made of amino acids e.g., dopamine from tyrosine, serotonin from tryptophan (Gerber *et al.,* 2023).

Cognitive development, including psychomotor function, motor abilities, and language, were all particularly enhanced by omega-3 supplementation. In a previous study, which involved 44 children aged from birth to four months, it was discovered that supplementing with long-chain polyunsaturated fatty acids (which are converted to DHA) leads to greater problem-solving abilities and more thoughtful solutions than in the infants who were not supplemented. The addition of 100 mg of DHA to a multi-micronutrient treatment for older kids (ages 6 to 10) can considerably enhance cognitive function (short-term memory and reasoning). For 35 days, 4 grams of fish oil (800 mg DHA and 1600 mg EPA) can greatly increase attention. Young adults who receive an omega-3 supplement for one month improve cognition and brain efficiency (Sittiprapaporn *et al*., 2022).

PUFAs with long chains are essential for developing young children's brains. Learning and behavioral issues can be caused by a lack of essential fatty acids (EFAs) and the long-chain PUFA derivatives, that are prevented or treated by taking supplements of these fatty acids (Zhang *et al*., 2005). The eating of fish may be linked to improved verbal skills and perceptual reasoning, while meat and potato diets are likely to have the opposite effect (Marinoni *et al*., 2022). Consumption of five foods that are unhealthy because they include trans and saturated fats: fried meals, cheese, butter and margarine, red meat, and butter and margarine. Poor brain health is linked to consuming trans fats and excessive saturated fats. A much lower memory was linked to dietary trans fatty acids. It suggested a link between consuming saturated and trans fats and the risk of cognitive impairment (Kheirouri & Alizadeh 2022). Childhood is a time of relatively rapid brain growth, making nutrition during this period especially important. Nutrients help the brain form new synaptic connections while learning in both the classroom and at home. 90% of the adult volume of the brain is present in children under the age of six. Essential nutrients, such as the omega-3 fatty acid alpha-linolenic acid (ALA), which is present in nuts, particularly walnuts, are important throughout this time of brain development. In the long term, a child's neuropsychological development, academic achievement, and potential for professional success may all benefit from sufficient nutrition that supports neurodevelopment throughout the foetal period. However, little research has been done on the potential preventive effects of nut consumption on cognitive health in young children (Nishi *et al*., 2023).

Physical and cognitive development are significantly influenced by haemoglobin and micronutrients. Deficits in iron, vitamin B12, and folate have been linked to poor cognitive development, memory problems, and even decreased intelligence. Zinc and vitamin D deficiencies have also been linked to impaired behaviour and cognition (Sing *et al*., 2023). The growth of neural networks in the brain that affect how the brain functions depends on iron. Children endure rapid growth throughout the first two years of life, which raises their iron needs and puts them at a higher risk for iron deficiency anemia. Iron deficiency or iron deficiency anemia can have negative impacts on general intellect and cognitive development, particularly if it develops in childhood (Robert *et al*., 2022). To date, the majority of dietary interventions for brain development have focused on micronutrient supplementation, with results that suggest benefits of dietary supplementation in specific cognitive areas in children who are nutrient-deficient. Short-term impacts on cognitive and motor development have been observed in several treatments using dietary supplements (e.g., fortified meals) in early childhood or in children with atypical neurodevelopment (Mou *et al*., 2023).

Zinc deficiency has many negative consequences, including impaired mental capacities, poor academic performance, poor cognitive performance, a short attention span in class, and reduced cognitive ability. More specifically, more than 200 enzymes that regulate several cellular metabolic processes, as well as the synthesis of protein, DNA, and RNA, use zinc as a component. Zinc also helps to create synapse and to support the growth, development, and mobility of neurons (Hameed & Salibi, 2023). Zinc (Zn) is essential for maintaining healthy brain function and preventing oxidative stress in cells. (Wang *et al*., 2022).

Many enzymes involved in redox processes, such as cytochrome c oxidase, ascorbate oxidase, and superoxide dismutase, require the crucial trace element copper as a cofactor. Dyshomeostasis of trace metals like zinc and copper has been associated to a decline in cognitive function, and oxidative stress has been hypothesised as a regulatory factor in ageing and a number of neurological illnesses (Gong *et al*., 2022). In addition to serving as cofactors for a number of vitamin-dependent enzymes, the minerals calcium, magnesium, and zinc also directly and significantly influence membrane excitability and neurotransmission. With the exception of calcium, none of these micronutrients are stored in the body in large amounts, making it important that daily intake be sufficient for cognitive function and performance (Huskisson *et al*., 2007).

For full brain growth and cognition, vitamin B12 is an essential element that can only be obtained through animal food sources (Annan *et al*., 2019). An adequate supply of folate (vitamin B9) is necessary for brain function, and insufficient folate can cause neurological problems like depression and cognitive loss. Folate supplementation has been shown to be useful in preventing cognitive decline and dementia, either alone or in combination with other B vitamins (Szot *et al*., 2022). People's cognitive function decline is also influenced by vitamin A, an antioxidant in the central nervous system. Both beta-carotene and gamma-carotene are capable of being turned into retinol, which is then changed into a long-chain fatty acid ester that serves as the body's primary source of vitamin A. Better cognitive performance was linked to plasma levels of alpha-carotene and beta-carotene that were higher. (Zhong *et al*., 2023).

The nutrient-dense eating pattern, which is characterised by a higher consumption of eggs, beans and peas, potatoes, and red-orange and dark-leafed vegetables, was linked to improved reading abilities. The use of processed (high calorie) foods, which are characterised by greater intakes of breads, processed meats, fats and oils, sweetened beverages, and

sweetened yogurt/dairy products, was not linked to improved cognitive function (Barg *et al*., 2023).

Animal-source foods (ASF; meat, offal, fish, eggs, milk, and other dairy products) are significant sources of high-quality calories that supply energy combined with vital amino acids and minerals. The diet of humans must contain micronutrients in order for people to grow to their maximum potential, maintain physical and mental health, function cognitively, regulate metabolism, build immunity, and enjoy general wellbeing throughout their lives (Mckune *et al*., 2022). Foods derived from animals are rich in accessible vitamins and minerals. ASFs contain highly accessible forms of the vitamins A and D, iron, and zinc, and are the sole intrinsic food source of vitamin B12. These micronutrient deficiencies can have severe and long-lasting effects, including birth abnormalities, anaemia, stunted growth, cognitive impairment, and increased susceptibility to infections (Beal *et al*., 2023).

The consumption of breakfast improves speaking fluency, mood, memory recall, intellectual performance, and school attendance. The quality of breakfast is also essential, and children's overall diet quality can be improved by consuming a high-quality breakfast that includes the three main food groups, such as grains, fruits, and dairy items (Dogui *et al*., 2023). Breakfast gives the brain the energy it needs to function more intellectually throughout the day. Cognitive function may be hampered by poor cerebral glucose uptake. Breakfast is commonly referred to as the most important meal of the day and has been associated with successful learning (Adonu *et al*., 2023). Evidence suggests that eating breakfast may enhance cognitive performance related to memory, test scores, and attendance at school. Children's health and wellbeing can benefit when breakfast is included in a healthy diet and lifestyle (Rampersaud *et al*., 2005).

Students who eat lunch at school perform superiorly to those who don't on tests, exams, and other assignments demanding rational mental processing of information. In a similar vein, Ayoola's (2014) research found that there was a statistically significant difference in reading and math test scores between pupils in schools that provide school lunches and those in schools that do not. School lunches significantly affect pupils' academic success, according to research by Maijo (2018). The results of the study also revealed a 31% increase in the percentage of students who finished their tests (Rabiu *et al*., 2023).

Early academic performance and learning depend on cognitive function, which is influenced by a variety of factors, including food. It is commonly accepted that consuming too much sugar or simple carbohydrates might lead to cognitive decline (Yan *et al*., 2023). The excessive use of sugar-sweetened drinks (SSBs) in children and adolescents can also result in depression, attention deficit/hyperactivity disorder (ADHD), and other mental illnesses (Zhang *et al*., 2023). Higher consumption of total sugars and liquids with added sugar was linked to poor memory function, although eating solid desserts was linked to better verbal fluency (Goncalves *et al.*, 2023). A diet high in processed foods, saturated fats, and sweets has a negative impact on children's cognitive development. On the other hand, a Mediterranean diet resulted in more effective neurodevelopment in middle childhood, especially in terms of verbal intelligence and executive functioning (Zupo *et al*., 2023).

Children's attention at age 7-9 can be improved by folic acid supplementation used past the first trimester of pregnancy at the current periconceptional recommended dose to prevent neural tube abnormalities. In addition, boys and girls may respond differently to low FA usage. It can affect males' working memory while affecting girls' alertness, two crucial cognitive processes for success in school and in daily life (Compa-Gabucio *et al*., 2022).

Children's growth and cognitive development are at danger due to iron and vitamin A deficiency (Bassouni *et al*., 2022).

All physiologic processes and cognition require optimal hydration (Jean-Pierre Chouraqui, 2023). Students' cognitive performance may be enhanced by boosting hydration, eating more fruit and fish, and avoiding fast food (Pilato *et al*., 2020). In terms of hydration, children (those under the age of 18) confront particular physiological and sociocultural challenges (Almalki *et al*., 2022). Drinking too much or not enough water can both be harmful to your health. Dehydration, which is defined as a lack of total body water, can make it difficult for someone to exercise and raises their risk of developing cardiovascular and urinary system problems. The majority (about 75%) of the brain's mass is made up of water, which controls both mood and cognitive function. There may be links between hydration levels and cognitive function as well as mood (Zhang *et al*., 2019).

Metal exposures had a significant impact on cognitive function. Children's neurobehavioral and cognitive development are known to be negatively impacted by lead, cadmium methylmercury, and arsenic exposures (sasaki & carpenter 2022). Children's cognitive capacities at school age may be weakened by prenatal exposure to Pb, As, and Cu (Wang *et al*., 2022). Lead is not regarded as safe for human intake at any amount. Lead is a neurotoxin that can permanently harm children's growing brains. Numerous studies have shown that exposure to lead in early life, even at low levels, is linked to lower intelligence quotient in young adults and impaired attention span and academic performance in children (Lee *et al*., 2022).

Wang & Cheng (2022), school feeding plans encourage dietary adequacy for both macronutrients and micronutrients (Abizari *et al*., 2014). School feeding programmes are also beneficial for improving schoolchildren's cognitive functions (Cueto and Chinen, 2008), test scores (Aurino *et al.,* 2020; Chakraborty and Jayaraman, 2019), psychosocial behaviour (Metwally *et al.,* 2020), and school enrollment and attendance (Bundy *et al.,* 2013; Jomaa *et al*., 2011). The Osun State School Feeding Programme improved pupils' performance in the state's primary schools by 55.2% (Rabiu *et al.,* 2023).

LITERATURE REVIEW

Berg *et al*. (2023) examine the study to investigate the association between two dietary patterns and contextualized tests of cognitive function in children aged 6 to 8 years from Montevideo, Uruguay, in low- and middle-income neighborhoods. To complete the study and collect the data, 270 first-graders participated. The amount of food consumed was calculated using two average 24-hour dietary recalls conducted in the mother's presence. "Processed (high-calorie) foods" and "nutrient-rich" foods are two different eating patterns. Reading performance was linked to a nutrient-dense eating pattern that included more eggs, potatoes, beans, peas, and red-orange and dark-leafed vegetables. Additionally, there was a link between the nutrient-dense food element and reading inconsistencies. Higher consumption of bread, processed meat, fats and oils, sweetened beverages, sweetened yogurt, and dairy products are characteristics of a pattern of processed (high-calorie) foods; reduced intake of milk, bread, and pizza was not related to cognitive function. Children's reading proficiency was favorably correlated with a nutrient-rich food pattern. Starting school with a diet high in nutrients can help students learn written language.

Sing *et al*. (2023) identified the relationship between micronutrients and cognitive function in urban Indian schoolchildren and adolescents. Participants in the multicenter cross-sectional study range in age from 6 to 16. The purpose of the study was to look into the relationship between general intelligence and specific cognitive abilities, such as attention, concentration, vasomotor coordination, and working memory, in urban children and adolescents aged 6 to 16 in ten Indian cities. Eight micronutrients were assessed in this study, including four minerals (calcium, iron, zinc, and selenium) and four vitamins (vitamin A, vitamin B12, vitamin D, and folate). The development of children's cognitive and motor skills is influenced by a number of distinct physiological processes that are related to all micronutrients. The current study demonstrates that cognitive outcomes are impacted by two or more micronutrient deficits. Developmental delay and poor academic performance are closely related to these impairments.

Utami *et al*. (2023) conducted a study on Indonesian children aged 4-6 and their cognitive abilities. The 2012-starting Bogor Longitudinal Study of Child Growth and Development (BLSCGD) provided the data. For this study, 165 kids between the ages of 4-6 were involved. The determinants of cognitive development in children between the ages of 4-6 years were determined by independent variables, which included sociodemographic factors, determinants from an early age (0-23 months), and determinants from current situations. According to a bivariate analysis, low child stimulation and insufficient caloric intake throughout childhood were strongly connected to verbal IQ, while parental education level was significantly related to full-scale IQ. Low paternal education levels continue to have a major impact on full scale IQ. Verbal IQ was highly correlated with psychosocial stimulation, while performance IQ was significantly correlated with insufficient calorie intake throughout infancy. For 4-6-year-old children, inadequate psychosocial stimulation and low levels of parental education are risk factors for poor cognitive development. It demonstrated the significance of adequate caloric intake in infancy, even though it was not statistically significant because it had a high OR for poor verbal IQ and Performance IQ.

Borasio *et al*. (2023) examine the relationships among blood levels of polyunsaturated fatty acids (PUFA), nutritional status, and the reading, writing, and phonological awareness abilities of 42 school-age children with varied reading levels. Reading scores, PUFA levels (particular omega-6/omega-3 ratios), and the proportion of calories from omega-6 sources to total calories all showed significant associations. 42 children between the ages of 8 and 13 were part of the entire sample (mean age, 10.68 years; SD, 1.39 years). There were 25 kids with developmental dyslexia (DD), and 17 of them could read properly. PUFA levels in the blood, nutritional intake, and academic performance are all linked, regardless of whether a child has been diagnosed with DD or not. The impacts of favourable circumstances linked to a larger intake of omega-3 PUFAs reflected in the higher omega-3 blood levels appear to be sensitive to the effects on children's reading, writing, and phonological awareness performance. Variation in the reading and writing ability scores in comparison to the normative population tends to indicate that the association between dietary consumption and PUFA levels in the blood is mediated by possible genetic/constitutional factors.

Derese & Marisennayya (2023) conducted a study to compare school feeding recipients with non-recipients in public private schools in the Wolaita zone of the southern Ethiopian area Southern Nations Nationalities and People's area (SNNPR) in order to evaluate the

effects of school feeding programmes on students' academic achievement. 306 students in grades two to four, 32 instructors, and seven key informants participated in the data collection. On a test, pupils from benefited schools wrote 8.6 words per minute, whereas students from unbenefited schools wrote 6.16. This showed that children from the beneficiary schools wrote more words than the pupils from the non-beneficiary schools. The influence of school food programmes on indicators of student learning outcomes, such as average test scores and improved reading and writing in their mother tongues, is statistically significant and favourable. The importance of the school meal Programme for the academic performance of primary school children should be understood by the school community as well.

Ullah & Khan (2022) conducted a cross-sectional study from 400 students aged 6 to 11 from various public and private schools in the tehsil of Timergara Lower Dir, KPK (Pakistan), of which 200 participated in private and 200 in public schools. The huge population of children who are malnourished makes the issue of child malnutrition critical. Education and health are closely related because children might attain their best health during their school years. The study came to the conclusion that school-age children's nutritional state had a significant impact on their academic performance. Students with stunted, underweight, and low BMI have performed poorly in academics.

Sherzai *et al*. (2022) studied how eating n-3 long-chain polyunsaturated fatty acids affects a person's ability to develop their brain. It assesses research studies on cognitive outcomes from fetal development to adolescence that were published between 2000 and 2022. LC PUFA and omega-3 fatty acids will be used interchangeably for the duration of this review. Three developmental stages—in utero, during nursing and early childhood, and during childhood and adolescence—were used to segment the study group. Each article was evaluated on a number of important criteria, including the study type, PUFA type and dose, number of subjects, length of intervention, age range of participants, population characteristics, outcome measure (both primary/cognitive and secondary/other), results, and conclusion, as well as confounding factors and other limitations. The study included a total of 88 papers. The intervention had a mixed effect, but there were some short-term gains in visual attention, working memory, executive function, and communication. Omega-3 dietary supplements may benefit neurodevelopment at all three phases in the short term. Supplementation is advised at all stages of life, not just during early development.

Mantey *et al*. (2022) conducted a study to assess the impact of biscuits fortified with orange-fleshed sweet potato (OFSP) and palm weevil larvae-enriched (PWL) on the cognitive performance and dietary status of schoolchildren from low-income families attending a government-owned school in a rural area of the Ghanaian city of Kumasi. In a 12-week randomised, blinded, controlled trial, 102 schoolchildren between the ages of 6 and 11 were given the option of eating fortified or unfortified biscuits. Initially, participants were randomly assigned to one of two groups: control (n = 51) or treatment (n = 52). To prevent teachers and students from knowing which group was the treatment group or the control group, the two groups were coded. After a 12-week intervention period, there was conflicting evidence regarding how fortified PWL and OFSP biscuits affected school-aged children's (SAC) ability to concentrate and their nutritional status. Serum ferritin levels were shown to have significantly improved within the treatment group, although there was no statistically significant difference between the treatment and control groups as a result of the observed improvements. However, enhancing the nutritional value of biscuits for SAC by fortifying PWL and OFSP biscuits may be beneficial and appropriate.

Pattebahadur *et al*. (2022) carried out research on 28 urban school-aged children in the age range of 12 to 15 years by simple random sampling to determine the effects of anaemia on cognitive abilities in school-aged children in an urban area of India. 89% of the participants in the study were anemic, while 11% were not. In comparison to the non-anemic group, the anemic group has poorer mean IQ, Mini-Mental State Examination (MMSE), and Addenbrooke's Cognitive Examination (ACE-R) scores. In this investigation, there was no statistically significant association between haemoglobin level and cognitive function.

Van Beekum *et al*. (2022) conducted a study that more than 250 million children under the age of five globally do not develop to their full potential for a number of reasons, including hunger. In Cambodia, the prevalence of stunting and wasting among children is highly significant. This prospective cohort study had the goal of determining how early childhood stunting and wasting were related to the achievement of motor and cognitive developmental milestones. From March 2016 to June 2019, researchers tracked up to seven children from three Cambodian districts who were 0 to 24 months old up until the age of 5. For 7394 kids, data was accessible. At 12 months, stunting prevalence was 23.7% and wasting prevalence was 9.6%. Both were consistently linked to delays in the majority of motor and cognitive milestones. Stunting was highly correlated with delayed gross motor milestones. Delays in the development of fine motor skills and the majority of cognitive milestones were more strongly linked to attrition.

Kasambala *et al*. (2022) conducted a study to determine that, despite the fact that schistosomiasis is

known to impair children's cognitive function, little is known about how it affects young children's development in developing countries where the disease is endemic. The purpose of the study was to establish the impact of schistosomiasis, namely Schistosoma haematobium infection, on early childhood development in children under the age of five from the Murewa District in Zimbabwe, as well as the advantages of therapy. Up to 5-year-old children who had been identified with S. haematobium infections using the urine filtration method were evaluated at baseline and six months following therapy. S. haematobium-infected preschool-age children (PSAC) were more likely to have worse scores in the fundamental learning domain, language and communication domain, hand-eye coordination domain, personal-social-emotional domain, and overall general development domain after controlling for confounding variables. The domains of language and communication, hand-eye coordination, and general development all showed improvements in cognitive function six months after treatment. The research found a link between S. haematobium infection in PSAC and inferior cognitive scores in the domains of language and communication, hand-eye coordination, personality-social-emotional development, and general development in general. Outcomes support the necessity for PSAC to be incorporated into regular deworming programmes to combat urinary schistosomiasis and the demand for locally validated techniques to track early child development in resource-constrained endemic locations.

Kabero *et al*. (2021) outlined the relationship between nutritional status and cognitive function in school-age children attending urban and rural government primary schools in Soddo Town and Soddo Zuriya Woreda in the Wolaita Zone, southern Ethiopia. A comparative cross-sectional institution/school study was undertaken from February 25 to April 15, 2014. All government primary school students in Soddo town and Soddo Zuriya Woreda between the ages of 7 and 10. Children in 5 chosen primary schools in Soddo town and Soddo Zuriya Woreda, aged 7 to 10 years. Who have lived there permanently for at least six months were considered for the study. In comparison to their urban counterparts, study participants in rural areas performed poorly on most cognitive performance tests and in school. Poor nutritional status was significantly linked to lower cognitive function test scores and poor academic performance among study participants, showing that malnutrition has long-term negative effects on children's physical and cognitive development, which may affect their learning potential. The majority of sociodemographic and economic factors were associated with children's cognitive performance test results and academic success. The study participants' scores on cognitive tests and academic achievement were positively correlated with maternal education and the wealth index, while stunting was adversely correlated with both. The results of children's cognitive function tests were positively correlated with the diversity of the children's diets.

Lewis *et al*. (2021) reviewed a comprehensive article Using PubMed, a thorough article search was carried out. The name of the vitamin or phytonutrient and the phrase "cognitive function" were used to search for articles published in English between 2000 and 2021 that had complete texts available. Aloe polysaccharides, omega-3 fatty acids, lipoic acid, Bacopa monnieri, B vitamins, cholinergic precursors, vitamin D, vitamin E, ginseng, lion's mane mushroom, N-acetyl cysteine, Rhodiola rosea, rosemary, saffron, cherries, turmeric, wild yam, Withania somnifera, xanthines, and zinc were among the nutrients and phytonutrients. This narrative review points out the most recent research on specific nutrients and phytonutrients that can enhance certain cognitive functions, result in improved results on important cognitive tests, and enhance perceptions of attention and affect. As a result, several of these nutrients may be helpful in the prevention and additional treatment of diseases like Alzheimer's disease (AD) and other similar neurodegenerative disorders that are characterised by cognitive dysfunction. The efficacy of treatment may differ depending on the disease state, so treatment regimens should be as individualised as possible with ongoing evaluation of benefits and risks for modification. It should be noted that some specific nutrients and phytonutrients appear more promising for improving cognitive function.

Peni *et al*. (2020) examine a study to find the connection between eating habits, nutritional status, and elementary school students' cognitive ability. Dietary habits are actions that are suitable for choosing the proper foods to ensure a decent nutritional status. Macronutrients like carbs, proteins, and fats, as well as micronutrients like vitamins and minerals, which the body needs for growth and development. 192 students were chosen using a stratified random sampling technique. The investigation of eating habits and nutritional status yielded data that demonstrated a strong positive link between school-age children's eating habits and nutritional status. According to the results of the analysis of nutritional status variables with cognitive skills, there is a correlation between nutritional status and children's cognitive learning achievement in elementary school. Applying a healthy diet will allow the intake to enter the body in accordance with the body's needs, resulting in a normal nutritional status. The cognitive abilities of children with normal dietary status are strong. The key factor in promoting children's healthy growth and development is parental involvement.

Naveed *et al*. (2020) undertook a cross-sectional study to examine the relationships between mid-childhood intakes of dietary fats and carbohydrates and cognition. 487 children, 250 males and 237 girls, between the ages of 6 and 8, live in Kuopio, Finland. Implementing 4-day food records, dietary fat and carbohydrate intake were measured, and the Raven's Coloured Progressive Matrices (RCPM) score was used to measure cognition. With regard to age, gender, percent body fat, family income, parental education, and daily calorie intake, linear regression models were used to assess cross-sectional correlations of dietary carbohydrate and fatty acid intake with cognition. For boys aged 6 to 8 years, but not for females, higher dietary intakes of fructose, total fiber, and soluble fiber were linked to improved cognition. After correcting for age, body fat percentage, family income, parental education, total physical activity, and daily caloric intake in girls, carbohydrate or fatty acid intake was not linked to RCPM scores. However, there is no connection between dietary fat and cognition in children. Increased intake of high-fiber meals like grain products and fruits and fruit juices, which are natural sources of fructose, may therefore help boys develop normally minded behaviour.

Hassevoort *et al*. (2020) examined the link between dietary lipids (saturated and omega-3 fatty acids), simple carbs (added sugars), and fiber, as well as their effects on creativity in preadolescent children. The verbal form of the Torrance test of creative thinking (TTCT), a standardised examination of creativity known to require the hippocampus, was completed by 57 participants, with a mean age of 9.1 years. The participant's 3-day dietary records were also completed with parental assistance. Overall TTCT performance was positively correlated with fiber consumption and adversely correlated with added sugar intake. Given the hippocampus' critical role in learning, memory, and creative thinking, there may be consequences for education and public health if there is an association between added sugar consumption and hippocampus-dependent cognitions during childhood.

Lam & Lawlis (2017) highlighted studies conducted on the impact of micronutrient interventions on school-age children's cognitive function. This comprehensive review evaluated the impact of new micronutrients on various cognitive domains. Studies assessing the impact of both single and multiple micronutrient interventions, as well as studies from both developing and developed countries, were examined. Micronutrients' impact on cognitive or academic performance in children aged 4 to 18 was examined in randomised controlled trials (RCTs). 119 studies were found in 18 papers. The primary cognitive outcomes evaluated were fluid and crystallized intelligence, short- and long-term memory, processing speed, attention and concentration, and academic performance. In children with baseline iron or iodine deficiency in particular, eight out of ten studies testing fluid intelligence found significant favourable effects of micronutrient supplementation. Interventions with micronutrients had erratic impacts on other dimensions. Overall, research has revealed that children's ability to develop their cognitive and intellectual capacities is limited by nutritional deficits.

Nyaradi *et al*. (2014) did a study to find potential links between dietary patterns and cognitive ability in adolescence. The study, Western Australian Pregnancy Cohort (Raine), which comprises 2868 kids born in Perth, Western Australia, between 1989 and 1992, was used for the investigation. Cognitive performance was evaluated in children aged 17 (2006–2009). Using a food frequency questionnaire administered to the children when they were 14 years old (from 2003 to 2006), "healthy" and "western" eating patterns were found using component analysis. It evaluated the relationships between dietary habits at age 14 and cognitive function at age 17. For 602 participants, information on diet and cognitive function was provided. Once "healthy" dietary patterns, total calorie intake, the mother's level of education, the family's income, the presence of the father in the home, family dynamics, and gender have been taken into account, A high intake of takeout food, red and processed meat, soft drinks, fried and refined foods, and takeaways were characteristics of the "Western" way of eating. Furthermore, it was observed that certain components of cognitive function were positively associated with greater intakes of fruits and leafy vegetables but negatively associated with high intakes of fried potatoes, crisps, and red meat within dietary patterns. Three years later, at age 17, lower cognitive function is linked to higher dietary intake of the "Western" way of eating at age 14.

Martinez-Lapiscina *et al*. (2013) conducted a study to evaluate the effects of the Mediterranean Diet (MedDiet) on cognition are examined using a controlled study. Following 6.5 years of nutritional supplementation, a randomised examination. The University of Navarra is connected to eight primary healthcare centers. There were 285 participants in the PREDIMED-NAVARRA trial, 95 of whom were randomly assigned to each of the three groups. (74.1 5.7 years old, 44.8% men, at the time of the cognitive test) They were all at a significant vascular risk. a dietary experiment comparing a low-fat control diet to two MedDiet—one with extra virgin olive oil [EVOO] and the other with mixed nuts. Participants in the MedDiet groups were given either 1 L of EVOO or 30 g of mixed nuts each week. To assess eating patterns, a 137-item validated food frequency questionnaire (FFQ) was used. At the beginning and after one year, MedDiet adherence was evaluated using a 14-item questionnaire. Participants in the MedDiet+EVOO group performed much better than controls in fluency and memory tests,

and they outperformed controls post-test across all cognitive domains. After adjusting for sex, age, education, apolipoprotein E genotype, family history of cognitive impairment/dementia, smoking, physical activity, body mass index, hypertension, dyslipidemia, diabetes, alcohol, and total energy intake, this group also showed less mild cognitive impairment (MCI) than the control group. Participants in the MedDiet+Nuts group were equal to those in the controls. Long-term administration of the EVOO-rich MedDiet enhanced cognitive performance in comparison to the control diet. Nevertheless, non-significant differences were found for the majority of cognitive categories. The MCI was lower in participants selected to the MedDiet high in EVOO than in controls.

Micha *et al*. (2010) examine a study to determine how breakfast's glycemic potency—its ability to raise blood glucose levels—relates to students' cognitive function (CF), 60 students between the ages of 11 and 14 were chosen based on their usual breakfast. Their breakfast and any snacks they consumed in the morning were noted. According to the glycemic load (GL) and glycemic index (GI) of the breakfast, they were divided into four groups: low GI, high GL; high GI, high GL; low GI, low GL; and high GI, low GL above or below the median for GI = 61 and GL = 27. A high GI breakfast was linked to better performance on the immediate word recall task; a high-GL breakfast was linked to better performance on the matrices task; and a low-GI, high-GL breakfast was linked to better performance on the speed of information processing and serial sevens task 90 minutes later. Performance was correlated with GI, GL, or both. This study describes the macronutrient composition of breakfast foods that may benefit schoolchildren's cognitive development.

Hoyland *et al*. (2009) draw attention to a studies on the impact of breakfast on school-aged children's cognitive function. They examined 45 studies that were included in 42 journals written between 1950 and 2008.The study is published online by Cambridge University press. Overall, the study's findings indicate that eating breakfast generally improves cognitive performance compared to skipping it. Both short-term studies and long-term school breakfast programmes seem to show that this effect is significant. The benefits of school breakfast programmes may, however, be associated with improved attendance and decreased absenteeism, and it is unknown how providing breakfast to older children may affect them. Additionally, breakfast's benefits can be more clearly seen in kids who are nutritionally insufficient. It is challenging to suggest the best breakfast for cognitive performance based on the research that is currently available. According to one study, solid breakfasts may be healthier than liquid ones. Furthermore, some research indicates that low-GI or low-GL breakfasts can be advantageous, but it is challenging to differentiate between these two glycemic response indicators in the few studies that have examined these food benefits.

METHODOLOGY

For this review, articles were searched on Google Scholar, Scihub, and PubMed. Articles published between 2005 and 2023 were taken using the names nutritional status, school-good children, Macronutrients Micronutrients, school breakfast, school feeding programmes, and the term cognition. Most of the articles taken for this review are recent. The majority of cited uses for this article are from 2023, 2022, 2021, and 2020. For this qualitative review, 960 articles were cited, of which 200 were readed and some articles, which were authentic to this review objectives were taken in the study. In this review, macronutrients, micronutrients, breakfast, hydration, physical activity, and lunch's impact on the cognitive performance of school-going children were discussed. For this review school-going children are about 4 to 17 years old. The goal of this review were to identify how diet effect the cognitive performance and to find how diet is associated with the academic performance. Objective of the review was to find how diet effect the cognitive performance of school going children.

RESULTS

Table 1

References	Country	Studies on types of food/nutritional status	Impact
Berg et al. (2023)	Uruguay	Process food and nutrient rich food	Process food is not related and nutrient rich food is favorably correlated to cognitive function
Sing et al. (2023)	India	Micronutrient	2 or more micronutrient deficiency has a great impact on cognitive function
Derese & Marisennayya (2023)	Woliata Zone of the Southern Ethiopian area Southern Nation alieties & People's area (SSNNPR)	School Feeding Programs	School feeding programs has a great impact on reading & writing
Ullah & Khan (2023)	Timergara Lower Dir, KPK (Pakistan)	Malnourish children	Nutritional status has a great impact on cognitive function

Sherzai et al., (2022)	Published by American journal of life style medicine	n-3 long chain poly unsaturated acids	Omega-3 dietary supplement has a great impact on neurodevelopment in all 3 phase in the short term
Pattebahadur et al., (2022)	India	Anemia	No statistical significant association between hemoglobin level & cognitive function
Van Beekum et al., (2022)	Cambodia	Stunting & Wasting	Both were consistently linked to delay the majority of motor & cognitive milestone. Stunting was highly correlated with delay gross motor milestone.
Kabero et al., (2021)	Soddo towr & soddo zuriya Woreda in the Woliates zone, Southren Ethiopian	Nutritional status & cognitive function	Poor nutritional was significantly linked to lower cognitive function & diversity of the children's diet is positively correlated with children cognitive function.
Peni et al., (2020)	Published by international journal of nursing and midwifery science	Eating habits, nutritional status and elementary school students cognitive ability	There is a correlation between nutritional status and children cognitive learning. The cognitive ability of children with normal dietary status or strong.
Naveed et al., (2020)	Kuopio (Finland)	Relationship between dietary fats, CHO & cognition.	No correlation between dietary fats & cognition in children. Higher dietary intake of fructose, total fiber & soluble fiber were linked to improved cognition.
Lom & lewlis (2017)	Australia	Micronutrient intervention	Cognitive & intellectual Capacities is limited by micronutrient defects.
Nyaradi et al., (2014)	western Australia	Dietary pattern & cognitive ability in adolescence.	Cognitive function positively associated greater intake of fruits & leafy vegetables & negatively associated with fried potatoes, crisp & meat.
Hoyland et al., (2009)	England	Impact of break fast on cognitive function	Eating breakfast has a significant impact to improve cognitive function.

DISCUSSION

This review aimed to giving an overview to find how diet can effect cognitive performance of childrens and to identify how diet is associated with school performance. All studies included in this review were also assessed to examine the effect and benefits of diet on the cognitive performance of school going childrens. Review contains the impact of nutritional status, macronutrient, micronutrients, Nutrients dense, rich foods and processed foods, diversity of diet, Nutrients and phytonutrients, Dietary lipids(saturated fatty acids and Omega-fatty acids, simple carbohydrates(sugar) and fiber, polyunsaturated fatty acid consumption, Breakfast consumption, MedDiet, Healthy and western dietary patterns, dietary carbohydrates and fatty acids, Malnutrition, Inadequate caloric intake and paternal education, effect of anemia on cognitive performance and schistosomiasis , stunting and wasting and school feeding programs on the cognitive performance of school going children.

The present review has identified relative food quality studies that examine the effects of nutritional status on the cognitive performance of school going children. The articles cited for the review is published between the year 2004 and 2023. Most of the studies in this review is were all conducted recent. The studied articles examine the association of the diet with cognitive performance and school performance. Many positive effects were found on the consumption of diet on cognitive performance of school going childrens.

The ability of children to read was positively correlated with eating a nutrient-dense diet. A diet rich in nutrients can helped the student's ability to learn, write, and use language (Berg *et al*., 2023). Certain cognitive functions can be improved by specific nutrients and phytonutrients. i.e., improve cognitive test scores and increase attention (Lewis *et al*., 2021). Two or more micronutrients deficiencies effect the cognitive performance, developing delay and poor academic performance or closely related to these impairments (Sing *et al*., 2023). A higher intake of omega-3 PUFA can improve children's reading, writing, and phonological awareness abilities. Omega 3 dietary supplements may have short-term positive effects on neurodevelopment in all three stages including utero, nursing, and childhood (Sherzai *et al*., 2022).

Children with a healthy nutrition status have strong cognitive abilities (Peni et al., 2020). The diversity of a child's diet is positively associated with cognitive

function. Fructose, total fiber, and soluble fiber intake are all positively associated with cognitive function. However, there is no association between dietary fats and children's cognition (Pattebahadur *et al*., 2022). There is also no significant association between hemoglobin level and cognitive function (Pattebahadur *et al*., 2022). Cognitive function were positively associated with greater intakes of fruits and leafy vegetables but negatively associated with high intakes of fried potatoes, crisps, and red meat within dietary patterns (Nyaradi *et al*., 2014).

Lower cognitive function and poor academic achievement tend to be significantly associated with poor nutritional status. Cognitive and intellectual development are impacted by nutritional deficiencies Malnutrition has long-term negative impact on children's physical and cognitive development, which may affect their learning potential (Kabero et al., 2021). Stunting and wasting were consistently associated to delays in the majority of motor and cognitive milestones. Stunting is strongly associated with delayed gross motor milestones (Van Beekum *et al*., 2022).

Break fast have a positive impact on the cognitive performance of school going childrens. Eating breakfast generally improves cognitive performance as compared to skipping break fast. Both short-term studies and long-term school breakfast programmes seem to show that this effect is significant (Hoyland *et al*., 2009). Macronutrient composition of breakfast food may benefit school children cognitive development. High GI and high- GL breakfast was linked to better performance, and a low-GI, high-GL breakfast was linked to better performance on the speed of information processing. Performance was correlated with GI, GL, or both (Micha *et al*., 2010). The school feeding programs have also positive impact on cognitive function of childrens (Derese & Marisennayya, 2023).

Several studies show that Nature environment, Home environment, physical activity, early poverty, school and class room environment has also great impact on the cognitive performance of school going children.

CONCLUSION

The review concluded that nutritional status has a great impact on the cognitive function of children and is also associated with school academic performance. Macronutrients, micronutrients, breakfast, school feeding programs can effect the cognitive function of school going children. There is also a variety of other factors which effect the cognitive performance of school going children including physical activity, nature environment, home environment, school environment, and class room environment have been associated with the cognitive performance of school-going children. Poor nutritional status is negatively associated with cognitive performance in school-going children. Globally, food insecurities, micronutrient deficiencies, stunting, wasting, and other health-related problems increase day by day in children, which affect school-going in different ways.

RECOMMENDATIONS

There is a lack of knowledge about a healthy nutritional status in children, which also contributes to different deficiencies and interrupts their poor cognitive function. Different programmes and policies are required worldwide to promote nutritional status among children. There is also need of School feeding programs which help to improve the cognitive performance.

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