RETRACTED ARTICLE: Functional behavior of DHA and EPA in the formation of babies’ brain at different stages of age, and protect from different brain-related diseases

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ABSTRACT

Omega-3 fatty acids are rich in marine animals and plant-based foods like grains and seeds. Docosahexaenoic acid (DHA) and Eicosapentaenoic acid (EPA) are directly present in different fish types, whereas they are indirectly available in various seeds and grains. Plants seeds and grains contain omega 3-fatty acids in the form of ALA that is converted into EPA and DHA with the help of specific enzymes. DHA and EPA play an important role in developing brain and nerve cells. Several studies confirmed that children need these fatty acids at all stages, including pre-birth and after-birth. During pregnancy and lactation, the fetus fulfills its requirements by the mother’s diet. During childhood, DHA and EPA demands are fulfilled from different food sources. Different Clinical studies suggested that n-3 fatty acids supplementation during pregnancy, lactation and infants may play an important role in brain development, including neurodevelopment, nervous tissue, optimal visual and neuronal signaling. Animal and cell studies showed that DHA is a vital fatty acid with brain function for neuronal cell growth. Pharmacologically, these omega 3 fatty acids improve mental health and reduce the risk of brain-related diseases such as Alzheimer’s disease, mild cognitive impairment, depressive symptoms, epilepsy, schizophrenia, stroke, Parkinson’s disease and autism spectrum disorders. This review described the importance of fatty acids including EPA and DHA in supporting the optimum growth and development of brain. The conclusive statement, DHA and EPA are vital functional materials for forming babies’ brain at different age periods.

INTRODUCTION

Omega-3 polyunsaturated fatty acids are major dietary components that are central modulators of many neural functions in the brain. They are major components of neuronal membranes. Polyunsaturated fatty acids (PUFAs) have two or three double bonds in their carbon chain[1] Fatty acids play a significant role in growth, and development,[2] regulation of visual signaling, blood pressure (hypertension, CVD, asthma, cystic fibrosis, dermatitis and neurodegeneration).[3] In the brain, both (DHA) and (EPA) treat depression and neuro-inflammatory diseases. Many of the
important functions in signaling (signal transduction pathway) are brought about by fatty acids like the production of eicosanoids, neurological modulation and the peroxidation of low-density lipoprotein.[4] Additionally, the development of eicosanoids that act as signaling molecules in immune response, the formation of lipids, and energy reserves in the form of adipose tissues (special cells for fat storage) are all attributes of fatty acids. Besides playing a major role in cell membrane formation, increased intake of EPA and DHA ultimately improves light transduction. Likewise, an increased level of omega-3 fatty acids positively affects membrane flexibility, resulting in better microcirculation.[5] DHA is a long chain polyunsaturated fatty acid that is basically a structural constituent of membranes in the central nervous system.[6] During infancy, DHA plays an important function in brain development and plays a vital role in the brain function of babies (breastfeeding).[7] Previous animal studies confirm the evaluation of the relation between brain functioning and DHA for neuronal cell growth. Human studies showed that DHA is an important constituent of optimal visual acuity development. Accumulating data indicate that DHA may have effects on the brain in infancy. DHA aids in the reduction of cognitive and psychiatric disorders.[8]

**FATTY ACIDS AND ITS DIFFERENT TYPES**

Saturated (long-chain ≥ C16), mono-unsaturated (contains a single double bond), poly-unsaturated (further classified as omega fatty acids) and trans fats are the generally recognized classes of fatty acids.[9] The most abundant among long-chain monounsaturated fatty acids is oleate. Most monounsaturated fatty acids C16 – C22 contain cis double bonds. The n-3, n-6 and n-9 all belong to unsaturated fats based upon the place of double bond nearest to Ω-carbon.[10]

**Omega –3 fatty acids**

Fats that the body cannot make on its own and need to be taken from an external source are essential fatty acids.[11] The term essential emphasizes that they are necessary for survival, so they must be obtained through diet.[12] PUFAs are categorized as n-3 and n-6; depending on the position of double bonds on 3rd and 6th carbon, respectively, from the methyl end.[13] DHA chief double bond is located at the 3rd carbon from the omega end.[14] Das.[15] explained that few of the actions and functions could be performed by essential fatty acids (EFAs) after converting to eicosanoids or other products. Differences in omega-3 to omega-6 ratios affect membrane fluidity, membrane thickness and movement of embedded proteins.[15]

**Polyunsaturated fatty acids and its types**

Essential fatty acids (n-3 fatty acids) have been categorized as α-linolenic acid (ALA), EPA and DHA.[16] Omega-3 and omega-6 can be considered major types of PUFA’s, particularly DHA and EPA.[17] DHA is one of the main components of the omega-3 essential fatty acid and makes up 60% of fats in the brain,[18] contributing almost half portion (30–50%) of total fatty acids in the mammalian brain,[12] accounts up-to 97% of total omega-3 fats in the brain,[19] found in the gray matter of the brain,[6] that’s why vital for the growth of brain,[18] and is an imperative structural component of heart tissues.[19]

**CHEMISTRY AND HEALTH PROSPECTS OF EPA AND DHA**

DHA, sometimes called cervonic acid,[20] a member of long-chain highly unsaturated fatty acids contains 22 carbon atoms in its acyl chain. The human body comprises almost 7 trillion cells and fundamentally, all of them depend on omega-3 fatty acids for performing cellular activities.[21] Moreover, DHA is a major structural component of the eye’s cerebral cortex and photoreceptor cells.[6] EPA is a n-3 polyunsaturated fatty acid (20:5) having 20-carbons 5 double bonds. EPA possesses non-lipid and non-lipoprotein properties that help prevent atherogenesis, such as protecting against oxidative damage and improving vascular and endothelial functions.[22] Brain cell membranes and receptor allow the cell to communicate. The level of EPA and DHA in brain membrane lipids depends on the type and amount of fatty acids.[23] Furthermore, DHA plays a role in reducing blood cholesterol, regulating cell signals and protecting the brain against oxidative degradation of lipids, therefore assisting in maintaining the plasticity of brain,[6] lipid metabolism, adding in different eyes functions,[24] and maximizing cognitive potential in the central nervous system.[25]
DiNicolantonio et al.\textsuperscript{[26]} stated the proven effects of EPA and DHA in preventing and treating depression. Yet, research has proven that omega-3 oil derived from the DHA component is much more effective in neurological functions than the EPA. DHA and ALA collectively makes 20% of brain’s dry weight. Phospholipids (PL) acts as carrier of DHA to the brain,\textsuperscript{[6]} therefore, providing fluidity to these structures.\textsuperscript{[27]} EPA and DHA helps in the maintenance of neural and photoreceptor membrane supported by the liver that supplies DHA incorporated into plasma lipoproteins. Retinal pigment epithelium (RPE) involvement in the uptake of DHA by the retina and its delivery to photoreceptors has been elaborated by Bazan.\textsuperscript{[28]} Peroxisome proliferator-activated receptors (PPARs) belong to the high nuclear receptor, a group of transcription factors involved in regulating the oligosaccharides components and condition of optimal functioning of fatty acids.\textsuperscript{[29]} It also regulates oxidative stress, cell proliferation, adipogenesis, inflammatory responses, and differentiation. It plays a fundamental role in life cycle stage prior to birth.\textsuperscript{[30–32]} DHA is considered to be the most important functional long-chain polyunsaturated fatty acids. It is considered to possess the numerous biological functions for human health, therefore EPA and DHA act as a ligand for PPARs. DHA plays a very important role in the binding activity of PPARδ DNA and H9c2 cells, which strongly suggest that the cytotoxic effect of EPA and DHA may be mediated by PPARδ signaling.\textsuperscript{[33–37]} Another research indicated that fatty acid binding triggers a mutation in these receptors, which induces the transcription of specific genes encoded for various metabolic and cellular functions.\textsuperscript{[38]}

EPA and DHA increase gene activation through membrane-associated G-protein-coupled receptor 120 (GPR 120) to boost anti-inflammatory effects.\textsuperscript{[22]} Aside from PPAR activation, DHA also enhances insulin sensitivity and reduces lipid and inflammatory levels in the bloodstream. Neurogenesis, anti-nociceptive effects, anti-apoptotic effects, synapse plasticity, brain Ca2+ homeostasis, and nigrostriatal activities are all dependent on EPA and DHA and its metabolites’ signaling pathways.\textsuperscript{[26]} DHA and its metabolites have a wide range of effects on the brain at various levels and locales.\textsuperscript{[39]} Figure 1 depicts the metabolites of EPA and DHA, and their role in brain development. Several randomized control trials have been conducted on the supplementation of EPA and DHA on neonatal growth and cognitive development through pregnant women, infants and school-going children.\textsuperscript{[40]} Different trials and their results are shown in Table 1.

**CHEMISTRY OF ALA**

ALA, 18-carbon fatty acid with three double bonds at different positions of the carbon chain (9, 12, and 15),\textsuperscript{[51]} is an essential fatty acid (EFA) that contains a substantial amount of energy for the body. It can also be converted to EPA and DHA but in very limited amounts.\textsuperscript{[29]} Studies

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**Figure 1.** Metabolites of EPA and DHA and their functions toward brain development.
suggest that ALA converts to EPA in 3 subsequent steps and further 4 reactions proceed with the conversion of EPA to DHA. Since DHA and EPA can be produced in the human body in very limited amounts as a result of ALA breakdown. Dietary polyunsaturated fatty acids down-regulate the expression and activity of enzymes involved in DHA synthesis in the liver, thereby reducing the rate of synthesis of DHA in the liver. The brain can synthesize DHA. However, the synthesis of DHA in the brain is approximately 100 times lower than the rate of absorption and consumption of DHA in the brain, indicating that DHA synthesis does not contribute significantly to DHA homeostasis in the brain. Interestingly, in contrast to the increased synthesis found in the liver, dietary deprivation of n-3 PUFA does not affect the expression of desaturase or elongase in the brain or the rate of DHA synthesis. The amount of DHA synthesis and secretion in the liver is at least 3 to 10 times greater than the rate of DHA consumption in the brain, combined with the findings that the synthesis of DHA in the liver is upregulated during n-3 deprivation, suggesting that DHA synthesis in the liver may maintain DHA homeostasis in the brain. DHA after being synthesized in the liver is secreted into the bloodstream, where other organs like the brain take it up. Among neural cells, including neurons, astrocytes, oligodendrocytes, and microglia, astrocytes are the major site for DHA synthesis, whereas neurons (which can’t synthesize because it lacks desaturase) serves as accumulating site. However, infants were found to be more efficient converters when compared to adults. Preformed DHA consumption is the only implication of poor conversion. Arachidonic acid (AA) (20:4, n-6) is later converted into inflammatory prostaglandins or leukotrienes with the help of enzymes containing 2 and 4 double bonds, respectively. On the contrary, prostaglandins and leukotrienes produced by n-3 fatty acids include 3 and 5 double bonds, respectively; they are biologically less active. Recently, an alternative mechanism for DHA synthesis has been proposed. An experiment determined that D6-desaturase also has D8-desaturase activity. Based on this discovery, the author proposes an alternative approach to the synthesis of DHA from ALA, which works in parallel with the classical approach, including the initial extension of ALA to 20: 3 n-3, followed by desaturation of D8 to generate 20: 4 n – 3, which is then desaturated and elongated into DHA.

Table 1. Supplementation of EPA and DHA in randomize control trials among pregnant women, infant and children of different age.

| Population and country | Duration of supplementation | Outcome | References |
|------------------------|-----------------------------|---------|------------|
| Pregnant women (n = 300, United Kingdom) | 42 mg/day of EPA and 300 mg/day of DHA for 12 weeks (from third trimester) | Showed increase correlation of DHA with brain volume | [41] |
| Pregnant women (n = 315, Germany) | 150 mg of EPA/day and 500 mg of DHA/day for less than 20 weeks to delivery | Increased cognitive development of children aged 5-5 years | [42] |
| Infant (n = 420, Australia) | 60 mg of EPA/day and 250 mg of DHA/day (from birth to six months) | Increased communication skills and early language development | [43] |
| School going children aged 7–10 years (n = 90, Australia) | 264 mg or 1109 mg of EPA and 1032 mg or 108 mg of DHA for 4 months | Increased spelling and reading capability of children | [44] |
| Pregnant women (n = 143, Norway) | 803 mg/10 mL of EPA/day and 1183 mg/10 mL of DHA/day for 18 weeks to three months of post delivery | Increased mental processing score | [45] |
| Pregnant women (n = 150, Iran) | 180 mg of EPA/day and 120 mg of DHA/day for 20 weeks to one month of post delivery | Increased primary neurodevelopment of 4–6 months of infants | [46] |
| Pre-school children (n = 175, USA) | 400 mg of DHA for 4 weeks to 4 years of children | Increased vocabulary score of children | [47] |
| Pre-term infant (n = 107, United Kingdom) | 0.5% of DHA in supplemented formula from birth to 9 months | Increased verbal and intellectual capability | [48] |
| Pregnant women (n = 1094, Mexico) | 400 mg of DHA/day from 18–22 weeks to delivery | Increased birth size and head circumference, also increased attention score | [49] |
| Infant (n = 27, Taiwan) | 0.05% of DHA in supplemented formula for 6 months after birth | Increased mental development index | [50] |

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Another recent study questioned D6 desaturation as the only rate-limiting step in the synthesis pathway. The authors found that the elongation of DPA n-3 maybe 24: 5 n-3, which may be another key checkpoint in DHA synthesis. The elovl2 enzyme catalyzes this reaction, and the lack of expression of this enzyme in the heart is believed to be the reason for the very low rate of DHA synthesis in heart tissue.

**ORIGIN OF DHA AND EPA**

DHA and EPA are n-3 fatty acids that are produced from fish. Indirectly, ALA is present in different plant seeds and grains that convert into EPA and DHA after human consumption. Flaxseed oil is a major plant source of ALA ([67](#)) (Table 2).

**Animal sources (marine)**

In the human diet, the main contributors of DHA and EPA are marine ecosystems (fish and other marines). Fish is consumed as a significant dietary component in various parts of the World that provide fatty acids necessary for the well-being of individuals. Polysaturated fatty acids, particularly n-3 PUFA, DHA and EPA are the prominent compounds found in fish. Fish liver contains a large number of omega-3 fatty acids that have been proven by different studies to lower blood triglycerides and cholesterol levels. Actually, fatty predatory fish like sharks have a lot of omega-3 fatty acids in their tissues that possess a lot of health benefits, particularly in terms of reducing inflammation, improving mental health, and serving as an anti-oxidant. Fatty fishes including *Gadus morhua* (cod), *Thunnus thynnus* (tuna), *Salmo salar* (salmon) *T. ilisha, S. longiceps, S.richardsonii*, and *N. hexagonolepis* have numerous roles as principal sources of DHA and other polysaturated fatty acids in the Western World. Seafood including fish, shellfish, micro-and macroalgae, supplies DHA in substantial amounts to the body. Echeverría et al. concluded that individuals consuming seafood as a regular diet showed increased brain size that ultimately improved motor skills and behavior with strong cognitive constituents. The undisclosed fact is that fish do not produce omega-3 itself, they actually get a significant amount from eating microalgae. It is noteworthy that omega-3 enriched eggs can also be good sources of DHA and EPA but this statement is just confined to omega-3 enriched eggs. Another study stated that egg yolk contains ALA (0.8%), DHA (0.7%) and EPA (0.1%). Additionally, egg yolk, lean red meat, chicken and human milk are also good sources of ALA.

Abedi and Sahari described that; although long-chain PUFA can be produced from ALA and LA (Linoleic acid), the quantity is very low in beef and lamb (0.28 mg/g and 0.52 mg/g) as compared to oily fish (19.9 mg/g). This suggests that algae oil can be an alternative of fish to people who do not consume fish, for supplementing DHA to the body. DHA and EPA are very low in ruminant fats, including milk and dairy products. Hen’s egg yolk can be another dietary source of DHA, considered an affordable source for the general population. In retina and brain, DHA is found in a visible amount that plays a vital role in normal vision and brain functioning.

**Plant sources (seeds and grains)**

Vegetable oils do not contain DHA and EPA, although they can be good sources of ALA. Mammals cannot synthesize LA (Linolenic acid), which must be taken through diet. LA (Linolenic acid) exists in plant bases like seeds, nuts and vegetable oils. ALA (Alpha-linolenic acid) institutes flaxseed, walnuts,

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**Table 2. Direct and Indirect sources of EPA and DHA.**

| Source Classification | Sub-Classes |
|-----------------------|-------------|
| Direct Sea food/marine | Salmon, sebass, oysters, sardines, shrimp and trout |
| Indirect Plant-based food | Seeds and grains |

References: [66,67] [68–71]
soya beans and leafy vegetables and maybe endogenously transform to DHA and EPA. Linolenic acid and Alpha-linolenic acid can be changed into arachidonic acid, Eicosapentaenoic acid, and eventually Docosahexaenoic acid respectively, involving desaturation and elongation as major steps subsequent oxidation yields DHA. Delta-5-desaturase (D5D) and Delta-6-desaturase (D6D) are the carriers of this entire process. Figure 2 show the conversion mechanism of ALA into DHA and EPA. Moreover, studies stated that the conversion of ALA to DHA accounts for 1% in infants and lesser in children.

Marine microalgae (extensively used in aquaculture as animal nutrition) is the primary producer of DHA. In industrial bio-reactors, species of algae like Mortierella, Cryptochytrium, Schizophyllum and Cryptochytrium cohnii can be cultivated artificially; to produce oils rich in DHA. A considerable amount of EPA is found in algae like eustigmatophytes, prynnesiophytes, diatoms and cryptomonads. In addition to that, DHA is commonly restricted to the dinoflagellates and some marine heterotrophs. Several microalgae species such as Schizophyllum and Cryptochytrium cohnii produce microalgal oil. Plants cannot synthesize DHA and EPA, but phytoplankton and animals can.

ALA is readily found in different seeds, including Flaxseed, hemp seeds, and chia seeds. Plant sources including nuts and seeds like walnuts, flaxseed and its oil, chia seeds, soy, safflower, corn, kale, spinach, canola oil and soyabean oil are good sources of omega-3 fatty acid like ALA (Alpha-linolenic acid) and EPA (Eicosapentaenoic acid). Flaxseed can be considered a substitute for marine products. Flaxseed is ranked on top among plant-based ω-3 fatty acids (α-linolenic acid (ALA)). Omega-6 riched seeds oil like corn oil and soybean oil intake has been increased primarily; the ratio of omega-6 to omega-3 in these oils is as 60:1 and 77:1 respectively.

Other sources

Oils are processed to get highly de-odorized, stabilized, and cholesterol-free oil; which is then consumed in capsulated/micro-encapsulated or nano-capsulated form in various food matrices, including milk, cereals, and juices. Poultry and eggs supplement DHA in very minor quantities. DHA can be consumed either in ALA (precursor of DHA) or EPA (precursor of DHA). Conventionally, seafood is consumed to get DHA in the body. Nevertheless, other substitutes like fish oils are also available in the market to fulfill the nutritional demands of DHA in the body. DHA is found in chicken and flesh of red meat as Alpha-linolenic acid.
Abedi and Sahari,[52] quantified that infant formulas should contain 0.2% as DHA and 0.35% as Arachidonic acid (AA) of total fats. Moreover, they stated that omega-3 supplements in the form of fish oil are available in the market that is generally safe to consume. The cellular (free of odor and contaminants) products obtained from algae can be incorporated into food matrices, particularly in infant formula.[27]

**AID IN THE DEVELOPMENT OF CHILDREN’S BRAIN AT DIFFERENT STAGES**

**Development of fetal brain During pregnancy**

The health of offspring is dependent on maternal diet during pregnancy that exerts long-lasting effects in the future. The significance of maternal diet during pregnancy is quite evident and accepted Worldwide.[78] The maternal diet is important for a healthy pregnancy and fetal outcomes. The theory that an unhealthy early life diet raises the susceptibility of the offspring to poor results and illness is quite well recognized. Numerous researchers have shown that the amount and content of dietary fats eaten during breastfeeding have significant health consequences both during and after delivery.[79] Increased essential fatty acid consumption throughout gestation has also been linked to lower maternal stress, preterm delivery, lower allergies, improved brain nerve tissue formation,[80] and improved neurocognitive outcomes in offspring.[81] DHA is essential for healthy brain growth in breastfed babies, especially throughout prenatal/brain development. On the other hand, EPA has a stronger effect on performance and mood. As a result, DHA and EPA develop neuroprotective compounds.[82] A low DHA and EPA serum rate in pregnant or breastfeeding women can harm their infants,[83] particularly during prenatal brain development in breastfed infants. DHA and AA are delivered to the fetal venous fluid through the placenta,[79] from where fatty acid carrier protein-4 (FATP 4) takes it to the fetal brain, plays part in the development of the brain particularly in synaptic activity during developmental phases of fetus till 2 years of age.[27,84] The brain receives 70% of the energy supply during embryonic development, fats contribute up to 50–60% of brain structure, DHA forming 30% of brain and 50% of the retina.[85] The placenta preferentially transfers DHA and AA, while the short-chain (omega-3 and omega-6) ALA and LA are reserved.[85] DHA levels in the brain appear to decrease with age, particularly in patients with Alzheimer’s disease.[84] The neurological development of a baby depends on dietary intake of essential nutrients, omega-3 fatty acids as potent nutrients. Although fetus and child brain cannot convert ALA oil into DHA, the baby’s supply is totally dependent on the mother’s diet. Data indicates that starting early in pregnancy, the mother can accumulate more adipose tissue as a backup, which can be tapped later. During the last trimester of pregnancy, the stresses on the fetus are expected to be high as, the fetus is thought to absorb around 60 to 70 mg n-3 LCPUFA (Long chain polyunsaturated fatty acids), often in the form of DHA. Around 6 to 7 grams will be fetal accretion, mostly for brain growth, during the third trimester. Inside around 1 kg of fetal adipose tissue, almost 2 g DHA will be stored. The mother is the main carrier of these vital fatty acids for the fetus and breastfed baby.[85] According to Echeverra et al.[27] the US dietary report suggests 8–12 ounces of seafood per week as a safety limit for pregnant or breastfeeding women, particularly people living in poverty. During the third trimester, they can eat two servings of fish a week or complement their diet with fish oils from a range of seafood types. Since low-income pregnant women who have insufficient access to fish or fish oil supplements, are more vulnerable to DHA deficiency.[86] Moreover, the Expert Committee’s regular DHA prescription during pregnancy is 200–300 mg/day.[83] The European Food Safety Authority (EFSA) advises infants to get 100 mg of DHA on daily basis.[87] (Figure 3)

In addition to neural tissues, the retinal tissues are responsible for visual acuity in infants during the final months of pregnancy and the first six months of childhood.[88] Infants born before 33 weeks of pregnancy have lower levels of DHA in their brains than those born at full term.[89] Though DHA and AA contribute to fetal central nervous system development, lesser intake of EPA and high consumption of linoleic acid can impact pregnancy outcome by disturbing the balance of eicosanoid release.
A high AA (Arachidonic acid) to EPA (Eicosapentanoic acid) ratio leads to unfavorable outcomes including preterm labor and preeclampsia. A diet high in linoleic acid contains a lot of AA, which is a precursor to the powerful prostaglandins (PGs) E2 and PGF2 and the vasoconstrictor thromboxane (TX) A2. Both PGE2 and PGF2 have been linked to preterm labor initiation, while thromboxane A2 has been linked to preeclampsia.\[90\]

Studies of clinical trials conducted during pregnancy revealed that PUFA (Polyunsaturated fatty acids) supplementation resulted in prolongation of gestational duration moderately (by 1.6 days).\[91\] Conversely, PUFAs supplementation did not prolonge the pregnancy period or did not result in premature birth in women with high-risk pregnancies, but reduced the incidence of early premature births.\[85\] Another research found that taking omega-3 PUFAs during pregnancy limited the chances of premature birth, but had little chances of perinatal death.\[92\] Although, various studies have reported more conversion of ALA to EPA by women of childbearing age. DHA and EPA are principally important to developing fetuses.\[26\] Pregnant women who ate DHA-rich fish oil (approximately 2.2 grams of DHA/day) from the 20th week before delivery, gave birth to children with significantly improved visual and balance abilities. Similar findings were observed when mothers were supplemented with 500 mg of DHA/day that raised blood DHA levels and ultimately resulted in better cognitive performance in children aged 5.5 years.\[27\] The retina and brain are the two most infiltrated fetal regions can be linked to normal vision and brain activity.\[17\] DHA helps young adults develop their recall and response speed,\[25\] essential for the brain growth of the fetus,\[72\] increases problem-solving, vision acuity and can impair brain development during infancy.\[25\] DHA, EPA and omega-3 fatty acids are important nutrients that play a vital role in improving life quality and reducing the chances of premature deaths. Numerous studies have proved the essentiality of DHA in pre-natal and post-natal brain growth.\[82\]

DHA and EPA supplementation (during pregnancy and lactation) positively impacted infant cognitive development at 4 years of age but had no impact at 3 and 6 months. When administered in very large doses to term babies, LCPUFAs sharpened vision acuity. The evidence for LCPUFA supplementation having an effect on preterm infants is also inconclusive.\[93\] Omega-3 fatty acids are important for fetal neurodevelopment and can also influence gestational age and birth weight.\[90\]
**Brain Development of Breastfed Infant**

Breast milk supplies Arachidonic acid (AA) and Docosahexaenoic acid (DHA) to neonates after birth; the level of essential PUFAs in breast milk can be calculated by the maternal intake of these fatty acids. Another study analyzed the impact of PUFAs supplementation during pregnancy and lactation. DHA accumulates at around 10 mg/day in the entire body of breastfed babies during the first 6 months of development, with 48% of that amount appearing in the brain. Breastfed infants must eat a minimum of 20 mg DHA per day to reach the amount of accumulation. The alphalinoleic acid is an omega-3, essential fatty acid converted into DHA in the human body. The DHA is omega 3 polyunsaturated fatty acid that aid in development of brain and visual function. Previous research showed lactation women that ingestion of oil has high ALA contents such as chia seeds oil. The data results showed that chia oil or other oils with a high content of ALA to scientifically support the recommendation of ALA consumption to increase the DHA content of breast milk.

Bzikowska-Jur et al. calculated fatty acid (FA) concentration in mothers’ milk. They further studied the relation between omega-3 fatty acids and maternal dietary intake; finally found no association between the current dietary intake of omega fats and their amount in milk. Tough, found that regular consumption of fatty fish affected the concentration of omega fats in maternal milk. Besides this, beef intake affected the DHA concentration. adversely, suggesting that omega-fat consumption did not affect DHA concentration significantly. On contrary, the regular consumption seems to have a significant impact on milk concentration. Prematurely born children miss out on the mother’s peak DHA accumulation. The DHA is an essential nutrient for brain development. However, its intake is very low, generating lower DHA levels in breast milk. The fetus and breast feeding baby intake DHA from the mother sources. During the pregnancy and lactation period, the balance of DHA is necessary for women’s diet. However, for better brain development, women’s diet is needed to consume vegetable oils, fish, and seafood. An alternative source is direct supplementation of DHA capsules during pregnancy and lactation. Breastfed infant obtain EPA and DHA from mother milk are presented in Figure 3.

**Development of Childhood Brain**

For good cause, docosahexaenoic acid (DHA) is often referred to as “brain fuel.” DHA is the main structural part of brain tissue, and fats make up 60% of the brain and nerves that run every system in the body. This long-chain omega-3 fatty acid seems to have a significant effect on the developing brain, and can also influence that how well the children behave intellectually and socially. n-3 fatty acids play a key role in brain and CNS (Central Nervous System) development and its functioning. Besides this, plays a significant role in psychomotor development like eye-hand coordination, sensory development and nerve signal transmission. Children require balanced diets that include sufficient levels of fat and fatty acids. Childhood dietary intakes can promote potential adult health by preventing metabolic diseases and cardiovascular disease, supporting immune functions, and maintaining a healthy reproductive system.

DHA has been shown to help young adults develop their recall and response speed. The combination of EPA and DHA has been shown to reduce the prevalence of asthma in infants. DHA and other omega-3 fatty acids have improved memory and behavior. A diet with a lesser amount of omega-fats increases the probability of developing ADHD (Attention Deficit Hyperactivity Disorder). In a survey of almost 200 students, people who ate low-omega-3 diet had 31% higher chance of being diagnosed with ADHD. Children with ADHD have lower omega-3 levels in their serum. According to a review conducted by researchers stated that the amount of n-3 fatty acids in children suffering from ADHD is 38% lower than non-sufferers. The lower level of DHA in the blood is associated with mood fluctuations, anger and academic disabilities. On the other hand, according to tentative data from treatment trials, long-chain omega-3 fatty acids can be a supportive therapy for ADHD and associated childhood developmental disorders. The EPA seems to have a greater
impact on action and attitude. Omega-3 fatty acids like DHA is clearly essential for understanding, memory and action. Low DHA blood concentrations were linked to impaired reading capacity, working memory, higher levels of parent-related oppositional behavior and emotional responsibility in a study of schoolchildren aged 7 to 9 years. Another study of boys aged 6 to 12 years found that those with lower omega-3 fatty acid levels had a higher proportion of behavioral issues such as temper tantrums and sleeping problems.

Some meta-analyses concluded that omega-3 polyunsaturated fatty acids might be helpful as a complement to existing therapies. Since children’s brains grow quickly, they benefit from omega-3 fatty acids rich diet from an early age. At the age of six, the most significant brain development is complete, and by the age of five, a child’s brain has increased in mass by 3.5 times. Human breast milk contains elevated amounts of DHA. Children eyes, like their brain are heavily saturated with omega-3 fatty acids that began to develop when they are still in the womb. In the retina, DHA is present in elevated concentrations. As a result, for children’s eyes to work properly, they need a steady supply of DHA. The European Food Safety Authority (EFSA) has also approved the argument that DHA helps maintain normal vision.

Numerous researches have proved the beneficial effects of omega-3 fatty acids on behavior and reading ability. Fish oil supplements are used by 28% of children with autism. Many tests show that omega-3 fatty acids can help people with autism. Fish oil supplementation was found to mitigate hyperactive behavior in autistic children. Many of the experiments in this field are small or poorly performed, so more comprehensive and well-conducted randomized controlled trials are needed. According to a report undertaken by Plourde, found that the synthesis of docosahexaenoic acid (DHA) is impaired during aging and in E4 carriers, a discovery that was confirmed in homozygous mice with the human E4 allele knocked in (hAPOE4).

### Pharmacological Functions of DHA and EPA

Essential fatty acids are known to play a substantial role in cognitive processes, brain function, visual acuity, ADHD (Attention Deficit Hyperactivity Deficit), autism, behavioral patterns and intellectual ability. Omega-3 fatty acids deficiency during neuro-degeneration has been shown in both animal and human studies to affect dopamine uptake in the organ, resulting in conditions such as ADHD, depression, and schizophrenia. Neurodegenerative disorders (biomedical problems), characterized by brain communication loss, rise with age. Preclinical research suggests that long-chain omega fatty acids can have neuroprotective properties, perhaps by suppressing amyloid accumulation, limiting neuro-inflammation and boosting cerebral blood flow. EPA and DHA cover many metabolic and neurologic diseases. While DHA appears to be more helpful in the treatment of neuro-inflammatory disorders, DHA intake strengthens memory in cases of dementia and improves memory in general.

Different studies have proved the effectiveness of n-3 fatty acids against cystic fibrosis as well as against dementia. Likewise, researchers have revealed that the fact behind mitigating effect against inflammatory diseases is the dislocation of n-6 fatty acids including AA (Arachidonic Acid), in the cell membrane. It lessens the formation of metabolic end products, including prostaglandins, thromboxanes, and leukotrienes. Other miracles of omega-3 fatty acids include managing cellular inflammation and controlling Age-Related Macular Degeneration (AMD) as well. Eicosanoids, derivatives of AA (omega-6-fatty acid) serves as primary mediators of cellular inflammation, EPA is the most imperative in reducing cellular inflammation. DHA is known to mediate the expression of at least 100 genes in the area of neural growth, functioning and metabolism. Throughout postnatal development, a quick deposit of DHA in the brain and retina takes place. DHA reaches its maximum level (60% of all fatty acids) in central nervous system synapses and in retinal photoreceptors. Claims for EPA beneficial effects are believed to treat numerous neuropsychiatric illnesses. EPA and DHA are extremely active polyunsaturated fatty acids. Moreover, experts have linked an increased level of DHA with a reduced risk of dementia.
Zhang et al., [56] have been proved the beneficial effects of omega-3 fatty acids against neuropsychiatric conditions, including ADHD. The beneficial effects of omega-3 oils on neurological activity and brain defense are of special concern. A variety of findings have found that higher omega-3 fatty acids oil intake is beneficial, [116] including a major reduction in risk of cardiovascular death, [72] reducing the prevalence of Alzheimer’s disease and increasing the life quality of dementia patients. [116] (Table 3)

**Alzheimer’s disease**

Alzheimer’s disease (AD), first identified by Alzheimer (German physician) in 1906 after seeing irregular clumps and twisted packets of protein in the brain of a woman who had memory loss, linguistic problems and abnormal behavior. [81] Alzheimer’s disease characterized by progressive dementia is the most prevalent form of dementia (contributing about 60–70% of cases). [126,127] Dementia is a neuropsychiatric disorder marked by memory regression, gradual behavioral and psychological manifestations and physical impairment. [127] The accumulation of amyloid plaque in the brain and nerve cell degeneration are hallmarks of Alzheimer’s disease. Indications of the disease, such as memory problems and confusion, intensify with age. The prevalence of AD is less than 1%, still affects millions of people Worldwide. [126] Cognitive dysfunction or cognitive alteration, memory loss, behavioral modifications, [84] expression disturbances, sudden changes in mood and behavior all are common clinical characteristics of Alzheimer’s disease. Neurofibrillary tangles, senile plaques, synaptic dysfunction and consequent brain atrophy are the common symptoms of Alzheimer’s disease. [128] Socioeconomic conditions, physical activity level and nutritional factors like caffeine, antioxidants and fatty acids are the primary modifiable risk and preventive factors for Alzheimer’s disease. [126] DHA (abundant in neuron membrane phospholipids) together with EPA helps to combat atherosclerosis, dementia, RA (Rheumatoid Arthritis) and age-related disorders such as Alzheimer’s disease. [71] It is evident from the previous researches that omega-3 fatty acids enriched diet including eggs, onions, poultry, fruits, almonds and green leafy vegetables have been proven to be closely linked to reduced risks of AD (Alzheimer’s disease). [16] Several research studies have looked at the relationship between PUFA consumption (dietary fish) and the likelihood of cognitive loss, dementia, and Alzheimer’s disease. [129] Conversely, elevated DHA levels in the blood can mitigate the risk of Alzheimer’s disease by 47%. Besides this, a rise in DHA and EPA in plasma was associated with a substantial decrease in the expression levels of genes implicated in inflammation and neurodegenerative processes in mononuclear leukocytes of patients with Alzheimer’s disease. [27] Araya-Quintanilla et al. [126] concluded that omega-3 fatty acids intake increases memory function in patients with cognitive dysfunction but not dementia, though not in people with Alzheimer’s disease.

Another study found a correlation between DHA use and a lower risk of dementia and Alzheimer’s disease, but did not discover a linear dose-response relation. When compared mice fed on DHA-enriched diet to mice fed on placebo, image analysis of brain parts from an aged AD mouse model

| Fatty acid          | Experimental types | Improvement against Disorder | Authors                      |
|---------------------|--------------------|------------------------------|------------------------------|
| PUFAs               | In vivo clinical trial | n-3 PUFAs can be decreased the risk of Parkinson disease (PD) | [1781,117]                 |
| n-3 fatty acids (DHA and EPA) | Animal Models, Clinical Trials | n-3 fatty acids may be health benefits in people with epilepsy | [118,119]                 |
| PUFAs               | Clinical Trials    | PUFA levels define two clinically distinct endophenotypes of schizophrenia | [120,121]                 |
| DHA and EPA         | Clinical Trials    | EPA effects on the primary and secondary prevention of stroke | [122]                      |
| PUFAs               | Clinical Trials    | PUFA supplementation can aid an important role in ameliorating autistic behavior. | [123,124]                 |
| DHA                 | Animal Models      | Increased intake of the docosahexaenoic acid (DHA) is concerned with reduced risk of Alzheimer’s disease (AD) | [125]                      |
revealed that total plaque load was decreased by 40.3%. The hippocampus and parietal cortex, which are believed to be involved in Alzheimer’s disease, showed the greatest declines (40–50%). Omega-3 fatty acids (major constituents of neuronal membranes) have a broad range of possible positive effects on neural activity, infection, oxidation, and necrosis; they also help inhibit vascular dementia by having potential benefits on lipids and inflammation, thrombosis, and vascular function. Consumption of EPA and DHA enriched diet has been demonstrated to play a strong anti-inflammatory role in aged rats. A similar finding was found in a survey of Alzheimer’s patients. Inflammatory signals such as cytokines were slightly lower in patients who took an EPA or DHA supplement daily. Omega-3 polyunsaturated fatty acids (n-3 PUFAs) have been shown to protect brain from aging and age-related cognitive loss, with the most consistent benefits against Alzheimer’s disease (AD) occurring in the early or subclinical stages of the disease.

Numerous experimental studies proved a correlation between improved fish intake and reduced risk of AD (Alzheimer’s Disease). Moreover, a study revealed that individuals suffering from Alzheimer’s disease had lesser DHA in their frontal lobe and hippocampus than those who do not. Furthermore, experiments in mice confirmed the defensive role of n-3 LC-PUFA, indicating that dietary DHA intake increased DHA levels in the hippocampus, resulting in improved memory efficiency. Carriers with the ApoE-4 gene are more likely to inherit Alzheimer’s disease later in life. This group also has a lower response to EPA and DHA, and they are less likely to benefit from fish consumption in terms of cognitive performance. In another study, AD patients who received EPA and DHA supplements had higher plasma concentrations of EPA and DHA linked to lower inflammatory factors released from peripheral blood mononuclear cells (IL-1B, IL-6 and granulocyte colony-stimulating factor). Many patients with Alzheimer’s disease may experience unintended weight loss. Meanwhile, DHA and EPA intake has been proved to reduce weight gain in these patients.

**Mild cognitive impairment (MCI)**

Lipids make up most of the brain. Omega-6 and omega-3 fatty acids are the most abundant LC-PUFAs in the brain. DHA influences brain development by affecting neurogenesis, neurotransmission, and synaptic activation. Omega-3 fatty acids help in improving memory and reasoning. Lack of these fatty acids is often thought to be a contributing factor in ADHD (Attention Deficit Hyperactivity Disorder), a neurobehavioral disorder marked by chronic signs of hyperactivity/ impulsivity and inattention that frequently continue through adulthood.

According to animal and human research, omega-3 fatty acids long chain polyunsaturated fatty acids are important for normal brain growth and cognitive performance. The majority of systematic reviews suggest that omega-3 supplementation can help in the early stages of Alzheimer’s disease-related cognitive brain disorder. According to few findings, children suffering from ADHD are lower in n-3 fatty acids. Supplementation of fish oil minimizes hyperactivity and behavioral issues, depression, bipolar disorder, and anxiety, with promising outcomes in adolescents. DHA deficiency is strongly linked to cortical and hippocampal atrophy, suggesting that it may have more neuroprotective properties than EPA. Researchers discovered that these patients’ red blood cell membranes had reduced levels of omega-3 fatty acids, resulting in diminished neurocommunication. Several pathways indicate that omega-3 PUFA supplementation can enhance cognitive capacity in individuals with Alzheimer’s disease. These PUFAs can in particular protect neurons, encourage synaptic plasticity, and reduce cell deaths by antioxidant and anti-inflammatory properties. The PUFA in the diet tends to have an effect on blood cholesterol and may play a part in Alzheimer’s disease pathology. Present data from clinical trials does not however justify the treatment of omega-3 in humans for Alzheimer’s disease. Likewise, supplementing with DHA increased memory in stable young adults whose diet was deficient in DHA. Another study discovered that high fish consumption, but not dietary n-3 LC-PUFA intake had a protective effect against cognitive decline. Another study found that supplementing DHA to people with mild memory problems improved their memory.
**Improve depressive symptoms**

Depression is a severe psychiatric illness that affects many people. According to reports, more than 350 million people are suffering from depression worldwide. In women who experience postpartum depression, however, suffers of n-3 LCPUFAs. The prominent symptoms include depressed mood, lack of interest in pleasant activities, diminished cognitive ability, sleep and weight changes. Observational findings suggest that n-3 LCPUFAs consumption and status are linked to the incidence of postpartum depression. Limited intake of long-chain PUFAs could develop depressive symptoms. As a result, higher dietary n-3 LC-PUFAs intake may be protective against mood swings or even prevent mood dysregulation in the long run. Scientific studies assessed the use of long-chain n-3 fatty acids supplements in managing depression. In animal research, DHA and EPA promoted neuron growth during the developmental phase, but only DHA improves the health of aged rats. DHA appears to be more helpful in the treatment of neuro-inflammatory disorders; while, EPA seems to be far more useful in the treatment of depression. However, the brain absorbs very little EPA and dietary supplements do not dramatically improve it. Researchers investigated that this failure is due to EPA absorption as triacylglycerol, while the blood-brain barrier transporter needs EPA as lysophosphatidylcholine (LPC). In brain, both DHA and EPA can aid in treating depression along with neuro-inflammatory illnesses like Alzheimer’s.

The EPA also plays a vital part in human wellbeing. EPA decreases platelet activation (an early stage in platelet accumulation) and lowers systolic blood pressure, which can help deter coronary heart disease. In a number of rodent models of breast cancer, EPA and DHA have shown to be safe. In mice, fish oil supplementation reduced tumor growth rates and metastasis extent. Supplementing with fish oil, especially those with higher levels of EPA, can help people with depression. Those that are currently on antidepressant drugs continue to benefit the most from them. Because of their importance in neurotransmitter regulation, omega-3 fatty acids have shown better control of psychiatric and behavioral disorders. According to another study, women who consumed more omega-3 fatty acids after birth had a reduced chance of postpartum depression. According to the researchers, overcoming postpartum stress benefits all mothers and their babies: “Children of affected mothers can have trouble attaching to their parents, and postpartum depression may have a negative impact on mental and cognitive development.”

Increased consumption of fish has been related to reduced risk of depression and n-3 fatty acids have been proven to be an important adjunctive therapy for adult depression. Supplementing with omega-3 fatty acids has since been shown in some meta-analyses. Surprisingly, dietary EPA and its positive effects are comparable to dietary DHA in many clinical and preclinical trials. This may be due to its inhibition of peripheral inflammation or its hepatic conversion to DHA, instead of a direct impact on the brain. The lack of dietary EPA has been demonstrated by the fact that, unlike DHA, EPA is quickly oxidized by the brain. Kinetic experiments with labeled fatty acids have shown that EPA produces more water-soluble degradation products in the brain than DHA. Likewise, two recent meta-analyses have found that omega-3 fatty acids have a moderate impact on reducing ADHD symptoms in children. If the effects are extreme, psychotherapy, primarily cognitive-behavioral therapy (CBT) and IPT (Interpersonal psychotherapy), is also prescribed as the first-line care for children and teens with depression.

Overall, heart disease, obesity, cancer, lung disorders, elevated cholesterol, increased BP level, RA (Rheumatoid Arthritis), bipolar disorder, some stomach inflammations (ulcerative colitis) and migraine pain prevention are only a few of the health problems for which DHA in combination with EPA is recommended. Conclusively, n-3 fatty acids supplementation may be helpful in dealing with mood swings, behavioral and other issues as well. Taking marine n-3 supplement regularly might be a cost-effective approach to deal with brain disorders, considering marine n-3 fatty acids (EPA and DHA) as safe. Nevertheless, antidepressants are not used in mildly depressed teenagers due to significant side effects and can only be used following a failed 3-month specific psychiatric treatment in moderate to seriously depressed teenagers.
**Epilepsy**

Epilepsy is a disease of the central nervous system (nervous system). Abnormal brain activity can cause seizures or abnormal behaviors and feelings, and sometimes loss of consciousness. Epilepsy influences 65 million individuals worldwide and addresses a huge weight as far as handicap, mortality, comorbidities, disgrace, and expenses related to epilepsy.[140,141] Epilepsy is a typical sickness that influences the mind and causes regular seizures. A seizure is a blast of electrical movement in the cerebrum that briefly influences its capacity. Epilepsy can begin at whatever stage in life, however, it ordinarily starts in youth or in individuals beyond 60 years old.[142] Manifestations of seizures can shift generally. Certain individuals with epilepsy just gaze vacantly for a couple of moments during the seizure, while others move their arms or legs over and again. A seizure doesn’t mean you have epilepsy.[143,144] Identified with epilepsy, n-3 unsaturated fats diminish neuronal sensitivity. Diminished edginess is profoundly subject to sodium and calcium particle channels, which EPA and DHA can manage. They mentioned a notable observable fact that EPA repressed voltage-gated Na+ current in refined rodent muscle cells, and observed that both EPA and DHA diminished the internal calcium current and delayed the inactivation state.[1340,145] Ye et al.[146] suggested that hindrance of sodium and calcium channels can happen through the juxtaposition of fundamental unsaturated fats neighboring transmembrane sodium and calcium channels. Accepting EPA and DHA are consolidated into the seventh lipid bilayer, the adversely charged carboxyl finishes of EPA and DHA are near the emphatically charged district of the particle channel α subunit.[147] This prompts inactivation and steadiness. In the cerebrum, EPA hinders activity possibilities in the hippocampus of mice, while EPA and DHA diminish the actuation pace of CA1 pyramidal neurons by 40-half.[148] Taha et al.[149] reported that the duration of seizures (prolonged epileptic latency) in fat-1 mice that endogenously synthesized EPA and DHA from arachidonic acid increased by 45%, but did not increase significantly. Trepanier et al.[150] observed that high-portion DHA isn’t so successful as low-portion. This intriguing finding is predictable with late epilepsy clinical preliminaries, demonstrating that low-portion n-3 unsaturated fats might be more successful than high-portion.

**Schizophrenia**

Schizophrenia is a chronic and severe mental disorder that affects a person's thinking, behavior, expression of emotions, perception of reality, and relationships with others. Although schizophrenia is not as common as other major mental illnesses, it can be the most chronic and disabling. Schizophrenia is characterized by a wide range of abnormal behaviors: hearing sounds (hallucinations) and distorted or false perceptions, usually strange beliefs. They cannot distinguish between real and imaginary events. These unusual experiences appear to be real for this person, while others think that this person is lost in their own world.[151,152] Many studies and reviews have shown that omega-3 fatty acids have potential efficacy in the treatment of mental illnesses (including schizophrenia).[153–156] Decreased degrees of omega-3 and omega-6 polyunsaturated unsaturated fats have been found in the minds of patients with schizophrenia. Low degrees of PUFA (LA (omega-6), arachidonic corrosive (omega-6) and DHA (omega-3)) were additionally found in cerebrum tissue later demise and low degrees of PUFA were found in red platelets of schizophrenia brain patients. The reduction mechanism has been hypothesized, but it is not clear whether the consumption is due to less incorporation of polyunsaturated fatty acids or greater decomposition.[157,158] The reduction in PUFA may be due to an increase in phospholipase A2 (the arrival of unsaturated fats from phospholipids) in the plasma, serum and platelets of patients with schizophrenia. Certain creators have accounted for this.[159] The expansion in lipid peroxidation (oxidative debasement) found in patients with schizophrenia is likewise speculated to expand PUFA corruption and digestion.[160] Previous research by,[161] utilizing phosphorous attractive reverberation spectroscopy, found that there are contrasts in phospholipid digestion in patients with schizophrenia, further supporting the possible consumption of omega-6 or omega-3 polyunsaturated fatty acids.
**Stroke**

A stroke occurs when the blood supply to a part of the brain is interrupted or reduced, preventing the brain tissue from receiving oxygen and nutrients. Brain cells begin to die within minutes. An estimated 4.5 million people worldwide die each year from stroke and more than 9 million stroke survivors. Over 45 years old, almost one in four men and almost one in five women may have a stroke by the time they reach 85. Loss of blood flow to the brain damages brain tissues. Stroke symptoms appear in parts of the body that are controlled by damaged areas of the brain. Stroke is the third most normal reason of death after cardiovascular and cancer. Particularly lately, the frequency and mortality from stroke have been expanding fundamentally. Nonetheless, contrasted with cardiovascular infection and cancer, stroke stays a worry. Past examinations have shown that oxidative pressure and inflammation are significant in the movement of mind injury brought about by stroke. Omega-3 polyunsaturated fatty acids (n-3 PUFAs) that is the fundamental part of fish oil. These fatty acids have been played significant role against stroke injury. The dietary supplement n-3 PUFAs can reduce the volume of cerebral infarction in part by regulating the activity of antioxidant enzymes and in part by acting directly as an antioxidant. n-3 PUFAs can act as antioxidants to reduce brain lipid peroxides and regulate oxidative stress by increasing oxidative load and enhancing antioxidant defense capabilities. n-3 PUFAs reduce ischemic injury by activating Nrf2 and increasing HO-1 production. The protection mechanism is related to the positive regulation of HO-1, the activation of Nrf2 and the oxidation of 4-HHE. 4-HHE is the end product of n-3 PUFAs peroxidation and is an effective inducer of Nrf2. Excessive or uncontrolled inflammatory processes can lead to the development of many diseases. The important role of DHA and EPA in the treatment of stroke has been confirmed, in which dissipation proteins with anti-inflammatory effects are formed. The current study showed that higher DHA in serum are negatively correlated with atherosclerotic thrombosis stroke, while higher docosapentaenoic acid (DPA) levels in serum are negatively correlated with cardiogenic stroke. DHA may reduce the risk of atherosclerotic thrombosis and stroke related to cardiac embolism.

**Parkinson’s**

Parkinson’s infection is a typical neurodegenerative sickness. The mix of hereditary and natural variables might be significant in delivering unusual protein inside explicit neuronal gatherings, prompting cell brokenness and later demise. Parkinson’s sickness (PD) is the second most normal neurodegenerative infection and its goal remains generally obscure. Polyunsaturated unsaturated fatty acids (PUFAs) including omega-3 (n-3) and omega-6 (n-6) are two sorts of fundamental unsaturated fats that should be gotten from the eating routine to keep up with ideal wellbeing. n – 3 PUFAS incorporates linolenic acid (LNA; 18: 3 n-3), which is found in vegetable oils, for example, rapeseed oil and docosahexaenoic acid (DHA; 22: 6 n-3) or eicosapentaenoic corrosive (EPA; 20: 5 n-3), which is tracked down primarily in greasy fish. The LNA content in the human cerebrum is irrelevant, while DHA addresses 20% of the complete unsaturated fats in dim matter and is the most bountiful PUFA in the mind. The n-3 polyunsaturated unsaturated fats (PUFAs) found in greasy fish have neuroprotective impacts in PD. Moreover, a high consumption of fish (and n-3 polyunsaturated unsaturated fats) is related to a lower PD hazard. The inquiry remains whether docosahexaenoic acids or eicosapentaenoic acids is the cerebrum’s n-3 polyunsaturated unsaturated fat answerable for the noticed neuroprotective impacts. Regardless of these reassuring information, the improvement of n-3 polyunsaturated unsaturated fats as medications has been hampered by being non-patentable mixtures, basically in their regular structure. Perceptions have shown that higher PUFA admission fundamentally diminishes the danger of PD. Previous examinations have shown that n-3 PUFAs can repress the arrival of favorable to incendiary cytokines, promote the expression of neurotrophic factors, restore mitochondrial function and membrane fluidity, reduce the level of oxidant production, and maintain protein homeostasis, alpha-synuclein, calcium homeostasis, axonal transport, and reducing endoplasmic reticulum stress.
Autism spectrum disorder

Autism spectrum disorder (ASD) is a complex long-lasting neurodevelopmental condition, the reason for which is to a great extent obscure. They are significantly more typical than recently suspected, and in serious formative problems, their occurrence is second just to mental hindrance.[177] Chemical imbalance range problem is a term used to portray various beginning stage social correspondence issues and tedious sensorimotor practices identified with a solid hereditary part and different reasons. Many individuals with mental imbalance range problems have a more brilliant standpoint today than 50 years prior; more individuals with this illness can talk, read, and live locally rather than in organizations, and certain individuals don’t encounter this in adulthood. Side effects of infection are the vast majority and live autonomously. Hereditary qualities and neuroscience have recognized intriguing danger models, yet there are few genuine advantages.[178,179] DHA can be gotten from the eating regimen or orchestrated from alpha-linolenic corrosive (ALA, 18: 3 n-3), which is a sort of n-3 found in pecans, chia seeds, flaxseed, rapeseed, and soybeans. In people, the capacity to change ALA over to DHA is very restricted, under 0.1%,[180] particularly in embryos, making them profoundly subject to the exchange of maternal DHA through the placenta. Docosahexaenoic acid (DHA) is a key n-3 polyunsaturated unsaturated fat that is fundamental for the ideal neurological improvement of posterity in the last trimester of pregnancy. The job of DHA in the neurological improvement of youngsters is to invigorate its part in the avoidance and help of ASD and ADHD. Low DHA supply appears to contrarily influence youngsters’ neurodevelopment under specific conditions and increment the danger and seriousness of ASD or ADHD. Upon entering the world, a higher DHA status is related to better baby neurodevelopment. Giving ideal DHA through the maternal eating regimen or breastfeeding may advance some neuronal assurance in explicit populaces of posterity.[181] Previous examinations have shown that short-time high dosages of DHA (0.86–1% of absolute PUFA) seem to add to ideal neurodevelopment in preterm newborn children,[182,183] predominantly in extremely low birth weight children (VLBW) (<1500 g).[184] Another study suggested that DHA, EPA and ARA, also called long-chain PUFA, manage phospholipid parts, take an interest in membrane fluidity, control the elements of catalysts, particle channels and receptors, and able direct neurotransmission[185,186]

CONCLUSION

It is concluded that omega-3 fatty acids aid in child brain development and assists in performing pharmacological functions. Omega-3 fatty acids can be obtained through plant sources (indirectly) and marine sources. Although the human brain can synthesize DHA from ALA very inefficiently estimated as less than 1% with the help of the enzymatic process in the liver, still converts ALA to EPA and then EPA to DHA in subsequent steps. Children need both of these fatty acids at all stages including pre-birth and after-birth as well. During pregnancy and lactation, the fetus fulfills its requirements by the mother’s diet. It helps fetus in neural and retinal development; but reduces maternal stress and the complications that result in preterm delivery. Omega-fats supplementation improves cognition, memory, behavior, mood and certain brain related disorders. Various studies have proved the effectiveness of omega-3 fatty acids supplementation against Alzheimer’s disease, cognitive impairment epilepsy, schizophrenia, stroke, Parkinson disease and autism spectrum disorders. In the future, further study is required to develop DHA and EPA-based food products to improve children brain health.

Disclosure statement

No potential conflict of interest was reported by the author(s).
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