ORIGINAL RESEARCH PAPER

Nutritional Science

FISH, FISH OIL AND DHA IN BRAIN DEVELOPMENT AND FUNCTION

KEY WORDS: fish oils, DHA, brain, development, adult, better mind, better life

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ABSTRACT

From the early time, fish has been thought to be"brain food" in cultures around the world. Generations of children were raised on a daily spoonful of cod liver oil, because smart parents had a general sense that it was "good for you." Recent research has proved this traditional wisdom. One of the most important components in fish oil from fish is DHA. Today, the scientific community has come to recognize that important compounds contained in fish oils have profound benefits for human brain health, development, and behavior. One of the major building blocks of the brain, the omega-3 fatty acid docosahexaenoic acid (DHA) is critical for brain development function and optimal brain health at all ages of life. Researchers are now finding that DHA provides brain-boosting benefits in infants and aging adults. Better mind gives better life. So the objective of the paper is to review and discuss the effects of DHA on brain development and function with enhancement of performance and reduction of neuro-diseases.

1. INTRODUCTION

From the early time, fish has been thought to be"brain food" in cultures around the world. Generations of children were raised on a daily spoonful of cod liver oil, because smart parents had a general sense that it was "good for you."

Recent research has proved this traditional wisdom[1]. Today, the scientific awareness is there to recognize that important compounds contained in fish oils have profound benefits for human brain health, development, and behavior[2].

Docosahexaenoic acid,22:6n-3 (DHA) and its metabolites are essential for the structure and functional brain. Development of the fetus and infants, and also for maintenance of healthy brain function of adults. So DHA is thought to be a vital required throughout the life span for the maintenance of overall brain health.[3]

However, the astonishing effects of omega-3 fatty acids - docosahexaenoic acid (DHA)—on human brain health and development have only emerged over the past 5-10 years, as research has uncovered powerful evidence that DHA supplementation during pregnancy enhances intelligence, cognition, and visual performance in infants and young children[3]. DHA appears to have beneficial impacts after birth also, boosting children's performance on various intelligence tests. Moreover, DHA is rapidly becoming an important nutrient in managing teen and adult behavioral problems [5].

The consumption of DHA gives many positive physiological and behavioral effects, including those on cognition. Advanced cognitive function is a unique human trait, and the optimal development and aging of cognitive abilities has profound impacts on quality of life, productivity, and advancement of society in general. However, the modern diet typically lacks appreciable amounts of DHA. So in modern populations, maintaining optimal levels of DHA in the brain throughout the lifespan likely requires obtaining preformed DHA via dietary or supplemental sources[6].

It will be challenging to get the appropriate intake of EPA and DHA through diet alone, even though EPA and DHA are produced by water plants such as algae and are prevalent in marine animals. Fish, shellfish and fish oils are the primary sources of Omega-3 fatty acids EPA and DHA.

In this review, we examine the role of DHA supplementation and mental effects during development, adulthood, and aging.

2. Crucial Role in Brain Development

Every mother, besides wanting their child to be healthy, wants their child to be intellectual, too. That's why modern mothers concentrate on "brain nutrition" rather than "regular" nutrition when it comes to the healthy development of their child.

Fatty acids make up the largest component of cell membranes, and the brain has the highest concentration of lipid found in the human body. Because brain cells depend largely on their membrane composition for proper electrical conduction, brain function is intimately connected to the composition of brain cell membranes.

Docosahexaenoic acid (DHA; 22:6*n*-3) is the most significant *n*-3 PUFA in the brain as both eicosapentaenoic acid (EPA; 20:5*n*-3) and α-linolenic acid (ALA; 18:3*n*-3) are present in only very small quantities. DHA makes up over 90% of the *n*-3 PUFAs in the brain and 10%–20% of its total lipids. DHA is found to concentrate especially in the gray matter [7]. It is present primarily in phosphatidylethanolamine (PE) and phosphatidylserine (PS) membrane phospholipids, with smaller amounts also found in phosphatidylcholine (PC), [8], where it plays an important role in the biosynthesis of PS (DHA-PS) in the brain [9]. DHA is rich in membranes structures found at synaptic terminals, mitochondria and endoplasmic reticulum [10], and it can ultimately affect cellular characteristics and physiological processes including membrane fluidity, lipid raft function, neuro transmitter release, transmembrane receptor function, gene expression, signal transduction, myelination, neuro inflammation, and neuronal differentiation and growth [11,12,13].

The brain's frontal lobes are particular responsive to the supply of DHA during development [14]. Decades of work have clearly established the responsibilities of the frontal lobes for executive and higher-order cognitive activities including sustained attention, planning and problem solving[15], and the prefrontal lobe in particular for social, emotional and behavioral development [16]. Therefore, maintaining optimal lipid composition in these brain regions, and specifically DHA levels, is not only important during the development and maturation of the brain from gestation through childhood and adolescence [17,18], but such maintenance is also critical for successful aging of the adult brain [19,20,21].

DHA and arachidonic acid, two fatty acids that are vital for human brain development,[22,23]. are especially critical during the last trimester of pregnancy and the first few months of an infant's life. During this period, the brain has a growth spurt, rapidly increasing in mass and its content of DHA and arachidonic acid. DHA in particular is accumulated in the brain's gray matter (where brain cell bodies are found) and in the retinas of the eyes. A deficiency of DHA in these

tissues is known to produce poor vision and delayed psychomotor development[24,25].

3. DHA Supplementation During Pregnancy

The accumulation of DHA in the brain takes place during the brain growth spurt in the intrauterine and neonatal period up to two years of age and the high levels of DHA in the brain are maintained throughout life [26]. Due to the lack of *de novo* PUFA synthesis, the rate of membrane DHA incorporation in early life—in the brain as well as in other tissues—depends on maternal transfer, dietary supply (*i.e.*, breastfeeding) and endogenous LC-PUFA production. The DHA accumulation in the brain during the third trimester of pregnancy is substantially higher (in % of fatty acids (FA%)) than the overall body deposition rates, whereas brain incorporation of AA is more in line with that which occurs in other tissues [27]. Fetal LC-PUFAs accumulation occurs mainly during the last trimester, in which weight increase becomes more rapid and growth is accompanied by a deposition of fat tissue, which begins around the 30th week of gestation [28]. Fetal fat tissues contain relatively low levels of DHA and AA [29,30] compared to the large relative amounts of LC-PUFAs that are deposited in the brain [31].

Numerous human studies have been conducted in response to evidence that fetuses may not get adequate DHA in the critical third trimester. These studies demonstrate that mothers who take DHA supplements have fewer preterm deliveries and give birth to larger, healthier infants who perform better on intelligence and visual acuity tests to the age of at least four years[32].

Supplementation with DHA increased the duration of pregnancy by almost one week among a group of women at high risk for preterm delivery[33]. Also observed was a trend towards higher birth weight, length, and head circumference in infants born to the DHA-supplemented mothers. Specific evidence of DHA's impact on newborn brain function comes from a 2002 study, which demonstrated greater maturity of the central nervous system (as measured by sleep patterns) in infants born to mothers with higher plasma DHA levels[34].

Mothers who are supplemented with cod liver oil containing high DHA concentrations gave birth to infants with significantly higher levels of DHA in their cell membranes,[35] and newborns who had the highest DHA concentrations were longer at birth. Newborns who had more "mature" brain-wave testing patterns at birth also showed higher DHA levels.

Even more dramatic effects of DHA supplementation during pregnancy are now emerging, with evidence that DHA directly influences cognition and intelligence.

4. DHA Supplementation After Delivery

The significance of adequate DHA intake for women does nottsop after the birth of a healthy baby. DHA continues to pile up in the brains of infants and young children upto the end of second year of life;[36] however, human infants have a limited ability to synthesize DHA, making them dependent on dietary sources such as breast milk, formula, or DHA supplements[37].

It has long been known that breast-feeding is superior to formula-feeding for many reasons, not the least of which is that breast-fed infants have higher IQs and more advanced cognition than do bottle-fed babies[38,39] . EPA and DHA supplementation during pregnancy has been associated with longer gestation and increased concentrations of EPA and DHA in fetal tissues[40].

The milk-producing apparatus in the human breast routinely extracts DHA and other brain-nourishing fatty acids from the mother's blood in preference to other fats, delivering the highest possible amounts to the breast-fed infant. Again, this effect can occur at the expense of the mother's own DHA supplies if steady intake is not assured. The DHA content of the maternal diet is the most important factor determining how much DHA is found in breast milk. There are expert opinion that the consumption of otherwise healthy low-fat diets by women of reproductive age could reduce the amount of DHA available to them during pregnancy and lactation.[41].

Breast-milk content and fat composition reflect maternal plasma lipid profiles depend on maternal diet and supplementation[42]. Even the known low levels of DHA in most women's diets, this observation strongly suggests that DHA supplementation in nursing mothers is critical to optimizing brain development in their infants.

DHA supplementation of nursing mothers raise up the DHA level in their milk and in infant red blood cells, which is associated with enhanced visual acuity at four months, and early language development in breast-fed infants[43]. High maternal DHA intake is also associated with improved long-term growth in breast-fed children[44].

A direct relationship between breast milk DHA content and childhood IQ was revealed in 2004. Analysis of breast milk was done for fatty acid composition at one and three months of age, and children's IQ scores were measured at 6.5 years of age. Longer duration of breast-feeding and higher ratios of DHA to arachidonic acid (a precursor to DHA) were associated with higher total IQ scores in these school-aged children.

The beneficial effects of early DHA consumption last well beyond the period of supplementation. A 1998 study demonstrated that infant performance on a problem-solving test (related to later IQ scores) at 10 months was superior in a group of infants who had received DHA-supplemented formulas from birth to four months[45]. These results again demonstrate the importance of early DHA supplementation for long-term brain development and function.

Adding DHA to infant formula produces dramatic results. A 1995 study measured developmental quotient (an early surrogate measure of IQ) at four months of age in a group of infants who received normal (unsupplemented) formula, DHA-supplemented formula, or breast milk. The developmental quotient of the DHA-supplemented and breast-fed infants was significantly higher than that of infants who were fed the unsupplemented formula[46]. Plasma, red blood cell, and brain lipid levels of DHA are lower in infants whose diets do not contain DHA. In infants who are fed DHA-supplemented formulas, positive results was demonstrated in visual acuity at two and four months of age, and in neurodevelopmental status at 12-18 months of age[47]. Companies that manufacture infant formula are now trying to catch up with breast milk by adding DHA to their products[48]. DHA supplementation enhanced visual acuity and must go on beyond six weeks of age to have maximum benefit[49].

5. DHA's impact on Behavior After Infancy

DHA's importance in prenatal and infant brain development—and its impact on IQ, other measures of cognition, and vision—are no longer in question. Psychologists are now discovering that DHA supplementation in older children, teens, and even adults can have powerful and beneficial effects on behavior, mood, and learning.

In a randomized, controlled experiment, DHA supplementation was done to show the prevention of increased age-related aggression among girls aged 9-12, and to reduce perceived stress among high-stress adults[50]. As its benefits become more evident, fish oil supplementation is becoming increasingly routine in many adolescent behavioral care facilities. In communication with Life Extension, Tiesha D.

Johnson, RN, BSN, a staff nurse at a large psychiatric and behavioral center for children and adolescents in western New York, noted that fish oil is prescribed regularly to children with impulse-control and attention disorders.

Attention deficit hyperactivity disorder (ADHD) in children may be related to deficiencies or excessive breakdown of DHA and related lipids[51]. Adults with ADHD symptoms have lower blood DHA levels than do healthy controls[52]. Low plasma DHA levels have also been associated with other neuro-psychiatric conditions, including Alzheimer's disease, schizophrenia, and depression, and studies of DHA supplementation show that DHA holds promise in improving these conditions [53].

The body of the child cannot produce adequate DHA:
As the body doesn't produce enough DHA to satisfy the increasing demand they need to get it through the food.

Before the child turn 5 his/her brain will grow up to 90% of its adult size:
The first five years of a child's life are very crucial. Most of the important milestones belong here. Therefore, it is very important to make sure your child gets the right amount of DHA during these year taking at the rate of 100-150 mg of DHA every day[53].

6. DHA Supplements for Better Adult Mental Health
There's abundant evidence that taking a DHA supplement can make you a happier, smarter adult.The human brain becomes smaller in size with age, but DHA helps to preserve brain volume. People low in DHA have smaller brains that age faster than those with normal levels. 80% of the world's population has a subpar in omega-3s. DHA increases brain-derived neurotrophic factor (BDNF). BDNF is a protein that keeps existing brain cells healthy and stimulates new brain cell formation.DHA also increases brain plasticity. Neuro plasticity is the brain's capacity to form new brain cells and neural connections and improve its capabilities throughout life[55].

7. DHA Deficiency Impairs Cognitive and Mental Health
DHA deficiency impairs many cognitive functions such as memory, problem solving, the ability to multitask, and thinking capabilities. Low DHA levels have relation to depression, ADHD, anger, and hostility. Serious psychiatric disorders such as major depressive disorder, suicidal behavior, bipolar disorder, and schizophrenia have also been linked to DHA deficiency.

Those with low levels of DHA are 62% more likely to commit suicide. But omega-3 acids and DHA supplementation were found to improve anxiety and depression scores and reduce suicidal thinking by 45%. Sufficient levels of DHA can promote memory and learning and protect against age-related mental decline in healthy older adults. A reduced level of DHA is associated with **cognitive decline** during ageing[55].

Any supplement to help stay mentally sharp during aging, it should be DHA. Better mind means better life.

8. CONCLUSION
DHA's stunning success in enhancing brain development and childhood IQ will continue to be a topic of intense study for decades. Fish oil really is "brain food," and thanks to the availability of toxin-free DHA supplements, expectant mothers can provide its benefits to their future offspring with great confidence. Moreover, a veritable ocean of research confirms that fish oil offers profound benefits for mental health and well-being throughout infancy and adolescence, and all the way through adulthood and aging.

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REFERENCES

1. Linday LA, Dolitsky JN, Shindledecker RD, Pippenger CE. Lemon-flavored cod liver oil and a multivitamin-mineral supplement for the secondary prevention of otitis media in young children: pilot research. Ann Otol Rhinol Laryngol. 2002 Jul;111(7 Pt 1):642-52.
2. Lovegrove JA, Brooks CN, Murphy MC, Gould BJ, Williams CM. Use of manufactured foods enriched with fish oils as a means of increasing long-chain n-3 polyunsaturated fatty acid intake. Br J Nutr. 1997 Aug;78(2):223-36.
3. Mallick R, Basak S, Duttaroy AK. Docosahexaenoic acid,22:6n-3: Its roles in the structure and function of the brain. Int J Dev Neurosci. 2019 Dec;79:21-31. doi: 10.1016/j.ijdevneu.2019.10.004. Epub 2019 Oct 17. PMID: 31629800.
4. Agostoni C, Trojan S, Bellu R, Riva E, Giovannini M. Neurodevelopmental quotient of healthy term infants at 4 months and feeding practice: the role of long-chain polyunsaturated fatty acids. Pediatr Res. 1995 Aug;38(2):262-6.
5. Richardson AJ, Montgomery P. The Oxford-Durham study: a randomized, controlled trial of dietary supplementation with fatty acids in children with developmental coordination disorder. Pediatrics. 2005 May;115(5):1360-6.
6. Weiser MJ, Butt CM, Mohajeri MH. Docosahexaenoic Acid and Cognition throughout the Lifespan. Nutrients. 2016 Feb 17;8(2):99. doi: 10.3390/nu8020099. PMID: 26901223; PMCID: PMC4772061.
7. Brenna J.T., Diau G.Y. The influence of dietary docosahexaenoic acid and arachidonic acid on central nervous system polyunsaturated fatty acid composition. Prostaglandins Leukot. Essent. Fat. Acids. 2007;77:247–250. doi: 10.1016/j.plefa.2007.10.016.
8. Rapoport S.I. *In vivo* fatty acid incorporation into brain phospholipids in relation to signal transduction and membrane remodeling. Neurochem. Res. 1999;24:1403–1415. doi: 10.1023/A:1022584707352.]
9. Garcia M.C., Ward G., Ma Y.C., Salem N., Jr., Kim H.Y. Effect of docosahexaenoic acid on the synthesis of phosphatidylserine in rat brain in microsomes and C6 glioma cells. J. Neurochem. 1998;70:24–30. doi: 10.1046/j.1471-4159.1998.70010024.x.
10. Suzuki H., Manabe S., Wada O., Crawford M.A. Rapid incorporation of docosahexaenoic acid from dietary sources into brain microsomal, synaptosomal and mitochondrial membranes in adult mice. Int. J. Vitam. Nutr. Res. 1997;67:272–278.]
11. Uauy R., Dangour A.D. Nutrition in brain development and aging: Role of essential fatty acids. Nutr. Rev. 2006;64:S24–S33. doi: 10. 1301/nr.2006.may.S24-S33.
12. Haubner L., Sullivan J., Ashmeade T., Saste M., Wiener D., Carver J. The effects of maternal dietary docosahexaenoic acid intake on rat pup myelin and the auditory startle response. Dev. Neurosci. 2007;29:460–467. doi: 10.1159/000107047.
13. Orr S.K., Bazinet R.P. The emerging role of docosahexaenoic acid in neuroinflammation. Curr. Opin. Investig. Drugs. 2008;9:735–743.
14. Goustard-Langelier B., Guesnet P., Durand G., Antoine J.M., Alessandri J.M. *n*-3 and *n*-6 fatty acid enrichment by dietary fish oil and phospholipid sources in brain cortical areas and nonneural tissues of formula-fed piglets. Lipids. 1999;34:5–16. doi: 10.1007/s11745-999-331-6.
15. Anderson V., Fenwick T., Manly T., Robertson I. Attentional skills following traumatic brain injury in childhood: A componential analysis. Brain Inj. 1998;12:937–949. doi: 10.1080/026990598121990.]
16. Barkley R.A. The executive functions and self-regulation: An evolutionary neuropsychological perspective. Neuropsychol. Rev. 2001;11:1–29. doi: 10.1023/A:1009085417776.
17. Kuratko C.N., Barrett E.C., Nelson E.B., Salem N. The relationship of docosahexaenoic acid (DHA) with learning and behavior in healthy children: A review. Nutrients. 2013;5:2777–2810. doi: 10.3390/nu5072777.
18. Stonehouse W. Does consumption of LC omega-3 PUFA enhance cognitive performance in healthy school-aged children and throughout adulthood? Evidence from clinical trials. Nutrients. 2014;6:2730–2758. doi: 10.3390/nu6072730.
19. Cederholm T., Salem N., Jr., Palmblad J. Omega-3 fatty acids in the prevention of cognitive decline in humans. Adv. Nutr. 2013;4:672–676. doi: 10.3945/an.113.004556.
20. Joffre C., Nadjar A., Lebbadi M., Calon F., Laye S. *n*-3 LCPUFA improves cognition: The young, the old and the sick. Prostaglandins Leukot. Essent. Fat. Acids. 2014;91:1–20. doi: 10.1016/j.plefa.2014.05.001.
21. Salem N., Vandal M., Calon F. The benefit of docosahexaenoic acid for the adult brain in aging and dementia. Prostaglandins Leukot. Essent. Fat. Acids. 2015;92:15–22. doi: 10.1016/j.plefa.2014.10.003.
22. Cetin I., Alvino G., Cardellicchio M. Long chain fatty acids and dietary fats in fetal nutrition. J. Physiol. 2009;587:3441–3451. doi: 10.1113/ jphysiol.2009.173062.
23. Haggarty P. Effect of placental function on fatty acid requirements during pregnancy. Eur. J. Clin. Nutr. 2004;58:1559–1570. doi: 10.1038/sj.ejcn.1602016.
24. Kuipers R.S., Luxwolda M.F., Offringa P.J., Boersma E.R., Dijck-Brouwer D.A.J., Muskiet F.A.J. Fetal intrauterine whole body linoleic, arachidonic and docosahexaenoic acid contents and accretion rates. Prostaglandins Leukot. Essent. Fat. Acids. 2012;86:13–20. doi: 10.1016/j.plefa.2011.10.012.
25. Kuipers R.S., Luxwolda M.F., Offringa P.J., Boersma E.R., Dijck-Brouwer D.A.J., Muskiet F.A.J. Gestational age dependent changes of the fetal brain, liver and adipose tissue fatty acid compositions in a population with high fish intakes. Prostaglandins Leukot. Essent. Fat. Acids. 2012;86:189–199. doi: 10.1016/j.plefa.2012.02.007.
26. Carver J.D., Benford V.J., Han B., Cantor A.B. The relationship between age and the fatty acid composition of cerebral cortex and erythrocytes in human subjects. Brain Res. Bull. 2001;56:79–85. doi: 10.1016/S0361-9230(01)00551-2.
27. Cetin I., Alvino G., Cardellicchio M. Long chain fatty acids and dietary fats in fetal nutrition. J. Physiol. 2009;587:3441–3451. doi: 10.1113/ jphysiol.2009.173062.
28. Haggarty P. Effect of placental function on fatty acid requirements during pregnancy. Eur. J. Clin. Nutr. 2004;58:1559–1570. doi: 10.1038/sj.ejcn.1602016.
29. Kuipers R.S., Luxwolda M.F., Offringa P.J., Boersma E.R., Dijck-Brouwer D.A.J., Muskiet F.A.J. Fetal intrauterine whole body linoleic, arachidonic and docosahexaenoic acid contents and accretion rates. Prostaglandins Leukot. Essent.Fat.Acids.2012;86:13–20. doi: 10.1016/j.plefa.2011.10.012.

30. Kuipers R.S., Luxwolda M.F., Offringa P.J., Boersma E.R., Dijck-Brouwer D.A.J., Muskiet F.A.J. Gestational age dependent changes of the fetal brain, liver and adipose tissue fatty acid compositions in a population with high fish intakes. Prostaglandins Leukot. Essent. Fat. Acids. 2012;86:189–199. doi: 10.1016/j.plefa.2012.02.007.
31. Clandinin M.T., Chappell J.E., Leong S., Heim T., Swyer P.R., Chance G.W. Intrauterine fatty acid accretion rates in human brain: Implications for fatty acid requirements. Early Hum. Dev. 1980;4:121–129. doi: 10.1016/0378-3782(80)90015-8.
32. Decsi T, Koletzko B. N-3 fatty acids and pregnancy outcomes. Curr Opin Clin Nutr Metab Care. 2005 Mar;8(2):161-6.
33. Smuts CM, Huang M, Mundy D, et al. A randomized trial of docosahexaenoic acid supplementation during the third trimester of pregnancy. Obstet Gynecol. 2003 Mar;101(3):469-79.
34. Cheruku SR, Montgomery-Downs HE, Farkas SL, Thoman EB, Lammi-Keefe CJ. Higher maternal plasma docosahexaenoic acid during pregnancy is associated with more mature neonatal sleep-state patterning. Am J Clin Nutr. 2002 Sep;76(3):608-13.
35. Helland IB, Saugstad OD, Smith L, et al. Similar effects on infants of n-3 and n-6 fatty acids supplementation to pregnant and lactating women. Pediatrics. 2001 Nov;108(5):E82.
36. Lauritzen L, Jorgensen MH, Olsen SF, Straarup EM, Michaelsen KF. Maternal fish oil supplementation in lactation: effect on developmental outcome in breast-fed infants. Reprod Nutr Dev. 2005 Sep;45(5):535-47.
37. Willatts P, Forsyth JS, DiModugno MK, Varma S, Colvin M. Effect of long-chain polyunsaturated fatty acids in infant formula on problem solving at 10 months of age. Lancet. 1998 Aug 29;352(9129):688-91.
38. Gustafsson PA, Duchen K, Birberg U, Karlsson T. Breastfeeding, very long polyunsaturated fatty acids (PUFA) and IQ at 6 1/2 years of age. Acta Paediatr. 2004 Oct;93(10):1280-7.
39. Auestad N, Scott DT, Janowsky JS, et al. Visual, cognitive, and language assessments at 39 months: a follow-up study of children fed formulas containing long-chain polyunsaturated fatty acids to 1 year of age. Pediatrics. 2003 Sep;112(3 Pt 1):e177-83.
40. Cohen JT, Bellinger DC, Connor WE, Shaywitz BA. A quantitative analysis of prenatal intake of n-3 polyunsaturated fatty acids and cognitive development. Am J Prev Med. 2005 Nov;29(4):366-74.
41. Innis SM. Polyunsaturated fatty acids in human milk: an essential role in infant development. Adv Exp Med Biol. 2004;554:27-43.
42. Heird WC. The role of polyunsaturated fatty acids in term and preterm infants and breastfeeding mothers. Pediatr Clin North Am. 2001 Feb;48(1):173-88.
43. Lauritzen L, Jorgensen MH, Olsen SF, Straarup EM, Michaelsen KF. Maternal fish oil supplementation in lactation: effect on developmental outcome in breast-fed infants. Reprod Nutr Dev. 2005 Sep;45(5):535-47.
44. Lauritzen L, Hoppe C, Straarup EM, Michaelsen KF. Maternal fish oil supplementation in lactation and growth during the first 2.5 years of life. Pediatr Res. 2005 Aug;58(2):235-42.
45. Willatts P, Forsyth JS, DiModugno MK, Varma S, Colvin M. Effect of long-chain polyunsaturated fatty acids in infant formula on problem solving at 10 months of age. Lancet. 1998 Aug 29;352(9129):688-91
46. Agostoni C, Trojan S, Bellu R, Riva E, Giovannini M. Neurodevelopmental quotient of healthy term infants at 4 months and feeding practice: the role of long-chain polyunsaturated fatty acids. Pediatr Res. 1995 Aug;38(2):262-6.
47. Heird WC. The role of polyunsaturated fatty acids in term and preterm infants and breastfeeding mothers. Pediatr Clin North Am. 2001 Feb;48(1):173-88
48. Heird WC, Lapillonne A. The role of essential fatty acids in development. Annu Rev Nutr. 2005;25:549-71.
49. Birch EE, Hoffman DR, Castaneda YS, et al. A randomized controlled trial of long-chain polyunsaturated fatty acid supplementation of formula in term infants after weaning at 6 wk of age. Am J Clin Nutr. 2002 Mar;75(3):570-80.
50. Itomura M, Hamazaki K, Sawazaki S, et al. The effect of fish oil on physical aggression in schoolchildren—a randomized, double-blind, placebo-controlled trial. J Nutr Biochem. 2005 Mar;16(3):163-71.
51. Ross BM, McKenzie I, Glen I, Bennett CP. Increased levels of ethane, a non-invasive marker of n-3 fatty acid oxidation, in breath of children with attention deficit hyperactivity disorder. Nutr Neurosci. 2003 Oct;6(5):277-81.
52. Young GS, Maharaj NJ, Conquer JA. Blood phospholipid fatty acid analysis of adults with and without attention deficit/hyperactivity disorder. Lipids. 2004 Feb;39(2):117-23.
53. Swanson D, Block R, Mousa SA. Omega-3 fatty acids EPA and DHA: health benefits throughout life. Adv Nutr. 2012 Jan;3(1):1-7. doi: 10.3945/an.111.000893. Epub 2012 Jan 5. PMID: 22332096; PMCID: PMC3262608.
54. Being the parent, Role of DHA in Child's Brain Development – Enfagrow A+. Avail: https://www.beingtheparent.com/role-of-dha-in-childs-brain-development-enfagrow-a/
55. Be BRAIN FIT. DHA supplements: why they're critical for your brain Avail: https://bebrainfit.com/dha-supplements-brain/ Accessed:-18-09-2022