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REPORT

DHA and the Developing Brain

By Julius G. Goepp, MD

For centuries, fish has been considered “brain food” in cultures around the world. Generations of children were raised on a daily spoonful of cod liver oil, because their parents had a general sense that it was “good for you.”[1]

Recent medical research has borne out this traditional wisdom. 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.[2]

The heart-healthy benefits of omega-3 fatty acids in fish oils have been recognized for more than a decade. More recently, these compounds were found to benefit the vascular endothelium, reducing the risk of stroke and other circulatory conditions.

However, the astonishing effects of omega-3 fatty acids—especially docosahexaenoic acid (DHA)—on human brain health and development have only emerged over the past 5-10 years, as scientists have 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 effects after birth as well, boosting children’s performance on various intelligence tests.[4] Moreover, DHA is also rapidly becoming an important tool in managing teen and adult behavioral problems.[5]

This article surveys exciting findings from the recent scientific literature that strongly support the brain-health benefits of DHA supplementation throughout the human life span.

CRITICAL ROLE IN BRAIN DEVELOPMENT

Fatty acids make up the largest component of cell membranes, and the brain has the highest concentration of cells 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.

DHA and arachidonic acid, two fatty acids that are vital for human brain development,[6,7] are especially critical during the last trimester of pregnancy and the first few months of an infant’s life. During this period, the brain undergoes 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.[8,9]

The developing fetus depends entirely on its mother’s DHA intake for its own supply of this vital brain nutrient. DHA is transferred across the placenta by special transport mechanisms that remove DHA from the mother’s blood at levels higher than for other fatty acids.[9] As with most ingested nutrients during pregnancy, the needs of the fetus get top priority and the mother’s body can be rapidly depleted of essential components if adequate intake is not assured. If the mother’s intake is borderline or low, fetal DHA levels will drop.[9]

During the third trimester, the fetus is estimated to accumulate 67 mg per day of DHA. Current recommendations for DHA intake in pregnant women call for 300 mg or more per day, according to the International Society for the Study of Fatty Acids and Lipids.[7] In two recent studies of pregnant women in Canada, average daily DHA intake was only 82-160 mg, and 90% of the women consumed less than the recommended minimum of 300 mg. The low end of the DHA intake range was 24 mg per day.[7,10] While mothers’ DHA intake varies around the world, these figures suggest that many women are consuming quantities of DHA that are borderline or inadequate for ensuring optimal brain development in their growing fetuses.

DHA SUPPLEMENTATION DURING PREGNANCY

Since the mid-1980s, animal studies have demonstrated DHA’s critical role in brain development during both the prenatal and

postnatal periods, with deficiency states associated with deficits in brain development, vision, and hearing.[11-15]

Studies of rhesus monkeys have shown that both prenatal and postnatal DHA deficiencies caused reduced visual acuity and abnormal retinal function.[16] The same investigations have now shown that, even with postnatal DHA supplementation, retinal DHA levels remained low at three years of life, and levels of retinal electrical activity were below normal. The study authors concluded that prenatal DHA deficiency could have long-term effects on the retina that cannot be reversed by supplementing the infant's feeding. Prenatal DHA supplements in female rats were shown to protect against experimentally induced brain damage in their infant offspring.[17] Such studies emphasize the importance of including DHA in prenatal nutritional supplements.

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.[3]

Supplementation with DHA increased the duration of pregnancy by almost one week among a group of women at high risk for preterm delivery.[18] 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.[19]

Mothers who supplemented with cod liver oil containing high DHA concentrations gave birth to infants with significantly higher levels of DHA in their cell membranes,[20] and newborns who had the highest DHA concentrations were longer at birth. Newborns who had more "mature" brain-wave testing patterns at birth also had higher DHA levels.

Even more dramatic effects of DHA supplementation during pregnancy are now emerging, with evidence that DHA directly influences cognition and intelligence. In a randomized, controlled, double-blind study,[6] women at 18 weeks of pregnancy were given cod liver oil (containing 1183 mg of DHA) or corn oil (placebo) until three months after delivery. All infants in the study were breast-fed until at least three months of age. Children whose mothers received the cod liver oil supplement scored significantly higher on intelligence tests at four years of age than those whose mothers received corn oil. A more complex statistical analysis showed that maternal DHA intake during pregnancy was the only significant variable associated with the mental processing score at four years of age.

In its summary of DHA's benefits for infant brain development and cognition, an expert panel convened by the Harvard Center for Risk Analysis reached the powerful conclusion that for each increase in maternal DHA intake of 100 mg per day, child IQ (intelligence quotient, a measure of cognitive abilities) increases by 0.13 points.[21] This would translate into a nearly 6-point increase in IQ among children of women who supplement with the 4.5 grams of DHA daily that has been used in some trials.[22]

Like the brain, the eye's retina consists almost entirely of nerve cells with very high levels of activity, as well as high levels of DHA in its cell membranes.[10] While it is impossible to directly measure vision in newborns, the retina's electrical activity can be measured by means of the visual evoked potential, which matures rapidly in the immediate postnatal period. Infants with higher levels of DHA have more mature patterns of visual evoked potential in the 10-16 weeks following birth.[23] Retinal sensitivity to light is also higher in infants with higher DHA levels.[24]

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DHA SUPPLEMENTATION AFTER DELIVERY

The importance of adequate DHA intake for women does not end with the birth of a healthy baby. DHA continues to accumulate in the brains of infants and young children through at least the second year of life;[25] however, human infants may have a limited ability to synthesize DHA, making them dependent on dietary sources such as breast milk, formula, or DHA supplements.[26]

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.[27,28] It is now becoming clear that one of the reasons for this difference may be that breast milk normally contains DHA; until recently, formula has not contained DHA.

Like the placenta, 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. Some experts have raised concerns 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.[8]

Breast-milk content and fat composition reflect maternal plasma lipid profiles, which themselves depend on maternal diet and supplementation.[29] Given 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 increases the DHA content in their milk and in infant red blood cells,[20] which is associated with enhanced visual acuity at four months[30,31] and early language development in breast-fed infants.[25] High maternal DHA intake is also associated with improved long-term growth in breast-fed children.[22]

A direct relationship between breast milk DHA content and childhood IQ was demonstrated in 2004.[27] Breast milk was analyzed 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.[26] 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.[4] 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, clear advantages have been demonstrated in visual acuity at two and four months of age, and in neurodevelopmental status at 12-18 months of age.[29] Companies that manufacture infant formula are now rushing to catch up with breast milk by adding DHA to their products.[32]

A randomized clinical trial in 2000 demonstrated a mean increase of seven points on the Mental Development Index of the Bayley Scale of Infant Development in infants who received DHA-supplemented formula for the first 17 weeks of life.[33] These infants showed superior performance on both the cognitive and motor sub-scales of the Mental Development Index. The same investigators later showed that DHA supplementation enhanced visual acuity (as measured by visual evoked potential) and must be continued beyond six weeks of age to have maximum benefit.[34]

DHA'S EFFECTS 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. However, behavioral scientists 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 animal studies, deprivation of omega-3 fatty acids such as DHA increases depression and aggression.[36] Scientists have recently hypothesized that decreased consumption of omega-3 fatty acids could be a risk factor for human depression and suicide, and some evidence from human volunteer studies suggests that increased intake of these fats can reduce impulsive and aggressive behavior.[37] These findings make biochemical sense because DHA is important in mitigating the human stress response through its role in regulating stress mediators such as catecholamines (epinephrine and norepinephrine) and pro-inflammatory cytokines.[38]

In randomized, controlled trials, DHA supplementation was recently shown to prevent increased age-related aggression among girls aged 9-12,[39] and to reduce perceived stress among high-stress adults.[38] 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.[40] Adults with ADHD symptoms have lower blood DHA levels than do healthy controls.[41] 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.[42]

WHAT ABOUT MERCURY?

Excitement about the health benefits of omega-3 fatty acids such as DHA has been somewhat tempered by growing concern about mercury contamination in fish that contain high levels of these nutrients. Conflicting reports have left many consumers confused.

A recent analysis concluded that the health benefits of fish consumption for older adults at risk for heart and circulatory diseases outweigh the risk.[35] However, because of the negative impact of even small amounts of mercury on children's IQ and development, the same study recommended that pregnant and nursing mothers, as well as mothers of school-aged children, select other sources of DHA, such as certified mercury-free DHA supplements.

Early studies of DHA supplementation in children with ADHD produced conflicting results, though all found DHA to be safe and well tolerated.[43,44] In 2005, however, Alex Richardson and his colleagues at Oxford University demonstrated the success of DHA supplementation in a group of schoolchildren with developmental coordination disorder.[5] This condition affects up to 5% of school-aged children and is closely related to other common disorders such as dyslexia and ADHD. In Richardson's randomized, controlled trial of 117 children aged 5-12, supplementation with omega-3 fatty acids produced significant improvements in reading, spelling, and behavior.

Omega-3 fatty acid status has a powerful influence on a host of other adult behavioral and psychiatric conditions. A recent study demonstrated that cocaine addicts with higher baseline DHA levels were less likely to relapse than were those with lower levels.[45] Adult women with borderline personality disorder who received omega-3 fatty acid supplements had diminished aggression and less severe depressive symptoms than controls.[46] Finally, elderly adult white-collar workers who received DHA supplements experienced significantly decreased aggression compared to subjects who received placebo.[47]

CONCLUSION

DHA's stunning success in enhancing brain development and childhood IQ is likely 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.

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