Introduction

Breastfeeding is the natural next step in the continuum of pregnancy. For a period of nine months during pregnancy, a mother's body prepares a very special blend of nutrients in the exact proportions the baby needs. Breast milk is the most complete food one can offer her infant, with just the right levels and quality of nutrients to suit the child's first food needs. It is a unique combination of fats, sugars, minerals, proteins, vitamins and enzymes, custom made to promote brain and body growth. (1) The well known advantage of breastfeeding has always been the passive transfer of maternal antibodies and other immune factors via breast milk which help to compensate for the newborn's immature immune system and give immunity to many serious bacterial and viral pathogens. However, over the past two decades, the essential fatty acid requirement of the infant for brain development has received increasing attention. Current research has started to focus more on the long term benefits of breastfeeding because of human milk's unique fatty acid composition that is not found in any of the formulas. This paper will concentrate on what these unique "fatty acids" are, how they endorse their long-term influences on infants and what those influences are.

Fatty acid composition of breast milk

In a study where the total lipid, fatty acid, sterol and carbohydrate contents of 10 currently available types of infant formulas were compared with those of 24 h milk samples collected from women on postnatal days, considerable differences were found in the composition of fatty acids, sterols and minor carbohydrates. The key compounds, however, that were only found in maternal milk were the long chain polyunsaturated fatty acids (LC PUFAs), in particular arachidonic acid (AA; 20:4w6) and docosahexaenoic acid (DHA; 22:6w3). (2) LC PUFAs are the structural components of cellular membranes and the precursors of thromboxnes, prostaglandins and leukorienes. They are found in relatively high contents in the brain, the retina, and other nervous tissue. Healthy brains are about 60% structural fat. Of this, about 25% is DHA and 15% is AA. In the retina, DHA makes up about 60% of the outer segments of the rods in the retina. (3) Antenatally, during a time of rapid neural multiplication and development, the fetus is enriched with LC PUFAs, in particular AA and DHA, from maternal stores via the placenta. Interestingly, the cord blood concentrations of AA and DHA at delivery correlate with birth weight, head circumference and duration of gestation. In formula fed infants, the concentrations of AA and DHA in red blood cell membranes and plasma phospholipids fall below those sustained by breast milk despite the presence of a diffident amount of precursors. This means that infants are incapable of synthesizing these essential compounds, hence they need to get them in their diets. (4) It is because of this reduced capacity of infants to synthesize AA and DHA from their respective precursors that they are considered to be essential in an infant's nutrition. This creates a problem for those infants who are formula fed since formulas do not contain these essential fatty acids.

Effects of LC PUFAs on child development and visual function

Indeed, AA and DHA are only found in maternal milk and yet research finds these fatty acids to be essential in the nutrition of infants since they are not capable of synthesizing these compounds on their own. So what impact does the absence of these fatty acids have on infants who are formula fed, thus missing these compounds in their diets. The effects, in fact, seem to be numerous including but not limited to visual acuity, child development and growth. A randomized clinical study by Carlson et al (5) showed that pre-term infants have a more rapid development of visual acuity if fed human milk or a formula supplemented with DHA compared to a standard formula devoid of LC PUFA. These results were later confirmed by other research groups, further strengthening the evidence for the correlation between breastfeeding and visual acuity in pre-term infants. These studies also provided further evidence for the findings that pre-term infants are incapable to meet their DHA needs by endogenous synthesis, hence making breastfeeding even a greater necessity for this group. Interestingly enough, the same type of studies performed on full-term infants are somewhat controversial. For example, in a study conducted by Innis et al (6), 17 breast-fed and 18 formula-fed healthy, full-term newborns were investigated. The formula contained 18% LA and 2% ALA, which are the precursors for AA and DHA, but it did not contain any AA or DHA directly. When the preferential acuity was determined at 14 days and 3 months of age, the two groups developed similar visual acuity, indicating that visual acuity in term infants was not related to dietary intake of DHA and AA. Interestingly enough, a similar type of a study conducted by Jorgensen et al (7) two year later showed the contrary. Here, the visual acuity and fatty acid composition in RBC for the first 4 months of life in 17 breast-fed and 16 formula-fed full-term infants were followed. Their results showed that breast-fed infants developed visual acuity more rapidly compared to formula-fed infants. This was further paralleled by a decrease in DHA of RBC in formula-fed infants compared to breast-fed infants, hence indicating a correlation between DHA levels and visual acuity. These two studies have the exact opposite results; therefore, more studies should be conducted before it could be realized whether or not full-term infants are capable of synthesizing DHA and AA from their precursors.

Studies have also been conducted in an attempt to correlate breastfeeding with cognitive development and intelligence. A large number of studies have suggested that low DHA and ARA levels might be associated with problems with intelligence and behavior. One study conducted by Carlson et al (5) showed that infants simultaneously supplemented with DHA and provided with a nutrient-enriched pre-term formula had a higher Bayley MDI score, an early test for mental development, at 12 months than controls who were only fed pre-term formula. Another study conducted by Agostoni et al (8) indicated that cognitive development benefited from the intake of these fatty acids. This study investigated the effect of LC PUFA-enriched formula on the Bruner-Lezine psychomotor development test at 4 months of age showing that infants who received supplementation actually scored higher compared to those who received the standard formula. Moreover, some long term studies even show correlation between breastfeeding and Intelligence Quotients. Several years ago, Lucas et al (9) showed that, in pre-term infants, breastfeeding was associated with higher developmental scores at 18 months. Then, in a more recent paper, Lucas et al reported IQ scores in the same children seen at around 8 years. Amazingly, children who had been breastfed as infants had significantly higher IQs than those who were formula fed. In fact, an 8.3 point advantage was observed even after adjusting for the differences among families and social status. Strikingly, these discrepancies were not found when infants were fed formulas supplemented with DHA and AA suggesting yet another positive effect of breastfeeding, this time having to do with IQs.

Influence of long-chain polyunsaturated fatty acids on growth and glucose uptake

Recent studies have also associated the first year growth in pre-term infants with AA and DHA content of plasma phospholipids. A relationship was observed between anthropometric measurements at birth and fetal LC PUFA levels. It was found that the levels of DHA in the arterial vessel wall correlated with birth weight, and that the contents of AA, DHA, and total LC PUFAs were related to the head circumference at birth. (10) Unfortunately, no study has yet been able to explain this consistent correlation between DHA status and prenatal growth.

Fatty acid composition of membrane structural lipids is also important for body's metabolic functions. Skeletal muscle is particularly important because it is the major site of insulin-mediated glucose uptake in the body. And since glucose uptake occurs through the membrane, one might expect the fatty acid composition of skeletal muscle phospholipid to be associated with insulin action. This, indeed, was the finding of the study performed by Pan et al. (11) The study found a direct relationship between the proportions of LC PUFAs in muscle membrane phospholipid and the actions of insulin. Thus it is easy to imagine how important these fatty acids actually are for the normal physiology of the human body. Indeed, studies done on adult humans have shown close association between the levels of these fatty acids and leanness and insulin sensitivity in adult humans. And since only breast milk contains some of these essential LC PUFAs such as AA and DHA, one would expect to see a difference in glucose uptake between breast-fed and formula-fed infants. In fact, a similar study which investigated the effect of the type of feeding on skeletal muscle membrane FA composition, and the relationship between muscle membrane FA composition and simple measures of carbohydrate metabolism in young children was conducted very recently by Baur *et al* (12) with the following observation. For the first time, this study demonstrated that infants who were breast-fed had a higher percentage of LC PUFAs in their muscle membrane structural lipids. And since membrane lipid composition is related to glucose uptake, these infants were also found to have lower mean fasting plasma glucose levels than infants who were fed formula do. Furthermore, these early changes in skeletal muscle membrane phospholipid FA saturation may play a role in the subsequent development of diseases associated with insulin resistance since breast-fed infants have a muscle phopholipid FA composition similar to that of insulin-sensitive adults who have higher proportion of LC PUFAs. The exact mechanism of the action of these LC PUFAs on glucose metabolism is unknown, however, studies show that the close correlation indeed exists.

What the future holds

Over the past few decades, research has found the benefits of breastfeeding to be far more than once thought mere acquisition of immunity from the mother through her milk. The benefits of LC PUFAs are numerous, among them being visual acuity, child development and intelligence, growth and glucose uptake. Unfortunately, in the U.S., only an estimated 30% of all two-month-old babies and 20% of all four-month-old babies are breast-fed. Further compounding the problem, none of the powdered baby formulas such as Isomil, Similac, Gerber, and Carnation contain the essential LC PUFAs found in breast milk. (13) Since the benefits these LC PUFAs are so numerous and since not too many mothers actually breastfeed their babies, a simple question that comes to mind is why not supplement formulas with those essential fatty acids that are currently only found in breast milk. In fact, recently there have been numerous suggestions to supplement the current infant formulas. The World Health Organization (WHO) has recommended the supplementation of infant formulas with DHA and ARA at the same levels found in human breast milk. Interestingly enough, this is already happening in Europe and Asia, yet infant formulas in the U.S. still contain no DHA or ARA even though these are found abundantly in fish oil, making the process of changing U.S. formulas technologically simple. Several Recommendations for the FDA to approve the supplementation of baby formulas have already been made. The only concern with this supplementation is that LC PUFAs are prone to oxidation and may affect the antioxidant status of the infant. Hence, numerous research groups are still closely investigating the potential side effects of supplementation before the FDA can make a final decision on infant formula supplementation.

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