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Omega-3 Fatty Acids in Maternal and Child Health

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Abstract: This paper presents an overview of the effects of omega-3 fatty acids on the duration of pregnancy, incidence of pregnancy-induced hypertension, fetal growth and development, including birth weight, neurocognitive and visual development in the infant, and postpartum depression in the mother. A brief introduction to the role of nutrition on the outcome of pregnancy provides a context for the review of the literature which follows. Much of the research is preliminary and includes epidemiological, animal, and human studies. The clinical applications of omega-3 fatty acid supplementation during pregnancy and breastfeeding are currently controversial due to mixed findings in the research. However, this nutritional factor warrants further study because of the clear physiological basis, strong epidemiological evidence, and positive clinical outcomes and because of the potential for improved physical and behavioral health.

Keywords: Omega-3 fatty acids, maternal health, child health, postpartum depression, pregnancy, nutrition, hypertension, neurocognitive development

INTRODUCTION

The effect of nutrition on the outcome of pregnancy has been studied since the Nazi imposed Dutch Hunger Winter in late 1944 when severe food rationing was imposed on the entire population for seven months. It was discovered that when the maternal food intake was below 800 calories per day fetal growth was negatively impacted (Lumey et al, 2007).

The emphasis on macronutrients, such as calories and protein, remained the focus of nutritional advice until recently, when studies of micronutrients produced significant public health recommendations. Most notably, the connection between folic acid deficiency and neural

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tube defects such as spina bifida is an example of the important role of specific vitamins and minerals in optimal nutrition for pregnancy. Recently, attention has turned to the role of a specific class of lipids, omega-3 fatty acids, and their role in contributing to the health of the mother, fetus, and infant. The range of potential effects includes the length of pregnancy, hypertension, pre-eclampsia, and postpartum depression in the mother, fetal growth and birth weight, as well as brain, nervous system, and visual development of the infant. The physiological mechanisms for these effects is based on omega-3 fatty acid metabolism in the mother and baby. This particular macronutrient provides an exciting interplay between the physical nurturing of the mother and her psychological and physiological status. The cascading effects for the fetus and infant lay down the foundation for permanent cognitive and behavioral consequences. The question now facing clinicians and public health officials is: are less than optimal pregnancy outcomes the result of a deficiency in omega-3 fatty acid ingestion?

OMEGA-3 FATTY ACIDS-METABOLISM AND DIETARY INTAKE

Omega-3 fatty acids belong to the dietary class of lipids, commonly known as fats. Along with carbohydrates and protein, fats constitute the third classification of macronutrients which provide calories for energy. Fats are further divided into two types; saturated and unsaturated. The distinction between these two types of fat can be recognized by noticing whether the fat is solid at room temperature (saturated) or liquid at room temperature (unsaturated). Omega-3 fatty acids belong to the unsaturated fat group and further delineation of this group pinpoints its characteristics. Unsaturated fats are either monounsaturated or polyunsaturated. Chemically, monounsaturated fats have one point of unsaturation (one double bond between carbon molecules) and foods of this type will thicken at refrigerator temperatures. Examples of monounsaturated fatty acids are olive oil, canola oil, and peanut oil. When a fat is polyunsaturated it has two or more double bonds between carbon molecules and it remains liquid at refrigerator temperature. Examples of polyunsaturated fats include soybean oil and walnut oil. The commercial production of hydrogenated oils changes the stability of the polyunsaturated fat and in the case of soybean oil, when it is processed in this way it will remain solid at room temperature.

Polyunsaturated fatty acids (PUFA) are structurally distinguished as either omega-3 fatty acids or omega-6 fatty acids on the basis of where the first double bond occurs on the carbon chain. In food, there are two fatty acids which occur that cannot be synthesized in the human body. They are called "essential fatty acids" because without them certain physiological functions cannot occur. Alpha-linolenic acid (ALA) and linoleic acid (LA) are the names for the essential fatty acids which are found in food.

Alpha-linolenic acid is found in leafy green vegetables, walnut oil, and flaxseed oil. Safflower oil, sunflower oil, and corn oil are good sources of linoleic acid. The ratio of omega-6 to omega-3 was about 1 to 2:1 in the North American diet as recent as 200 years ago and now it is estimated at 16:1 (Simonopoulos, 2002). It is believed that the current ratio of these two fatty acids is not conducive to the healthy functioning of the body and the results may be seen in the various effects on pregnancy and infants.

Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are long chain fatty acids which are produced in the liver from the omega-3 fatty acids found in food. There are further complexities which affect this conversion in the body. Fish is the primary food source for EPA. An important metabolic pathway converts omega-3 fatty acids to prostaglandins. Prostaglandins are hormone-like substances that are produced in the cells and regulate processes such as the movement of calcium in and out of cells, dilation and contraction of muscles, inhibition and promotion of blood clotting, hormone secretion regulation and fertility, and cell division and growth. Prostaglandins provide the mechanisms for the physiological effects of omega-3 fatty acids in pregnant women and the fetus and infant.

Omega-3 Fatty Acids And Maternal Outcome

The potential benefits of omega-3 fatty acids during pregnancy include improved gestation length and size of the infant, reduced maternal hypertension, and a possible role in reducing postpartum depression. In epidemiological studies of the Faroe Islands, diets high in fish oils were associated with increased birth weight, either by extending gestation or enhancing the fetal growth rate (Olsen, 1993). This effect may be due to the ability of prostaglandins to initiate labor or to enhance placental blood flow and decrease blood viscosity. Prostaglandins have been shown to initiate uterine contractions, cervical maturation, and rupture of membranes (Norwitz, Robinson, & Challis, 1999). Women who deliver prematurely have lower plasma omega-3 fatty acids and higher omega-6 fatty acids compared with women who deliver at term (Olsen, 1993, Reece, McGreggor, Allen, &

Harris, 1997). Fish oil supplementation from the 30th week of gestation has been shown to lower the risk of premature birth by 40 to 50%, increase the length of pregnancy by 5 days, and produce babies with a 100g higher birth weight (Olsen, 1993). Preterm birth occurs in 6% to 10% of pregnancies in the United States and is the most important cause of neonatal mortality and morbidity, long-term neurological problems and a low IQ (Saldeen & Saldeen, 2004). The link between a low consumption of seafood and premature delivery and low birth weight was shown in a study of 9,000 pregnant women in Denmark (Olsen, 1993).

Maternal hypertension occurs in approximately 6% to 8% of pregnancies and is the second leading cause of maternal deaths in the United States (NHLBI, 2000). There are varying degrees of severity including chronic hypertension, preeclampsia, and eclampsia. Omega-6 fatty acid derived prostaglandins such as thromboxane may enhance vasoconstriction and are found in maternal plasma and placental tissue of preeclamptic women (Mills et al., 1999). Inuit women who ate a diet rich in marine foods were 2.6 times less likely to develop hypertension during pregnancy (Popeski, Ebbeling, Brown, Hornstra, & Gerrard, 1991). It has been proposed that the most direct way to prevent preeclampsia is to consume fish (Odent, 2006). Further studies on the relationship between omega-3 fatty acids and hypertension in pregnancy are warranted.

The possibility of neurotoxic effects of mercury in fish is a concern for women wanting to increase their fish consumption during pregnancy. Both the American College of Obstetricians and Gynecologists and the Environmental Protection Agency recommend women of childbearing age consume 12 ounces of seafood per week from low mercury species (Greenberg, Bell, & Van Ausdal, 2008). Among the fish with the least mercury content are cod, salmon, herring, scallop, and shrimp (Hughner, Mayer, & Childs, 2008). The highest mercury content is found in king mackerel, shark, swordfish, and certain types of tuna.

While avoidance of fish with high mercury content is advisable, it is not wise to avoid all fish because approximately 73% of child-bearing women are not consuming enough low-mercury fish (Hughner et al, 2008).

Postpartum Depression

Postpartum depression (PPD), referred to in the DSM-IV as a major depressive episode with postpartum onset specifier, is a major depressive episode that begins within 4 weeks of delivery. PPD may affect 10 to 15% of mothers and may impair attachment and bonding within the mother-infant relationship, as well as the cognitive and behavioral development in the infant. Mother-infant bonding disorders were present in 29% of the mothers diagnosed with PPD (Klier, 2006). There may be a thirteen times higher incidence of depression in children of depressed mothers (Verny, 2006). It has been shown that maternal stores of essential fatty acids progressively decline during pregnancy (Freeman, 2006). DHA levels in mothers can decrease to half during pregnancy and not be restored until 6 months after the birth (Saldeen & Saldeen, 2004). Epidemiological and preclinical data support a role of omega-3 fatty acids in both pre- and post-natal depression.

However, the evidence to date has been somewhat conflicting with some studies showing a link (Freeman, 2006; Hibbeln, 2002; Otto, deGroot, & Hornstra, 2003) and others not supporting this hypothesis (Browne, Scott, & Silvers, 2006; Marangell, Martinez, Zboyan, Chong, & Puryear, 2004; Llorente et al., 2003). In cross-national studies, a higher prevalence of both major depression in general and PPD in particular are associated with lower per capita seafood consumption (Hibbeln, 2002). Whereas the incidence of PPD averages 12% in North American women, in Japan where fish consumption is high the incidence is about 2% (Hibbeln, 2002). Lower DHA content in mothers' milk has also been associated with higher rates of postpartum depression (Hibbeln, 2002). Although further studies are needed, the role of DHA as a preventative or adjunct treatment for postpartum depression appears promising.

Omega-3 Fatty Acids And Child Health

The potential benefit to children exposed to sufficient levels of omega-3 fatty acids during prenatal and early postnatal life include brain function, central nervous system, and visual development. Rapid growth and development of neural tissues continues during the first 18 months after birth and the accumulation of DHA in the brain is 3 times greater that the relative increase in brain weight (Martinez, 1992). DHA accretion in the human retina begins in the third trimester and peaks at 36 to 40 weeks gestation (Martinez, 1992). Improved intelligence quotients and mental processing scores at 4-years-of-age were shown in offspring of mothers who consumed cod liver oil in late pregnancy and early lactation (Helland, Smith, Saaren, Sougstad & Drevon, 2003). Fatty acid levels were shown to be lower in children with attention-deficit hyperactivity disorder (Stevens et al., 1995). A randomized clinical trial with British children receiving fish oil supplements showed improvement in their reading skills compared to the controls (Richardson & Montgomery, 2005). One randomized controlled study which fed healthy term infants formula supplemented with DHA showed improvement in both cognitive and motor test results (Birch, Garfield, Hoffman, Uauy, & Birch, 2000). In animal studies, omega-3 fatty acids were shown to alter the metabolism of dopamine and serotonin in the brain and this may infer a role in cognitive functions such as attention, motivation, and visual pathways (de la Pressa & Innis, 1999). DHA has been identified as a structural component of phospholipids of brain gray matter and in the outer segments of the retina's rods and cones (Connor & Neuringer, 1998).

There is concern that changes caused by early deprivation during critical periods of retinal development may be irreversible despite later correction of DHA status (Conner & Neuringer, 1998). Observational studies have shown that breast-fed infants have improved neurocognitive development compared to formula fed infants, possibly due to differences in DHA content (Anderson, Johnstone, & Remley, 1999).

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Conclusion

In light of the compelling findings relating omega-3 fatty acids with maternal and child health, there remain several important questions:

1) Should omega-3 fatty acid supplements (such as fish oil capsules) be given during pregnancy and lactation?
2) If fish oil supplements are taken, should they be purified to eliminate potential toxicity from heavy metals, dioxins, or other contaminants?
3) Should infant formulas be supplemented with DHA to optimize neurodevelopment?

Dietary recommendations for pregnancy have already recognized the potential for toxicity from contaminated seafood. Further studies could be conducted to clarify the safety of consuming seafood during pregnancy.

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