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NUTRITIONAL AND ENVIRONMENTAL FACTORS DETERMINING DHA STATUS IN PREGNANT AND LACTATING WOMEN: IMPLICATIONS FOR MATERNAL AND NEONATAL HEALTH

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ABSTRACT

The intake of omega-3 polyunsaturated fatty acids, particularly docosahexaenoic acid (DHA), is essential for the proper development of the fetus and for maintaining the health and well-being of the pregnant woman, as well as of both the mother and the infant during the lactation period.
Numerous studies have demonstrated the beneficial effects of DHA on the development of the nervous system and retinal function, as well as its role in reducing the risk of preeclampsia, preterm delivery, low birth weight, postpartum depression, perinatal maternal mortality, and neonatal intensive care unit admissions. Moreover, DHA has been shown to positively influence the clinical course of certain neonatal disorders after birth.
Available data suggest that the dietary and supplemental intake of DHA among pregnant women in Poland may be insufficient compared with current nutritional recommendations. The richest dietary sources of DHA include fatty fish and seafood; however, it is advisable to select species with the lowest levels of methylmercury contamination. Storage and thermal processing affect the omega-3 content in food. Vegetarian women may be particularly susceptible to DHA deficiency. Dietary supplementation with DHA derived from controlled microalgae cultures or fish oils can effectively compensate for inadequate intake.
Maintaining an appropriate balance between omega-3 and omega-6 fatty acid consumption is crucial. It is also hypothesized that eicosapentaenoic acid (EPA) may be required for the efficient utilization of DHA by the fetus and may contribute to a reduced risk of preterm birth and preeclampsia. Consumption of DHA increases the risk of macrosomia in the fetus and may influence the extension of pregnancy beyond 42 weeks.

KEYWORDS

DHA, EPA, Pregnancy, Lactation, Preterm Birth

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Introduction

Women in the preconception period, during pregnancy, and throughout lactation should pay particular attention to an adequate intake of nutrients that are key determinants of fetal growth, pregnancy outcomes, and maternal health.

Essential fatty acids (EFAs) are fatty acids that cannot be synthesized de novo by the human body and therefore must be obtained from the diet. Docosahexaenoic acid (DHA) is one of the most important omega-3 polyunsaturated fatty acids (PUFAs), together with alpha-linolenic acid (ALA) and eicosapentaenoic acid (EPA). Although ALA can be converted in the human body into EPA, then into docosapentaenoic acid (DPA), and subsequently into DHA, this conversion process is inefficient for several reasons, even though women tend to have a higher conversion capacity than men. As a result, it is difficult to meet daily DHA requirements solely through endogenous synthesis. During prenatal development, long-chain polyunsaturated fatty acids play a crucial role in the development of the nervous system and the retina of the eye. The demand for DHA in pregnant women is higher than in the general population; therefore, ensuring adequate dietary intake and, if necessary, supplementation is of particular importance during this stage of a woman's life. (*Kamila P. Stepanow et al., 2018; Hanna Mojska et al., 2024; Aneta Mielnik, 2017*)

Methodology

To assemble the body of source literature, a systematic search was undertaken using the Google Scholar database. The search strategy incorporated keywords pertaining to docosahexaenoic acid (DHA), pregnancy, and breastfeeding. All retrieved records underwent an initial screening based on titles and abstracts, after which articles were examined to determine their relevance to the research question. This procedure was designed to ensure a methodologically rigorous and comprehensive synthesis of the current state of knowledge.

The Role of DHA

The impact of DHA supplementation on improving maternal and neonatal health outcomes has been widely discussed in the scientific community for many years. Its significance continues to grow, particularly in conditions with complex, multifactorial etiologies. Of note, both EPA and DHA exhibit anti-inflammatory properties. (*Wojciech Kolanowski, 2015*)

A 2022 review of randomized controlled trial meta-analyses reported that DHA supplementation during pregnancy was associated with a reduced risk of preeclampsia, low birth weight, preterm delivery, and postpartum depression. Moreover, DHA intake during infancy period has been shown to positively influence the severity of retinopathy of prematurity and cholestasis, as well as visual acuity and anthropometric outcomes. (*Fatemeh Dehghani Firouzabadi et al., 2022*)

The 2018 Cochrane meta-analysis found that pregnant women who received omega-3 fatty acids (from food and supplements) were likely to have a reduced risk of preterm birth, perinatal death, neonatal intensive care unit admission, and low birth weight, while showing a probable increase in the risk of fetal macrosomia. No association was observed between maternal omega-3 intake and intrauterine growth restriction or the incidence of postpartum depression. (*P. Middleton et al., 2018*)

A 2021 meta-analysis did not demonstrate a significant relationship between fish oil supplementation during pregnancy and/or lactation and the cognitive outcomes or birth weight of the offspring, although the authors emphasized the low quality and heterogeneity of the available data. (*A. Lehner et al., 2021*)

A 2022 meta-analysis neither confirmed nor excluded that omega-3 supplementation during pregnancy may reduce the risk of asthma and/or wheezing in offspring, and found no association between prenatal omega-3 supplementation and the development of other atopic diseases in childhood. (*L. Bärebring et al., 2022*)

A 2021 meta-analysis found no association between DHA supplementation during the first 1,000 days of a child's life (including pregnancy and infancy) and clinically diagnosed behavioral problems, or the incidence of ADHD and ASD. (*J. F. Gould et al., 2021*)

A 2018 meta-analysis demonstrated that omega-3 supplementation was associated with improvements in psychomotor development and visual acuity in childhood and likely had no effect on IQ scores in later childhood. (*M. Shulkin et al., 2018*)

A 2013 study showed that low maternal omega-3 levels in late pregnancy were associated with higher depression scores three months postpartum. (*M. W. Markhus et al., 2013*)

The ADORE study, published in 2021, indicated that a daily dose of 1,000 mg DHA was likely more effective than 200 mg in preventing chorioamnionitis, premature rupture of membranes, and pyelonephritis during pregnancy, as well as in reducing neonatal feeding, neurological, and urogenital complications. (*Susan E. Carlson et al., 2021*)

An experimental study published in 2010 investigated the effects of DHA supplementation in pregnant rats subjected to hypoxia. The results demonstrated that DHA supplementation had a neuroprotective effect, reducing brain injury and improving neurological outcomes in the offspring. This study highlights the potential importance of DHA supplementation during pregnancy in reducing the risk of hypoxia-related neonatal complications. (*Krzysztof Kamiński et al., 2011; H. Suganuma et al., 2010*)

Adequate DHA Intake During Pregnancy

Lipids are a major structural and functional component of the brain, constituting up to 81% of its dry mass. Among omega-3 fatty acids that make up brain tissue, DHA accounts for approximately 97%, representing about 10% of the total brain lipid content. (*Kamila P. Stepanow et al., 2018; Hanna Mojska et al., 2024*)

DHA accumulation in the fetus begins early, with approximately 2.3 mg deposited daily during the first five weeks of pregnancy, increasing to 16 mg per day between weeks 25-35, and reaching 42 mg per day between weeks 35-40. (*R. S. Kuipers et al., 2012*)

The highest DHA demand occurs during the third trimester, especially in the last ten weeks of gestation - the period of most intensive central nervous system and cognitive development. Infants born prematurely are at risk of DHA deficiency due to shortened exposure to intrauterine DHA transfer. (*P. Haggarty, 2004; Mieczysława Czerwionka-Szaflarska et al., 2023; Michelle L. Baack et al., 2015*)

The placenta facilitates preferential DHA transport to the developing fetus. DHA concentration is higher in umbilical cord blood than in maternal blood, which means that inadequate intake can lead to maternal depletion. (*Marcin Sadłocha et al., 2021; Aneta Mielnik, 2017*)

A survey conducted in 2014-2015 among 100 pregnant women admitted for delivery at a Warsaw clinic assessed daily DHA intake from fish, eggs, and supplements. The median dietary DHA intake during pregnancy was 60 mg/day, which increased to 90 mg/day when supplementation was included - used by only 28% of participants. In 92% of women, total DHA intake did not exceed 200 mg/day. The average fish consumption was 15 g per day, and only 10% of participants ate fish twice a week, with a median intake of 160 mg/day. These results indicate that the typical dietary intake was insufficient to meet DHA requirements. (*R. Wierzejska et al., 2018*)

Guidelines

According to the 2020 recommendations of the Polish Society of Gynecologists and Obstetricians, all pregnant women should receive at least 200 mg of DHA daily, with consideration of higher doses in the preconception period and during pregnancy in women whose diets are low in DHA. A daily dose of 1,000 mg DHA is recommended for women at risk of preterm birth. (*M. Zimmer et al., 2020*)

Pregnant women should consume at least 200 mg DHA daily, in addition to the recommended 250 mg of DHA + EPA for the general adult population, equivalent to 1-2 servings of fatty fish per week. Doses up to 1 g DHA/day (*Mieczysława Czerwionka-Szaflarska et al., 2023*) and up to 3 g/day of EPA + DHA combined (*Krzysztof Kamiński et al., 2011*) are considered safe.

DHA and Preterm Birth

As reported previously, the ADORE study (2021) involving 1,100 women with singleton pregnancies demonstrated that supplementation with 1,000 mg of DHA daily was likely more effective than 200 mg in reducing the risk of preterm birth before 34 weeks of gestation, particularly among women with low baseline DHA concentrations at study entry. (*Susan E. Carlson et al., 2021*)

The 2018 Cochrane meta-analysis found that pregnant women receiving omega-3 fatty acids (from supplements or dietary sources) had a lower incidence of preterm birth (<37 weeks) and early preterm birth (<34 weeks) compared with those who did not receive omega-3s. Omega-3 supplementation was also associated with a slightly higher likelihood of post-term pregnancy (>42 weeks), with the probability increasing from 1.6% to 2.6%. (*P. Middleton et al., 2018*)

Breastfeeding

Breastfeeding remains the optimal method of infant nutrition. Exclusive breastfeeding for the first six months of life is recommended, followed by continued breastfeeding for as long as desired by both mother and child, with the gradual introduction of complementary foods. (*Hanna Szajewska et al., 2021*)

The early years of life represent a period of rapid brain development, and within the first two years postpartum, the infant's brain accumulates substantial amounts of DHA. The best source of DHA for infants is human breast milk; supplementation in infants is unnecessary if the mother consumes a DHA-rich diet or appropriate supplementation. To support optimal brain and visual development in breastfed infants, lactating women should consume an additional 200 mg of DHA daily, on top of the 250 mg of DHA + EPA recommended for adults, including at least 200 mg of DHA. (*Mieczysława Czerwionka-Szaflarska et al., 2023*)

As complementary feeding progresses, dietary sources of DHA become more diverse. The minimum DHA requirement for infants and young children between six months and two years of age is 100 mg/day, which can be provided by two small servings of fatty fish per week. (*Mieczysława Czerwionka-Szaflarska et al., 2023*)

Because EPA competes with arachidonic acid, excessive EPA intake may impair growth and therefore is not recommended for infants; DHA does not exhibit this effect. For children aged three years and older, a minimum intake of 250 mg of DHA + EPA per day is recommended, which can be achieved through 1-2 servings of fatty fish weekly or DHA supplementation at 250 mg daily. (*Mieczysława Czerwionka-Szaflarska et al., 2023*)

The DHA concentration in human milk depends on maternal dietary intake and averages about 1.0 g per 100 g of milk. Evidence suggests that DHA stores accumulated during pregnancy may have a greater influence on milk DHA levels than current dietary intake. Breast milk contains substantially less EPA (0-0.1%) compared to DHA (0.01-0.56%). (*Krzysztof Kamiński et al., 2011*)

Sources of DHA

Major dietary sources of omega-3 fatty acids include fatty fish and seafood (providing DHA and EPA, but not ALA), egg yolks (mainly ALA), omega-3-enriched eggs (ALA, EPA, DHA), flaxseed oil, rapeseed oil, walnuts, leafy green vegetables, and almonds (primarily ALA). (*P. Sicińska et al., 2015*)

Modifying the fatty acid composition of poultry feed - by adding flaxseed, flaxseed oil, or fish oils - can enrich egg yolks with omega-3 fatty acids. Such omega-3-enriched eggs are now commercially available. (*Monika Wereńska et al., 2011*)

Public awareness has increased regarding contamination of aquatic environments with heavy metals, dioxins, and polychlorinated biphenyls (PCBs), which may affect fish and seafood - the main sources of omega-3s. Pregnant and breastfeeding women and children should limit consumption of fish from highly polluted waters.

In Poland, according to current legal limits for methylmercury and dioxins, most fish and fish products can be consumed in amounts exceeding 1 kg per week, except for salmon, sprats, herring, and sardines, where caution is advised. Predatory fish such as shark, swordfish, and tuna contain the highest levels of heavy metals. (*Hanna Mojska et al., 2020*)

Fatty marine fish are the richest sources of DHA, particularly Norwegian salmon (2.15 g DHA/100 g), rainbow trout (1.76 g/100 g), sprat, mackerel, tuna, herring, sardines, and cod. Consumption of Baltic fish is not recommended due to contamination of the Baltic Sea. (*Hanna Mojska et al., 2020; Mieczysława Czerwionka-Szaflarska et al., 2023*)

According to the 2015 EFSA opinion, consuming 1-4 servings of fish and seafood per week (1 serving - 150 g) during pregnancy has beneficial effects on children's neurological development compared with no consumption. Based on prenatal neurotoxicity data, the tolerable weekly intake for methylmercury was set at 1.3 µg/kg body weight/week, emphasizing the selection of low-mercury fish species. (*EFSA, 2015*)

Because of aquatic contamination, polyunsaturated fatty acids are also obtained from controlled microalgae cultures (e.g., *Schizochytrium sp.*), which are used to produce dietary supplements and fortified foods. (*Tomasz Półbrat et al., 2019*)

Fish oil supplementation is another option. However, traditional cod liver oil (Oleum Gadi) - derived from the liver of Atlantic cod - is rich in omega-3 and omega-6 fatty acids, whereas shark liver oil is low in omega-3s and therefore not considered a true cod liver oil substitute. Oils from small marine fish can also provide omega-3s, though their composition varies. (*Mirosław Cieśla et al., 2011; Natalia Lewkowicz et al., 2006*)

Thermal Processing of Fish

The cooking method significantly affects omega-3 content because polyunsaturated fatty acids (PUFAs) are highly susceptible to oxidation. Smoking, baking, or frying at high temperatures can decrease the omega-3 content of fish. (*Ewa Dybkowska et al., 2014*)

Moreover, frying in batter can lead to the accumulation of trans fatty acids, which impair omega-3 absorption. (*Krzysztof Kamiński et al., 2011*). Cooking, including steaming, is therefore recommended as a preferable preparation method. (*E. Mess et al., 2017*)

DHA Intake in Vegetarian Diets

Because the conversion of ALA to DHA in the human body is inefficient, direct DHA intake is necessary to meet physiological requirements. (*Mieczysława Czerwionka-Szaflarska et al., 2023*). Pregnant vegetarians and vegans are at particular risk of omega-3 deficiency. (*Aneta Mielnik, 2017*)

The best dietary sources of ALA are flaxseed oil, rapeseed oil, and walnuts. Assuming an ALA content of 52.7 g per 100 g of flaxseed oil, 96% absorption, and a 9% conversion rate to DHA in women of reproductive age, a woman would need to consume approximately 5.49 g of flaxseed oil daily (about half a tablespoon) to meet the basic 250 mg DHA requirement. (*Karol Mińkowski et al., 2011; Bożena Bałasińska et al., 2010*)

However, the nutritional value of oils depends on raw material quality, pressing methods, storage conditions, and protection against oxidation - especially for cold-pressed oils. Oils should be stored in light-protected containers, refrigerated, and consumed before their expiration date. (*Agata Pawłowska et al., 2018; Małgorzata Wroniak et al., 2007; Małgorzata Wroniak et al., 2015*)

Omega-6 and Omega-3 balance

Linoleic acid (LA), an omega-6 polyunsaturated fatty acid, is the precursor of arachidonic acid (AA) and must be obtained from the diet, as it cannot be synthesized endogenously. (*R. Wierzejska et al., 2018*)

A balanced omega-6 to omega-3 ratio is essential for proper brain development. (*Nobuyuki Sakayori et al., 2016*)

Because both fatty acid classes share the same metabolic enzymes, excessive dietary omega-6 (especially LA) competitively inhibits EPA and DHA synthesis, favoring AA production. (*Hanna Mojska et al., 2024*)

DHA competes with arachidonic acid for incorporation into neuronal membrane phospholipids.

(*R. Wierzejska et al., 2018*)

Omega-3 fatty acids exhibit anti-inflammatory properties, while omega-6 fatty acids can be pro- or anti-inflammatory, depending on the context. Therefore, a balanced intake ratio of 4:1 to 1:1 (omega-6:omega-3) is recommended. (*D. Gutierres et al., 2025*)

In Western countries, omega-6 PUFAs contribute up to 15% of total energy intake.

(*M. Mazidi et al., 2020*)

A high omega-6 to omega-3 ratio in pregnant women's serum has been negatively correlated with infant neurodevelopment. Animal studies have shown that a diet mimicking the modern Western pattern, rich in omega-6 relative to omega-3, impaired offspring neurological development; even after dietary correction postnatally, the adult offspring displayed increased anxiety-related behaviors. (*Nobuyuki Sakayori et al., 2016*)

Nevertheless, some studies show that higher linoleic acid intake is inversely associated with LDL and HDL cholesterol levels and reduces serum triglycerides.

Arachidonic acid constitutes a key phospholipid component of neuronal and retinal cell membranes. In infants, breast milk provides an adequate source, and its AA content is less diet-dependent than DHA levels. (*Hanna Mojska et al., 2024*)

Maternal ALA and DHA deficiency during pregnancy and lack of DHA in infants' diets decrease brain DHA concentrations, leading to compensatory increases in omega-6 fatty acids. (*Kamila P. Stepanow et al., 2018*)

The Role of EPA

The role of EPA during pregnancy and lactation remains incompletely understood. Available evidence suggests that EPA may reduce the risk of preeclampsia and preterm birth and facilitate the placental transport and fetal incorporation of DHA. (*Krzysztof Kamiński et al., 2011*)

Algal oils and eggs are poor in EPA, unlike fish oil. There is evidence that EPA may be associated with prolonged gestation. (*S. E. Carlson et al., 2013*)

Maximum Safe Dose

Studies have shown that long-term intake of DHA and EPA, individually or combined, at doses up to 1 g/day, does not adversely affect cardiovascular, neurological, or immune outcomes. Chronic intake of up to 5 g/day of combined EPA and DHA did not increase the risk of spontaneous bleeding, even among individuals taking aspirin or anticoagulants.

Supplementation with EPA and DHA (up to 5 g/day for 12 weeks) had no significant effect on glucose homeostasis in healthy or diabetic subjects. Higher intakes (2-6 g/day combined or 2-4 g/day of DHA) slightly increased LDL cholesterol (~3%) while lowering triglyceride levels without altering total or non-HDL cholesterol.

No maximal tolerable daily intake has yet been established for DHA, EPA, or DPA, separately or combined, in specific population groups. However, dietary supplementation with up to 5 g/day of EPA + DHA combined and 1.8 g/day of EPA alone is considered safe for adults.

In clinical studies assessing omega-3 intake, DHA and EPA quantities were known, while DPA intake was low and not well quantified. DPA-only supplements are not currently approved for human consumption. (*EFSA, 2012*)

Summary

Available data indicate a correlation between DHA intake in the diet of pregnant and breastfeeding women and its beneficial effects on the well-being of both mother and child in the prevention of various conditions. However, this knowledge is still incomplete, and further research is needed. The sources of DHA are well-known, along with guidelines for their use, although it seems that establishing a maximum safe DHA dosage for pregnant and breastfeeding women, as well as revising the recommendations regarding the dosage that would yield the most beneficial effects, could be advisable. Research should also focus on the role of EPA and DPA and their intake in the diet of pregnant and breastfeeding women.

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