

Essential fats for mothers and infants: Another dimension of dietary quality

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Summary of main points

1 The last trimester of pregnancy and the first 2 years of life is a crucial period for adequate intake of essential fats because brain and nervous system development is most rapid during this period.

2 The types and amounts of fatty acids in the diets of pregnant and lactating women and their infants have been linked with important health outcomes including duration of gestation, birth weight, neurobehavioral development, immune function, and maternal mental health.

3 A healthy diet includes adequate amounts and an appropriate balance of omega-3 and omega-6 fatty acids. In low-income countries, the availability of fat and omega-3 fatty acids in the food supply is generally low, often below the minimum recommended intake for vulnerable groups.

4 Interventions for improving the fatty acid status of *pregnant and lactating women* need to ensure adequate fat intake, discourage excess intake of fats that are high in omega-6 fatty acids, and encourage consumption of foods high in omega-3 fatty acids. These interventions, plus optimal breastfeeding practices and adequate fat and fatty acid content of complementary foods can improve the fatty acid status of *infants and young children*.

Public awareness of the health benefits of certain fatty acids in the diet increased only recently although it was known in the 1930s that they were necessary for growth and health.¹ In particular, omega-3 fatty acids have gained attention for their anti-inflammatory properties, which may help combat or prevent diseases such as arthritis, asthma, heart disease, and type II diabetes.

The last trimester of pregnancy and the first 2 years after birth is a crucial period for adequate intake of essential fats. Brain and nervous system development is most rapid during this period. The types and amounts of fatty acids in the diets of pregnant and lactating women and their infants have been linked with important health outcomes including duration of gestation, birth weight, neurobehavioral development, immune function, and maternal mental health.

This technical brief is divided into three parts. The first part briefly describes the importance of essential fats consumed by pregnant and lactating women and children under 2 years of age and recommends programmatic, research, and policy actions. The second part presents the evidence for the health effects of fatty acids, and the third part discusses factors affecting fatty acid status of pregnant and lactating women and children under two.

Importance of Essential Fats

Fats have a variety of biological functions in the body but are primarily involved in:

- Provision of energy and fueling of cells
- Membrane structure and function
- Communication within and between cells

Essential fats, in particular, play a critical role in neurobehavioral development, immune function, growth, mental health, and long-term metabolic health. Essential fatty acids are those that humans are unable to synthesize and must therefore obtain through their diet (see Box 1). They include alpha-linolenic acid (ALA), the building block for the longer-chain omega-3 fatty acids, and linoleic acid (LA), the building block for the longer-chain omega-6 fatty acids.

Fatty acids are especially important for brain function. More than 50 percent of the adult brain is made up of fatty acids (dry weight). Long-chain polyunsaturated fatty acids (LCPUFA) such as docosahexaenoic acid (DHA) and arachidonic acid (AA) are among the most important fatty acids in the brain. LCPUFA are incorporated into specialized cell connections (called synaptic membranes) through which transmission of messages between cells occurs. DHA has positive effects on nerve cell growth and differentiation and decreases

Box 1. Primer on fatty acids

Fatty acids are classified based on the position of the first double bond in their carbon chain. For omega-3 fatty acids, the double bond is located three carbon atoms from the omega end, and for omega-6 fatty acids it is six carbon atoms from the omega end. Within each family of fatty acids, the shortest fatty acid cannot be synthesized by the body, but once consumed it can be elongated by enzymes to form longer-chain fatty acids.

Omega-3 fatty acids

Alpha-linolenic acid (ALA) is the shortest omega-3 fatty acid and must be obtained from the diet; it is the “precursor” for the other omega-3 long-chain polyunsaturated fatty acids. Sources of ALA: walnuts and flaxseed; walnut, canola, and soybean oil.

Docosahexaenoic acid (DHA) and **eicosapentaenoic acid (EPA)** are examples of omega-3 **long-chain polyunsaturated fatty acids (LCPUFA)**. Sources of DHA and EPA: oily fish (herring, salmon, sardines, trout, tuna), oysters, and crabs.

Omega-6 fatty acids

Linoleic acid (LA) is the shortest omega-6 fatty acid and must be obtained from the diet; it serves as the precursor for longer omega-6 fatty acids such as **arachidonic acid (AA)**. Sources of LA: vegetable and seed oils (safflower, sunflower, corn, soybean). Sources of AA: Since animals, but not plants, can convert LA to AA, arachidonic acid is present in small amounts in meat, poultry, and eggs.

Cis vs. trans fatty acids

Cis fatty acids have hydrogen atoms that are all on the same side of the double bond. This is the common form of fatty acids.

Trans fatty acids have hydrogen atoms that are on opposite sides of the double bond. They are primarily found in processed foods containing partially hydrogenated fats.

This difference in geometry affects biological functions.

nerve cell death. In addition, omega-3 fatty acids provide the building blocks for chemical messengers that relay nerve signals through the brain and thus could affect mental health.

A healthy diet includes adequate amounts of both omega-3 and omega-6 fatty acids. Diets with fat dominated by LA (an omega-6 fatty acid) fail to support optimal omega-3 status. Examples of omega-3 deficient diets are ones in which nearly all of the fat comes from seeds such as cereal grains and peanuts and from seed oils. Numerous animal studies have shown that pregnant and lactating primates, mice, rats, and other species fed high omega-6/low omega-3 seed oils as the exclusive source of fat gave birth to offspring with biochemical, neural, visual, and behavioral abnormalities.²

In low-income countries, the availability of fat and omega-3 fatty acids in the food supply is generally low, often below the minimum recommended intake for vulnerable groups (Table 1).³ In populations living on a predominantly plant-based diet, vegetable oils and cereals are important sources of fatty acids. Some vegetable oils such as soy and canola oil have high contents of omega-3 fatty

acids while other oils from corn, peanut, safflower, and sunflower have very low omega-3 fatty acid levels (Figure 1). Among young children in low-income countries, fat intake is generally adequate while they are still breastfed but declines sharply after weaning.

Programmatic Implications

Most nutrition programs targeted at pregnant and lactating women and children under 2 years of age do not take into account the quality of fat in diets of mothers and infants, despite the fact that suboptimal consumption patterns are probably widespread.³ Several intervention strategies can improve the fatty acid status of these vulnerable populations.

Interventions for pregnant and lactating women

To assure adequate fatty acid status of pregnant and lactating women, several steps are recommended:

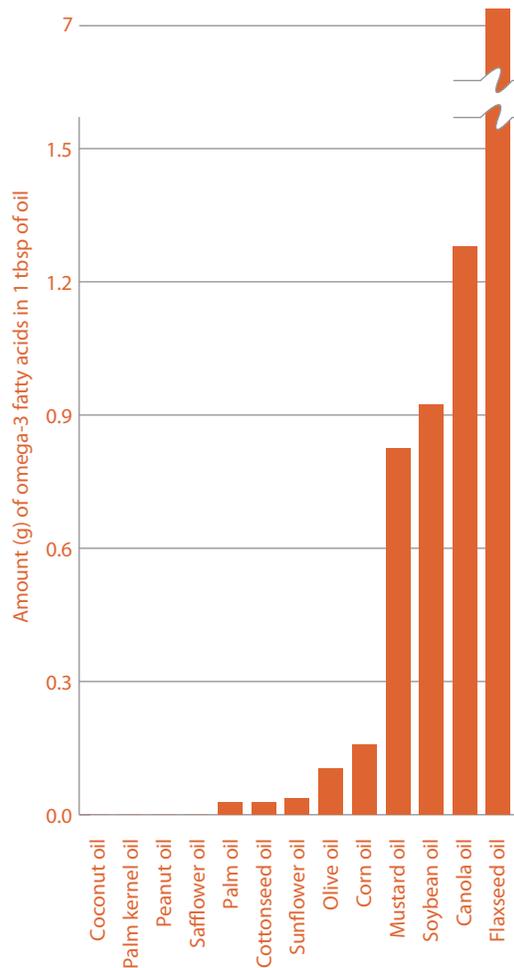
- Ensure adequate total fat intake (i.e., 20–35 percent of energy);
- Discourage excess intake of fats that are high in omega-6 fatty acids (e.g., corn, peanut, safflower, and sunflower oils)
- Promote use of vegetable oils that have high levels of ALA

Table 1: Recommended dietary intakes for total fat and essential fatty acids. FAO/WHO (2008).

	INFANTS AND YOUNG CHILDREN (6–24 MONTHS)	PREGNANCY AND LACTATION*
Total fat	Gradual reduction to 35% of total energy intake, depending on physical activity	20–35 % of total energy intake
Omega-6 PUFA	3.0–4.5% of total energy intake (linoleic acid only)	2–3% of total energy intake (linoleic acid only)
Omega-3 PUFA	0.4–0.6% of total energy intake (alpha-linolenic acid only)	0.5–2% of total energy intake (ALA + other omega-3 PUFA)

*Recommended intake for healthy adults; PUFA, polyunsaturated fatty acids.

Figure 1: Omega-3 fatty acid content of various vegetable and seed oils. *USDA National Nutrient Database for Standard Reference.*



Some vegetable oils such as soybean and canola oil have a high content of omega-3 fatty acids while other oils from corn, peanut, safflower, and sunflower have very low omega-3 fatty acid levels.

- Encourage consumption of food sources rich in omega-3 LCPUFA (e.g., fatty fish)

In some populations, local food sources of omega-3 fatty acids are already available. For example, in Malawi, a small, locally available dried fish called *usipa* has a DHA content close to that of salmon. The average breastmilk DHA

content of women living near Lake Malawi is about 0.7 percent of total fatty acids--about twice the global average. In Bangladesh, mustard seed oil, which has an omega-3 fatty acid content similar to that of soybean oil, is commonly consumed though in small quantities. These examples suggest that interventions may be built on pre-existing dietary habits where local food sources of high-quality fat are available and affordable.

Other sources of omega-3 fatty acids, which may or may not be locally available, include eggs, certain nuts/seeds (chia seeds, walnuts, soybeans), and pastes and spreads made with soybean oil or full fat soy flour. In some situations, increasing the year-round availability of foods with high-quality fat would be useful. For example, drying and storing fish should be encouraged so that it can be consumed in all seasons. In settings where the majority of fish are sold, households should be encouraged to keep and consume some of the fish.

Programs that make high-quality fats accessible and affordable to vulnerable populations are especially important. For example, pregnant and lactating mothers in Chile have benefited from the provision of DHA and EPA-fortified milk through the national nutrition program. It is estimated that the number of beneficiaries is approximately 113,000 per month, of whom about 95,000 are pregnant and 17,000 are breastfeeding.⁴

Home fortification with lipid-based nutrient supplements (LNS) can increase ALA intake of pregnant and lactating women while simultaneously providing essential micronutrients. One 20 gram sachet per day provides 10 grams of fat. In Bangladesh, the fatty acid content of LNS could increase the percentage of energy from ALA from

0.33 percent to 0.62 percent, allowing women to meet the recommendation of > 0.5 percent.⁵

Interventions for infants and young children

Improving the fatty acid status of infants and young children requires improving maternal fatty acid status during pregnancy and lactation, as described above. In addition, strategies in the first two years after birth are as follows:

- Promote optimal breastfeeding practices
- Ensure adequate fat and fatty acid intake during the period of complementary feeding and beyond

Simply adding fat to the diet of infants and young children is not advised. Fat has a high energy density (9 kcal/gram), and if extra fat is added to a porridge, it will greatly increase the energy density of the mixture, but lower the protein and micronutrient density of the food (amount per 100 kcal). Thus, if the child consumes the same amount of energy, the child will receive lower amounts of protein and micronutrients. For this reason, it is important to increase levels of all key nutrients when fat is added to complementary food diets to preserve or increase the micronutrient density of the foods.

One way to ensure adequate levels of all nutrients is to provide a fat source that also includes some protein and micronutrients, such as LNS. In a randomized controlled trial in Ghana, Nutributter increased energy intake from complementary foods and increased blood ALA levels by 33-40 percent.⁶ Data analysis suggested that the shift in plasma ALA explained a significant part of the positive impact of LNS on length gain. However, the effect on growth could also have been due to the milk content and/or other growth-promoting nutrients included in LNS.

Research priorities and policy implications

To inform intervention strategies, more research is needed to:

- Measure fatty acid supply, intake, and status in middle- and low-income countries
- Identify locally available and affordable sources of omega-3 fatty acids that could be incorporated into the diets of pregnant and lactating women and children
- Develop high ALA/low LA dietary fat sources in contexts where good sources of omega-3 fatty acids may be unavailable or expensive
- Understand factors influencing the conversion of LA and ALA into LCPUFA in low-income countries, particularly genetic and nutritional factors
- Assess both the efficacy and effectiveness of interventions aimed at improving LCPUFA status

To complement these interventions, policies that improve the quality of dietary fats are needed as well. For example, food labels on “vegetable oils” on the market should declare the precise type of oil or fat in the product. This may be especially important in countries where the consumption of high-LA oils is increasing, and omega-3 fatty acid status may be compromised. Increased public awareness of differences in quality of dietary fat is needed. For example, it has been reported that a brand of partially hydrogenated oils in India called *Vanas-pati* has trans fat levels 5-12 times higher than recommendations.⁷ In reaction to the findings, advocacy groups worked to (1) increase awareness of the high levels of trans fat in the oils, (2) convince oil manufacturers to reduce the levels of trans fat, and (3) ensure correct labeling.

Other strategies that could improve fatty acid status but would require policy action include the following:

- Health authorities should encourage fish consumption along with other foods that are rich in ALA (but not excessive in LA) and/or omega-3 LCPUFA.
- Agricultural sectors must work with public health programs to ensure adequate sources of essential fats for the public.
- Oils used in food aid for low-income countries should be shifted from those with little or no omega-3 content (e.g., corn oil, palm oil) to those with adequate omega-3 content (e.g., soybean oil).
- Fish feed could be designed to have a higher omega-3 content.
- Sustainable fishing practices need to be explored so as not to deplete fish stocks.
- Non-mainstream sources of essential fats should be explored, such as insects or algae.
- Collaborations between the public and private sector could facilitate marketing of products high in essential fats, as was done in China for the marketing of a full fat soy flour for complementary feeding.⁸

Evidence for Health Effects of Fatty Acids in Mothers and Their Children

Fatty acids and duration of gestation and growth in utero

In meta-analyses, maternal omega-3 LCPUFA supplementation during pregnancy was related to an increase in gestational age (+2.5 days), which was related to increased birth weight (~50 g) and length (~0.5 cm).⁹ Omega-3 LCPUFA reduced the risk of preterm birth (<34 wk gestation) by 31 percent

in all pregnancies⁹ and by 61 percent in high-risk pregnancies.¹⁰ Trials conducted in Bangladesh¹¹ and Mexico¹² after publication of the meta-analyses yielded mixed results: maternal supplementation with omega-3 LCPUFA had no effect on preterm birth or birth size in Bangladesh, while in Mexico, maternal supplementation had a positive effect on birth weight (+99 g) and head circumference (+0.5 cm) in first-time mothers but not in those who had been pregnant previously. A trial in Chile showed that maternal supplementation with ALA fortified milk increased birth weight.¹³

Fatty acids and neurobehavioral development

Most of the intervention trials that have examined the relationship between fatty acid intake and neurobehavioral development have been conducted in high-income countries and have mainly focused on the fatty acid composition of infant formula. A recent review concluded that omega-3 LCPUFA supplementation of lactating women expressing breastmilk for their preterm infants resulted in improved infant neurodevelopmental performance, but the effect of maternal prenatal and postnatal LCPUFA supplementation on neurobehavioral outcomes for children born at term remains unclear.¹⁴ Preliminary evidence described in the review suggests that dietary omega-3 long chain fatty acids may be neuroprotective for children from disadvantaged or low-income backgrounds, but further research is needed.

A randomized trial of Australian preterm (< 33 wk gestation) infants showed that at 18 months of age, infants in the high direct DHA supplementation group were half as likely to show severe

mental delay compared to infants in the standard DHA group.¹⁵ Further analyses identified that the protective effect of DHA against mental delay was only evident among girls: girls who received high amounts of DHA had less than half the risk of mild mental delay and less than a fifth of the risk of severe mental delay compared to girls in the standard DHA group. Among infants of mothers who did not complete secondary education, the high DHA group had a 5-point advantage in mental score at 18 months, whereas no significant effect on mental development was seen among infants of mothers with higher education.

Fatty acids and postnatal growth

Most studies on the relationship between fatty acids and postnatal growth have been conducted with formula-fed infants in high-income countries and have shown no effect of the addition of LCPUFA on growth of formula-fed term or preterm infants. The effect of postnatal fatty acid supplementation on the growth of infants in low-income countries, particularly those who experienced intra-uterine growth restriction, has not been well studied. A trial in rural Gambia that randomized 183 infants to receive fish oil or placebo (olive oil) from 3 to 9 months of age resulted in a significant increase in mid-upper arm circumference and skinfold thickness in the fish oil group, and a marginally significant but large increase in length gain Z-score (+0.79).¹⁶

Fatty acids and immune function

There are multiple pathways through which fatty acids, especially LCPUFA, may modulate immune function. Evidence for these actions is derived mostly from laboratory and small animal studies. Randomized controlled trials

in affluent populations, mostly aimed at ameliorating inflammatory conditions, have yielded fairly robust evidence for efficacy in a number of diseases such as rheumatoid arthritis. However, there have been almost no fatty acid trials in low-income countries in which immune function has been measured.

Fatty acid nutrition in early life and metabolic programming of long-term outcomes

Fatty acids can influence gene expression, protein function, and signal molecules that regulate appetite, energy balance, and inflammation. Nutrient deficiencies and excesses during development can reprogram how cells divide, differentiate, and respond to their hormone and nutrient environment. These effects can be long-lasting and increase risk of later chronic diseases, such as diabetes and obesity. Biological pathways and animal experimental data link high omega-6 (LA) and low omega-3 fatty acid intake to programming of appetite and energy metabolism. However, there is a lack of good studies to address this relationship in humans.

Fatty acids and maternal mental health

Observational studies suggest that low intakes of omega-3 fatty acids such as DHA are associated with postpartum depression, which affects 20-30 percent of women in developing countries and is a leading cause of disability worldwide. An ecological analysis including various countries showed that lower DHA content in mothers' milk and lower seafood consumption were associated with higher rates of postpartum depression.¹⁷ Evidence from well-designed intervention trials is very limited. Two large randomized controlled trials in Australia¹⁸ and Mexico¹² did not find any impact

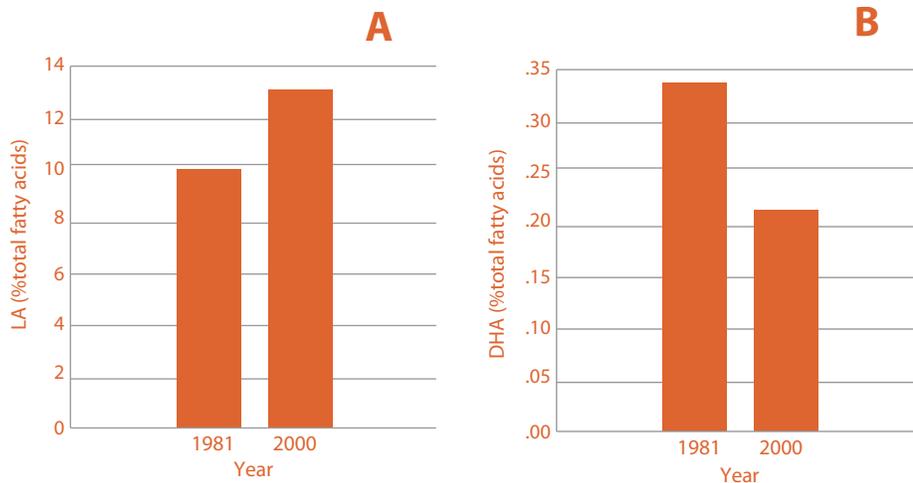
of prenatal DHA supplementation on postpartum depression. However, effects may depend on the presence/absence of other nutrient deficiencies (which may also impact mental health), total fatty acid intake, and genetic factors. More research is needed on the impact of fatty acids on mental health in developing-country settings where omega-3 fatty acid status is low.

Factors Affecting Fatty Acid Status of Pregnant and Lactating Women and Children Under Two

Modern day diets tend to be low in omega-3 fatty acids unless there is regular intake of fish or seafood. This contrasts with the situation throughout most of human evolutionary history. Prior to the agricultural revolution, when cereal grains became the predominant source of calories, diets were rich in omega-3 fatty acids. The Paleolithic diet was characterized by a high intake of wild game, fish/shellfish and insects; a very low intake of cereals; and no processed vegetable oils.¹⁹ As a result, the Paleolithic diet had moderate to high levels of fat and high levels of omega-3 fatty acids. The omega-6 to omega-3 ratio was close to 1.

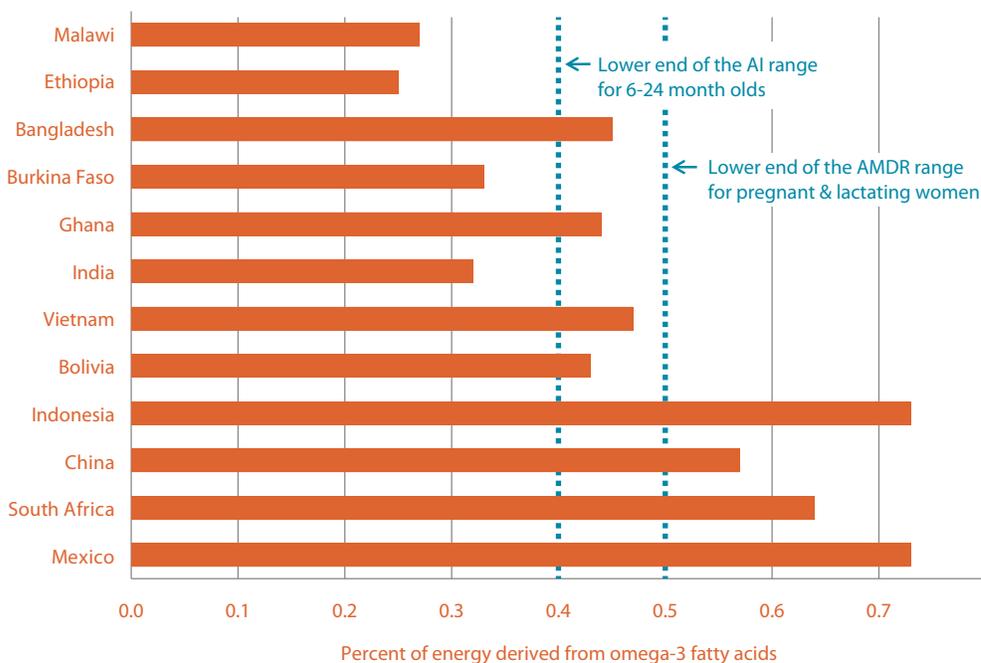
These dietary characteristics differ dramatically from those of most modern diets in low-income countries, where there is usually a low to moderate intake of fat and low intakes of omega-3 fatty acids. These trends of decreasing omega-3 fatty acid intake and increasing omega-6 intake have also been apparent on a smaller time scale in high-income populations: among Australian mothers, breastmilk LA content increased but DHA content decreased between 1981 and 2000 (Figure 2).²⁰

Figure 2: Average linoleic acid (omega-6) (graph A) and DHA (omega-3) (graph B) content of breastmilk of Australian women in 1981 and 2000. Gibson et al. (2000).



Trends toward increased omega-6 fatty acid intake and decreased omega-3 fatty acid intake are reflected in the increase in the LA content and decrease in DHA content of the breastmilk of Australian women between 1981 and 2000.

Figure 3: Omega-3 fatty acid supply (% energy) in 13 countries ranked by GDP. Taken from Michaelsen et al. (2011).



AI = Adequate Intake range; AMDR = Acceptable Macronutrient Distribution Range; E = Energy
In many low-income countries, omega-3 fatty acid supply in the diet is inadequate to meet omega-3 recommendations for infants 6-24 months old or for pregnant and lactating women.

Access to foods with adequate fat and fatty acids

Using estimated total fat and fatty acid supply in the diet for 13 countries based on FAO food supply data, positive correlations were found between GDP and per capita availability of total fat, omega-6 fatty acids, and omega-3 fatty acids.³ While supply was sufficient in most countries to meet the recommendations for omega-6 intake for pregnant and lactating women, in several countries it was inadequate to meet the recommendations for omega-6 intake for infants 6-24 months old and in most it was inadequate to meet omega-3 recommendations for infants 6-24 months old or for pregnant and lactating women (Figure 3). It is important to note that these data reflect per capita availability and not necessarily dietary intake. Intakes are generally lower than estimates of dietary availability. Moreover, women and children under two may have less access to foods with adequate fat and fatty acids than other members of the household. Thus, the estimates are probably a “best case” scenario. Note that for infants, estimates were only for complementary food and did not include breastmilk.

Fatty acid intakes of pregnant and lactating women

Huffman et al. recently reviewed studies that directly assessed fatty acid intake of pregnant or lactating women and their young children in low-income countries, which generally support the above findings.²¹ Although one study of pregnant and lactating women in urban India showed that their total fat intake met IOM recommendations,²² fat intakes of pregnant or lactating women in rural Bangladesh⁵ and rural Burkina Faso²³ were much lower than the recom-

mentations. Among the Bangladeshi mothers, average daily consumption of animal source foods was about one and a half tablespoons of fish (12.8 g), half a tablespoon of egg (4.7 g), and half a tablespoon of meat/poultry (4.2 g). These women consumed only about 1 teaspoon (4.0 g) of mustard oil each day and three-quarters of a teaspoon (3.5 g) of soybean oil each day.⁵ As a result, the average percentage of energy (calories) from fat was only 8 percent - a very low fat diet. In studies examining ALA intake during pregnancy, women in Mexico and the U.S. met recommendations while women in Chile, Bangladesh, and India did not (Figure 4). In studies examining the intake of DHA during pregnancy, none of the women in the U.S., Mexico, Bangladesh or India met recommendations (Figure 5).

Fatty acid status of infants and young children

LCPUFA transfer from the mother to her fetus/newborn during pregnancy and lactation is mainly dependent upon maternal status. Transfer is highly variable because there are large differences worldwide in dietary intake of LCPUFA, particularly DHA. This is reflected in the large differences in DHA content of breastmilk between and even within countries (Figure 6). For children under 2 years of age, the key sources of LCPUFA, especially omega-3 fatty acids, are breastmilk and fish.

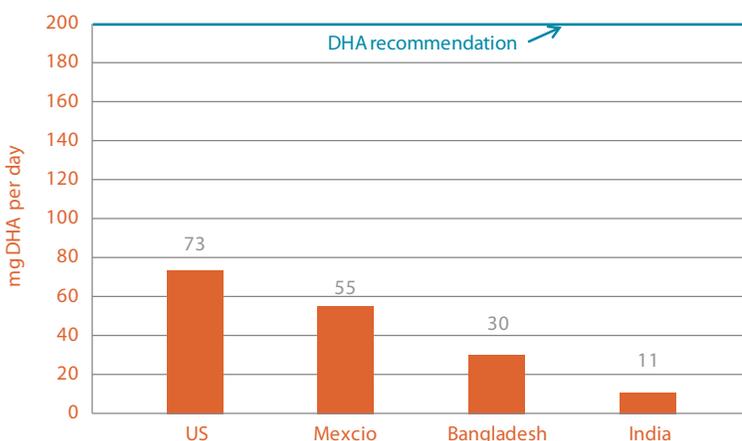
Total fat intake of children in the Gambia declined from about 50 percent of energy to 25 percent of energy between birth and 18 months due to a decline in breastmilk intake, and declined further to about 15 percent of energy by 2-3 years of age.²⁴ Omega-6 fatty acid

Figure 4: ALA intakes during pregnancy. IOM (2005), Ramakrishnan et al. (2010), Mardones et al. (2008), Yakes et al. (2011), Muthayya et al. (2009).



Average ALA (an omega-3 fatty acid) intake of pregnant women is far below recommendations in several countries.

Figure 5: DHA intakes during pregnancy. Koletzko et al. (2007), Nesheim and Yaktine (2007), Ramakrishnan et al. (2010), Yakes et al. (2011), Muthayya et al. (2009).



Average DHA (an omega-3 fatty acid) intake of pregnant women is far below recommendations in several countries.

intake was relatively stable, but omega-3 fatty acid intake fell precipitously as breastmilk intake declined. Pre-school children studied in Bangladesh⁵ and China²⁵ had total fat, ALA, and DHA intakes below recommendations.

The relative amounts of omega-3 and omega-6 fatty acids in the diet may also influence fatty acid status because the conversion of ALA to long-chain omega-3 fatty acids is affected by omega-6 fatty acid intake. Both the total fatty acid content of the diet and the balance of LA to ALA are determinants of LCPUFA status.

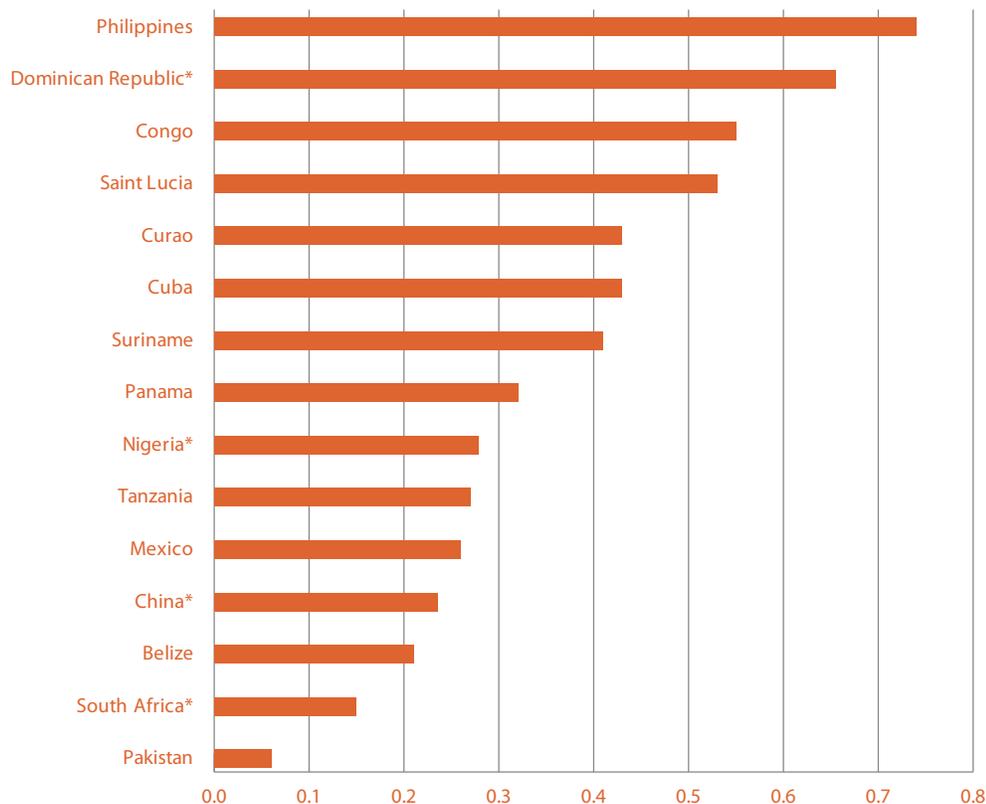
Genetic factors

Genetic variation in fatty acid metabolism can affect fatty acid status. Variants in the genes for the enzymes involved in the conversion of LA and ALA to LCPUFA markedly influence fatty acid status, including DHA levels in pregnancy and LCPUFA levels in human milk. More studies are required to explore the mechanisms by which these gene variants modulate fatty acid levels in blood, breastmilk and tissues, and to explore their effects on immune response and developmental outcomes in populations with different ethnic backgrounds, lifestyles, and dietary habits.

Conclusion

Essential fats have been linked with several positive maternal and child health outcomes, but the consequences of inadequate essential fatty acid intake in low-income countries have received little attention. The few studies that have assessed dietary intake to date suggest that the diets of pregnant and lactating women and young children often do not meet essential fatty acid recommendations. Promotion of improved dietary practices among pregnant and lactating women, optimal feeding of children in the first two years of life, and policy actions to enhance the quality of dietary fats could improve the fatty acid status of vulnerable populations.

Figure 6: Breastmilk DHA content of women in different countries. Adapted from Michaelsen et al. (2011).



*The bars for these countries represent the averages of separate studies. The range of averages of breastmilk DHA content was 0.4-0.91% for the Dominican Republic, 0.20-0.34% for Nigeria, 0.15-0.35% for China, and 0.1-0.2% for South Africa.

There are large differences in breastmilk DHA content within and across countries, probably related to differences in maternal dietary fatty acid intakes.

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The Insight series of technical briefs addresses the continuum of care for good infant and young child feeding, from initiation of early and exclusive breastfeeding through complementary feeding in later infancy and the second year of life. Alive & Thrive aims to improve feeding practices during this critical period to save lives, prevent malnutrition, and promote optimal growth. Alive & Thrive is funded by the Bill & Melinda Gates Foundation and managed by FHI 360. Other members of the team include BRAC, GMMB, IFPRI, Save the Children, UC-Davis, and World Vision

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