Chapter 3

Importance of Omega-3 Fatty Acids for Adults and Infants

The typical North American diet is "deficient" in omega-3 fats and overly rich in omega-6 fats, an imbalance that may have long-term health consequences (107). This chapter describes the current levels of omega-3 and omega-6 fatty acids in the modern diet and discusses the recommended dietary intakes of alpha-linolenic acid (ALA) for adults and infants.

Today's Diet Compared with the Paleolithic Diet

Humans evolved on a diet different from today's typical North American diet. The diet of hunter-gatherers during the Paleolithic era, which lasted from about 2 million to 10,000 years ago, was lower in total fat and saturated fat and contained small but roughly equal amounts of omega-6 (n-6) and omega-3 (n-3) fatty acids, giving an n-6/n-3 ratio of about 1:1. Paleolithic humans ate diets containing appreciable amounts of omega-3 fats provided by plants, fish and the fat of wild game, which is particularly high in ALA compared with grain-fed livestock (108,109).

Technological developments over the last 100-150 years have contributed to a shift in fat consumption patterns. Specifically, our intake of omega-6 fatty acids has increased due to our consumption of corn, sunflower and soybean oils, margarines made from these vegetable oils and animal products derived from grain-fed, feedlot livestock (29). Compared with Paleolithic humans, today's North Americans live in a nutritional environment that is high in omega-6 fats and low in omega-3 fats, making our modern diet different from the one on which humans evolved (107).

Omega-6 Fatty Acids in the Modern Diet

Pregnant Canadian women consume roughly 8-11 g of linoleic acid (LA) per day and 1.3-1.6 g of ALA per day, as shown in **Table 8** (110,111). Their intakes of the long-chain omega-3 fatty acids are higher than those of U.S. adults, due possibly to their greater intakes of fatty fish or fish oil supplements.

The average intakes of linoleic acid among U.S. adults aged 20-59 years are 18 g/day for men and nearly 14 g/day for women (112). The average intake of ALA among U.S. men aged 20-59 years is 1.7 g/day; for women of the same age, it is 1.3 g/day. The average intakes of the long-chain omega-3 fatty acids are 0.11 and 0.15 g/day or 110 and 150 mg/day for U.S. women and men, respectively. These findings show the dominant position of linoleic acid in the Canadian and U.S. diets.

TABLE 8

Dietary intakes of major omega-6 and omega-3 fatty acids in Canada and the United States[a]

Country	Omega-6 fatty acid intake g/day	Omega-3 fatty acid intake g/day	
	Linoleic acid	ALA	Long-chain fatty acids (EPA, DHA and/or DPA)
Canada[b]	8.0 – 11.2	1.3 – 1.6	0.14 – 0.24
United States[c]			
Men	18.0	1.7	0.15
Women	13.9	1.3	0.11

[a] Abbreviations = ALA, alpha-linolenic acid; DPA, docosapentaenoic acid; DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid.
[b] Values are for pregnant women living in British Columbia and Ontario (110,111).
[c] Values are for men and women aged 20-59 years (112).

Dietary Ratio of Omega-6 to Omega-3 Fatty Acids

The dietary n-6/n-3 ratio affects inflammation and gene expression, thus influencing the development of chronic disease (107). This section summarizes information about the current and recommended dietary n-6/n-3 ratio, the n-6/n-3 ratio in flax, the consequences of eating a diet with a high n-6/n-3 ratio and the best way of improving the ratio.

Current ratio

The n-6/n-3 ratio may be as high as 17:1 in some Western diets (107). It is roughly 10:1 in the U.S. diet (113). In the Women's Health Study, participants had an average dietary ratio of ~8:1, although some women ate diets with a low ratio of about 1:1 while others ate diets with a high ratio of 33:1 (114). People with high intakes of meat, French fries, some fast-food products and foods fried in omega-6-rich vegetable oils will have a higher n-6/n-3 ratio than average.

Recommended ratio

The n-6/n-3 ratio recommended by international agencies and some European countries ranges from 4:1 to 10:1 (112). The U.S. Institute of Medicine (IOM) supports a ratio of 5:1 for the U.S. and Canadian populations (24).

Ratio in flax

ALA comprises about 57% of the total fatty acids in flax, whereas the omega-6 fatty acids comprise about 16%. Thus, flax contains more than three times as much omega-3 as omega-6 fatty acids, giving an n-6/n-3 ratio of 0.3:1 (11). By comparison, the n-6/n-3 ratio for corn oil is 58:1; for soybean oil, 7:1; and for canola oil, 2:1. The high level of ALA in flax makes it a good source of omega-3 fat in the North American diet. Consuming flax or foods rich in ALA, such as omega-3-enriched eggs derived from hens fed flax, increases omega-3 fat intake and improves the dietary n-6/n-3 ratio (115).

Consequences of a high ratio

One consequence of the dietary imbalance between omega-6 and omega-3 fats is a high ratio of omega-6 to omega-3 fatty acids in cell membranes (116). An imbalance in the n-6/n-3 ratio in tissues and blood can have adverse effects, including the overproduction of pro-inflammatory eicosanoids, many of which are derived from arachidonic acid, an omega-6 fatty acid. Excess eicosanoids, in turn, stimulate the release of inflammatory cytokines and acute-phase proteins. The end result is low-grade chronic inflammation that contributes to health problems such as atherosclerosis, Alzheimer disease, cancer, cardiovascular disease, metabolic syndrome, obesity, osteoporosis, type 2 diabetes and periodontitis (29,84,117,118). **Table 9** outlines some consequences of eating a diet rich in omega-6 fats versus the benefits of eating a diet rich in omega-3 fats.

A high dietary n-6/n-3 ratio has been linked with adverse clinical outcomes. The Women's Health Study (114), which is a randomized trial of 39,876 professional women, found that women with a high n-6/n-3 ratio (>15:1) had a more than two-fold greater prevalence of dry eye syndrome than women with a low ratio. Dry eye syndrome is a common eye condition that can result in damage to the eye surface; about 20-30 million people in the United States are estimated to have mild dry eye syndrome (119). In a study of bone health, a higher dietary n-6/n-3 ratio was associated with lower bone mineral density at the hip in older white men and women participating in the Rancho Bernardo Study in southern California (120).

TABLE 9

Comparison of health consequences of diets rich in omega-6 versus omega-3 fats[a]

CONSEQUENCES of eating a diet rich in omega-6 fats

INCREASES IN:

- n-6/n-3 ratio in cell membrane phospholipids
- production of arachidonic acid
- release of pro-inflammatory eicosanoids derived from arachidonic acid
- production of pro-inflammatory cytokines
- expression (activation) of pro-inflammatory genes
- biomarkers of inflammation such as C-reactive protein
- blood viscosity
- constriction of blood vessels
- oxidative modification of low-density lipoprotein (LDL) cholesterol

LEADS TO

HIGHER RISK of chronic diseases

BENEFITS of eating a diet rich in omega-3 fats

DECREASES IN:

- n-6 fatty acids in cell membranes
- n-6/n-3 ratio in cell membrane phospholipids
- levels of pro-inflammatory compounds like eicosanoids and cytokines
- clumping (aggregation) of blood platelets
- expression (activation) of pro-inflammatory genes
- biomarkers of inflammation such as C-reactive protein

INCREASE IN:

- production of interleukin-10, an anti-inflammatory cytokine

LEADS TO

LOWER RISK of chronic diseases

[a] Sources: Gebauer (112), Simopoulos (107).

Consult **Appendix D** for a description and examples of eicosanoids, cytokines, acute-phase proteins and other agents involved in inflammation.

The best way to improve the ratio

Restoring the n-6/n-3 ratio to a better balance will help reduce inflammatory reactions and decrease the risk of chronic disease (107). Improving the n-6/n-3 ratio can be achieved by decreasing the intake of omega-6 fats, increasing the intake of omega-3 fats or both. The easiest way to improve the n6/n-3 ratio is to eat more omega-3 fats such as those found in flax, walnuts, canola oil and fatty fish. (See page 42 for food sources of omega-3 fats.) A higher omega-3 fat intake will increase the total omega-3 fat content of tissues and blood and help reduce the risk of chronic disease (116).

ALA and Omega-3 Fat Intakes

The recommended dietary intakes of omega-3 fatty acids specified by the U.S. Institute of Medicine (IOM) in 2002 set the goal for preventing essential fatty acid deficiency and ensuring adequate intakes across the life span (24). Even though the ideal omega-3 fat intake level for treating and preventing chronic disease has not been determined, some experts have called for higher omega-3 fat intakes.

Recommended dietary intakes of ALA

The IOM set an Adequate Intake for ALA, based on the median daily intake of healthy Americans who are not likely to be deficient in this nutrient (24). (The IOM's recommendations apply to both the Canadian and U.S. populations.) The Adequate Intakes of ALA are shown in **Table 10**. The Adequate Intake is 1.6 g ALA per day for men and 1.1 g ALA per day for women. Pregnant women should consume 1.4 g ALA daily to meet the needs of the developing fetus. Lactating women should consume 1.3 g ALA daily to ensure an adequate concentration of this essential fatty acid in their breast milk. Up to 10% of the Adequate Intake for ALA can be provided by EPA and DHA.

Adequate Intakes were set only for ALA, not EPA and DHA. The reason for this is that, strictly speaking, ALA is the only true "essential" omega-3 fatty acid in our diet, being required in the foods we eat because our bodies cannot make it.

TABLE 10

Adequate Intakes of ALA for children, adolescents, adults and pregnant and lactating women[a]

Life Stage	Age	Adequate Intake of ALA
	years	grams/day
Children (both sexes)	1–3	0.7
	4–8	0.9
Boys and Men	9–13	1.2
	14–18	1.6
	19+	1.6
Girls and Women	9–13	1.0
	14–18	1.1
	19+	1.1
Pregnant	14–50	1.4
Lactating	14–50	1.3

[a]Source: Institute of Medicine (24).

Proposed higher intakes of omega-3 fats

In 1999, experts with the International Society for the Study of Fatty Acids and Lipids (ISSFAL) called for an ALA intake of 2.2 g/day (121). This proposed intake is roughly 40% more than the current Adequate Intake of ALA for men (1.6 g/day) and twice the current Adequate Intake of ALA for women (1.1 g/day).

A healthy dietary allowance of 3.5 g EPA + DHA /day has also been recommended for adults consuming a 2000 kcal diet (122). This dietary allowance is 20-30 times greater than the current Adequate Intake of EPA + DHA (expressed as 10% of the Adequate Intake of ALA). The allowance is estimated to reduce the risk of cardiovascular disease (CVD) and mental illnesses for more than 98% of the population and corresponds to the omega-3 fat intakes achieved by the Japanese, who are one of the healthiest people in the world and have a low mortality rate from CVD. The allowance can likely be reduced to 350 mg EPA + DHA/day if the intake of omega-6 fats is reduced to <2% of energy.

The American Heart Association advises consumers to eat fish, especially fatty or oily fish, at least twice per week. Patients with documented CVD should consume ~1 g of EPA + DHA daily, preferably from fatty fish (123).

Omega-3 Fatty Acids in Infant Formula

Experts agree that infant formulas should be designed to approximate the fatty acid composition of breast milk and include omega-3 fatty acids (124). Virtually all infant formulas contain ALA obtained mainly from soybean oil. Infants have a unique need for essential fatty acids, including ALA, which is the most prevalent omega-3 fatty acid in human milk (52,53), constituting between 0.5% and 2% of the total fatty acids in breast milk (86). Given the importance of all omega-3 fatty acids in the diets of infants, the IOM set an Adequate Intake of 0.5 g of omega-3 fatty acids per day during the first 12 months of life (24).

For term infants, ALA should constitute 1.75-4% of total fatty acids in infant formula. The LA:ALA ratio of infant formula should not be less than 6:1 or exceed 16:1 (125). For the past 5 years, two long-chain polyunsaturated fatty acids – namely, DHA and arachidonic acid – have been added to U.S. formulas (126). In Canada, the addition to infant formula of Martek's proprietary oils rich in DHA and arachidonic acid is allowed (127).

Preterm infants appear to have special dietary needs and benefit from nutritionally fortified breast milk (128). Recommendations for the fatty acid content of formulas intended for preterm infants weighing <1500 g have been made. The concentration of ALA in preterm infant formula should be 1.75-4% of total fatty acids. The LA:ALA ratio should not be less than 6:1 or more than 16:1. The maximum DHA concentration should be 0.35% of total fatty acids. The EPA concentration should be a maximum of 30% of the DHA concentration (129).

DHA Synthesis from ALA and Brain Development in Infants

Despite being the essential omega-3 fatty acid and the most prevalent omega-3 fat in breast milk, the role of ALA in infant brain development is not well understood. The main controversy is whether ALA conversion to DHA is sufficient to achieve adequate brain stores of DHA in the fetus and during early infancy (130,131). A recent analysis suggests that

traditional breastfeeding practices provide an adequate supply of essential fats for brain development (132). Variations in DHA availability for brain development are managed by buffering systems that include the infant's ability to take up omega-3 fats from maternal stores, store DHA in adipose tissue and convert ALA to DHA. According to Langdon (132), there is no evidence that the breast milk of women who eat diets consisting of terrestrial foods fails to provide adequate levels of omega-3 fats, including DHA, nor is there evidence that infants born to vegan or vegetarian mothers have deficits in brain development (131).

Food Sources of Omega-3 Fatty Acids

ALA is found in plants, animals, plankton and marine species (133). Up to 80% of the fatty acids in leafy green plants is in the form of ALA; but because their overall fat content is low, leafy plants do not contribute significant amounts of ALA to our diets (134). Flax is the richest source of ALA in the North American diet. ALA is also found in walnut oil, canola oil, olive oil, and soybean oil; in nuts such as butternuts and walnuts; in soybeans and pumpkin seeds; in omega-3-enriched eggs; and in purslane. Fish contain only trace amounts of ALA, although some species of fish, particularly fatty marine fish such as salmon, mackerel and herring, are rich in EPA and DHA (112, 122, 135). **Table 11** shows the ALA content of some foods. EPA and DHA are found mainly in fatty fish such as mackerel, salmon, tuna, herring, lake trout and anchovy (135). Other sources include fish oil capsules; marine algae, which are rich in DHA but contain negligible amounts of the other omega-3 fatty acids (136); and omega-3-enriched eggs derived from laying hens fed a ration containing either microalgae, which increase the DHA content of the yolk (137), or flax, which increases the ALA, DPA and DHA content of the yolk (138).

TABLE 11

Food sources of ALA[a]

Food	Serving size	ALA
		g
Fats and oils		
Perilla oil	1 tbsp	8.9[b]
Flax oil	1 tbsp	8.0[c]
Hemp oil	1 tbsp	2.8[d]
Milled flax	1 tbsp	1.8
Canola oil	1 tbsp	1.3
Soybean oil	1 tbsp	0.9
Olive oil	1 tbsp	0.1
Nuts		
Walnuts, English	1/2 oz	1.3
Butternuts, dried	1/2 oz	1.2
Eggs		
Chicken, omega-3-enriched	1 large	0.34[e]
Chicken, regular, large	1 large	0.02
Plants		
Soybeans, green, raw	1/2 cup	0.48
Purslane, cooked	1/2 cup	0.2
Meat and Poultry		
Beef, T-bone steak, broiled	3 oz	0.18
Pork, wiener	1 wiener	0.12
Beef, ground, patties, broiled	3 oz	0.07
Chicken, breast, roasted	1/2 breast	0.03
Fish and Shellfish		
Shrimp, breaded and fried	3 oz	0.23
Mackerel, cooked	3 oz	0.10
Salmon, cooked	3 oz	0.04

[a] Unless otherwise noted, data were obtained from the U.S. Department of Agriculture (44).
[b] Nettleton JA. 1991. ω-3 Fatty acids: comparison of plant and seafood sources in human nutrition. J. Am. Diet. Assoc. 91: 331-337.
[c] Flax Council of Canada (11).
[d] Crew S. [Personal communication, 2003]. Hemp Oil Canada. Ste. Agathe, MB.
[e] Average of five brands of omega-3-enriched eggs. Flax Council of Canada. 2003. The novel egg: opportunities for flax in omega-3 egg production. Flax Council of Canada, Winnipeg, MB.