NutritionX

The Nutrition X—CHANGE

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OMEGA-3 POLYUNSATURATED FATTY ACIDS

A detailed look at omega-3 fatty acids and their impact on physical performance

Lana Ramić and Chris Mcglory

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Practical Implications

- Omega-3 fatty acids are polyunsaturated fatty acids that play important structural and signalling roles in the heart, muscle, and nervous system.
- Omega-3 fatty acids are an essential requirement in food intake with the need to consume ~ 250-500mg/day. This can be achieved by two servings of oily fish per week for adults above 14 years.
- Omega-3 fatty acids improve markers of muscle recovery, although there is little evidence that omega-3 fatty acid supplementation directly improves athletic performance.
- Omega-3 fatty acid intake may decrease muscle loss during immobilization and recovery from injury.
- Omega-3 fatty acids are an essential nutrient, and athletes who are deficient may benefit from increasing intake through food or supplementation.

What are omega-3 fatty acids?

Omega-3 fatty acids are polyunsaturated fatty acids that serve as components of phospholipids in cellular membranes and act as precursors for the synthesis of anti-inflammatory signaling molecules. The most well-known omega-3 fatty acids are alpha-linolenic acid (ALA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA). ALA is an essential fatty acid as it cannot be made by the body – it must be consumed in the diet. Both EPA and DHA are synthesized from ALA, however, the conversion of EPA and DHA from ALA is limited to ~ 8% and ~4% in men and ~21% and ~9% in women, respectively.[1] Therefore, EPA and DHA are referred to as 'conditionally essential' and should also be obtained from the diet. Intake of these omega-3 fatty acids and their subsequent incorporation into biological tissues such as the heart,[2] skeletal muscle,[3] and brain[4] are associated with improved health. The health promoting effects of omega-3 fatty acids can be attributed to their distinct chemical structure, see Figure 1.

How much omega-3 fatty acids should be consumed?

Most nutrient values are provided as a Recommended Dietary Allowance (RDA) that aim to prevent deficiencies in 97-98% of the population. An Adequate Intake (AI) is a recommendation made when there is insufficient scientific evidence to form an RDA. In the case of omega-3 fatty acids, there is an AI but not an RDA. For ALA, the AI for males and females above the age of 14 years is 1.6 g/day and 1.1 g/day, respectively.[5] There are no dietary reference intake recommendations for EPA and DHA, but it is generally advised to consume between 250-500 mg/day of combined EPA+DHA in adults, or about 2 servings of oily fish (100 g each) per week.[6–9] It is important to note that the RDA and AI aim to combat deficiency in the population and are not designed to achieve optimal health. Although there is now growing evidence that short-term intake of omega-3 fatty acids above the AI could be beneficial, especially for skeletal muscle. [3]

Ingesting the AI of omega-3 fatty acids does not necessarily require supplementation, and a 'food first' approach is the preferred method for obtaining essential nutrients.[10] Many studies have observed that a large part of the Western diets fail to obtain adequate levels of omega-3 fatty acids from diet,[11,12] despite about 40% of individuals self-reporting consuming the suggested 2 servings of fish per week. Notably, a 2020 survey of 1,528 Division I collegiate athletes in the United States found that

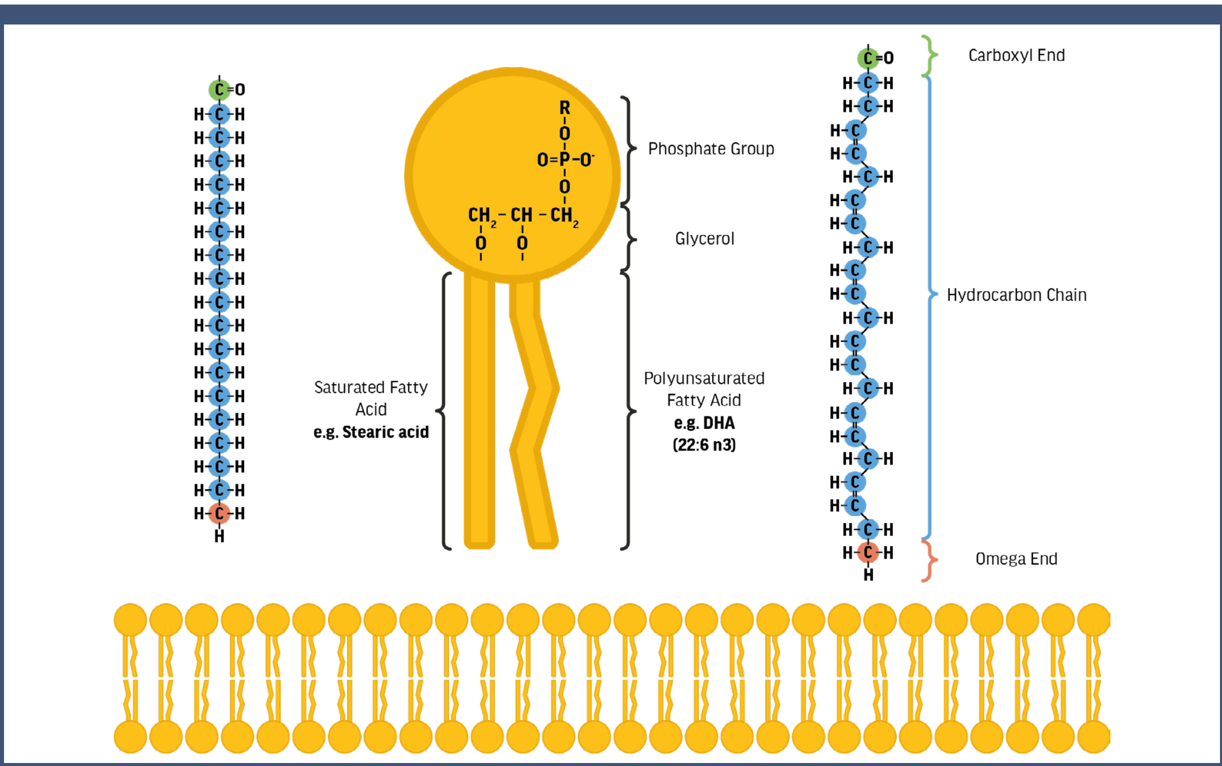

Figure 1. The chemical structure of a phospholipid containing a saturated fatty acid, stearic acid, and an omega-3 polyunsaturated fatty acid, docosapentaenoic acid (DHA). Phospholipids are components of cellular membranes that form a barrier between cells and the external environment. They are composed of a phosphate group and glycerol head and two fatty acid tails. Saturated fatty acids have no carbon-carbon double bonds, forming a straight chain. In contrast, omega-3 fatty acids such as DHA have double bonds, which add 'kinks' to the tail. These 'kinks' increase membrane order influencing intracellular signaling. The fatty acid chemical notation 22:6 n3 refers to the total number of carbon atoms (22), the number of carbon-carbon double bonds (6), and the position of the first double bond from the omega end (3).

only 6% were obtaining 500 mg EPA and DHA per day.[13] Since it may not be tolerable or financially accessible to obtain sufficient amounts of omega-3 fatty acids at all meals (e.g., salmon for breakfast), supplementation could be a practical alternative to the recommended food-based approach, particularly for those who prefer not to consume seafood.

Omega-3 fatty acids in foods.

The most common sources of ALA are in plants such as chia and flax seeds, while EPA and DHA are mainly found in algae and fish. Table 1 lists some of the most common omega-3 fatty acid sources.[14] Importantly, omega-3 fatty acids can also be found in food sources that contain high quality proteins as well as the branched chain amino acid leucine, which is critical for the stimulation of muscle protein synthesis.[15]

If adequate omega-3 fatty acid intake cannot be achieved with food intake, supplementation should be considered. As the majority of omega-3 fatty acid supplements traditionally consist of fish oils such as cod, anchovies, or sardines, consuming fish products may be problematic for vegetarians or vegans. People observing strict diets or with allergies to fish may consume omega-3 fatty acids as ALA in plant sources or as supplements made from algal oil, containing EPA and DHA from algae. Plant sources of omega-3 fatty acids (excluding algae) tend to be deficient in some essential amino acids and should be complemented with complete protein sources or a variety of plant-based proteins for maximal benefit.

What are the benefits to consuming omega-3 fatty acids?

Cardiovascular health. The most common health benefit linked with omega-3 fatty acid intake is improved cardiovascular health.[16] The association between omega-3 fatty acid intake and cardiovascular health has led to the development of what is known as the 'omega-3 index'. The omega-3 index was established by Harris and Von Schacky in 2004[2] and is an estimate of red blood cell membrane EPA + DHA composition as a function of total fatty acids. Levels under 4% EPA + DHA of total fatty acids are suggested to be associated with the most risk of coronary heart

Table 1. Food Sources of Omega-3 Fatty Acids

Food Source	Serving Size	EPA	DHA	ALA	Protein	Leucine
		mg/serving*		g/serving*		
Chia seeds	30 g (3 tbsp)	-	-	4.9	2.0	0.4
Hemp seeds (hulled)	30 g (3 tbsp)	-	-	2.6	9.5	0.6
Flax seed (whole)	10 g (1 tbsp)	-	-	2.9	1.8	0.6
Flax seed oil	14 g (1 tbsp)	-	-	7.3	-	-
Canola oil	14 g (1 tbsp)	-	-	1.3	-	-
Edamame	100 g	-	-	0.4	10.9	0.8
Salmon (wild)	100 g	320	1120	0.3	19.8	1.6
Salmon (farmed)	100 g	860	1100	0.2	20.4	1.6
Mussels (blue)	100 g	22	250	-	23.9	0.8
Oysters (wild)	100 g	180	140	0.1	5.7	0.4
Mackerel	100 g	210	1400	-	18.6	1.5
Herring	100 g	710	860	0.1	18.0	1.5
Trout (rain-bow, wild)	100 g	170	420	-	20.5	1.7

*Typical estimated composition in g/serving, however, these values may be affected by source and cooking method.14

disease outcomes, whereas 4-8% presents moderate risk, and over 8% is lowest risk.[17] A recent study found that the average omega-3 index of collegiate athletes is about 4.4%,[18] suggesting that atheltes may benefit from increasing omega-3 fatty acid intake. It is important to note that the link between the omega-3 index and improved cardiovascular health is mostly supported by epidemiological evidence, which does not represent true cause and effect.[16] Moreover, the omega-3 index was developed primarily from case controlled studies in middle-aged to older adults who already possess one or more cardiometabolic risk factors. Thus, the applicability of the omega-3 index to improve cardiovascular health outcomes in younger, athletic individuals, should be interpreted with caution.

Skeletal muscle. Although many studies have focused on omega-3 fatty acid intake to enhance cardiovascular health, evidence is emerging to suggest omega-3 fatty acid intake may also impact skeletal muscle. It takes ~2 weeks from commencement of omega-3 fatty acid supplementation (~5g/d) to detect changes in in the omega-3 fatty acid content of skeletal muscle and this plateaus at ~ 8 weeks (see Figure 2).[19,20] There are reports of increased expression of anabolic signaling molecules,[19] potentiated rates of muscle protein synthesis in response to amino acid infusion,[21] faster oxygen kinetics during endurance exercise,[22,23] and reduced content of markers of inflammation following omega-3 fatty acid intake.[24] Recent reviews of the literature also suggest that omega-3 fatty acid intake may enhance recovery from 'physiological stress' as well as elements of cognition such as reaction time and memory.[25,26] One area of particular interest is the impact of omega-3 fatty acid intake on protection against exercise-induced muscle damage with some studies demonstrating that omega-3 fatty acid ingestion attenuates reductions in muscle strength and subjective measures of soreness following damaging exercise.[25] However, studies that demonstrate an ergogenic effect of omega-3 fatty acids on markers of muscle damage often employ an exercise protocol specifically designed to induce muscle damage (i.e., repeated eccentric contractions) that is not reflective of real-world practice.[27] There is also very limited evidence that alterations in markers of physiological stress and soreness following omega-3 fatty acid supplementation translate to impoved endurance or strength performance. The conflicting findings regarding the role of omega-3 fatty acids in promoting exercise performance are compounded by the knowledge that omega-3 fatty acid supplementation fails to potentiate rates of muscle protein synthesis following resistance exercise and protein feeding-not infusion- in young men.[28]

One conspicuous observation of many studies in this area is the lack of female participants. One study in older adults has shown superior strength gains in response to 18 weeks of resistance exercise and omega-3 fatty acid supplementation in women compared to men.[29] Whether the same is true in younger women remains unknown but leaves the possibility that female atheltes may benefit from higher intakes of omega-3 fatty acids compared to males. The exact mechanisms as to why older women appear to benefit from omega-3 fatty acids to a greater extent than older men in this context is unknown. More work examining the impact of

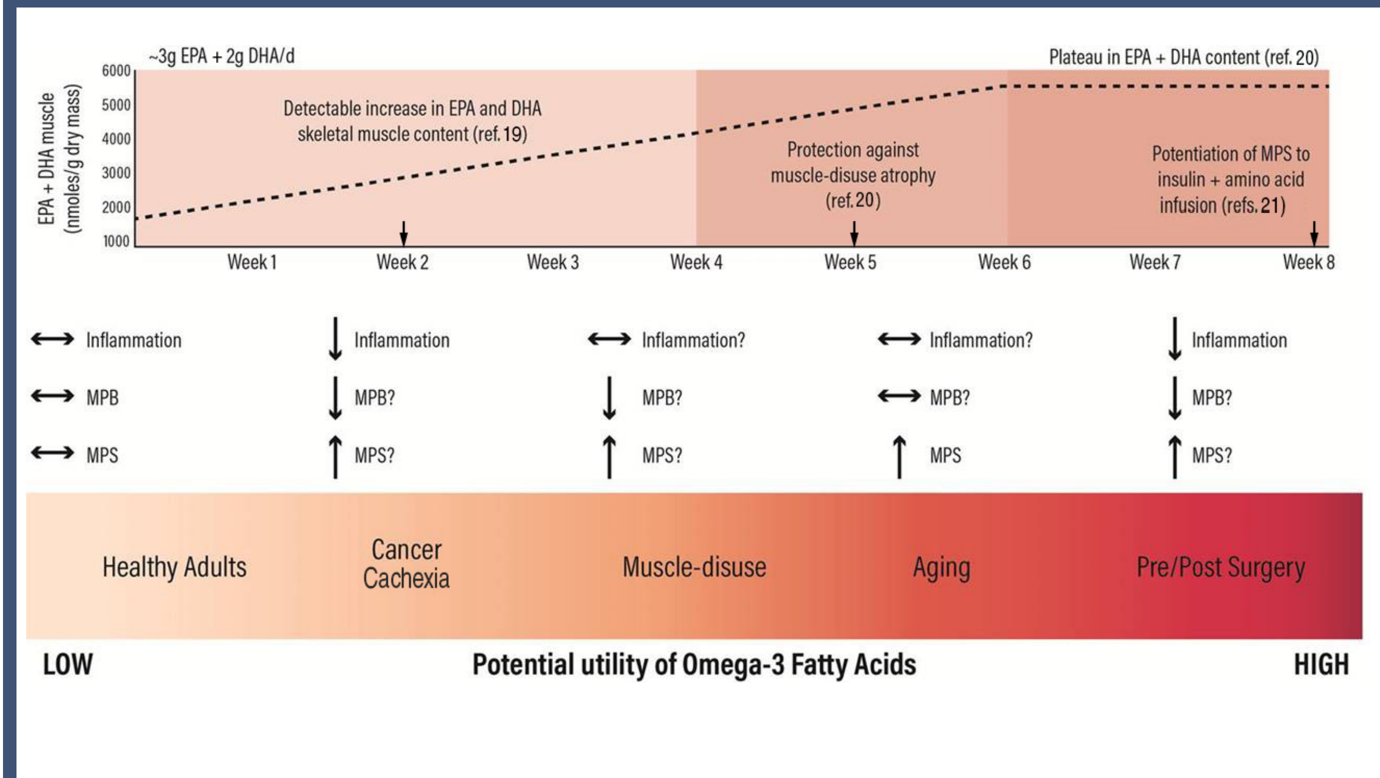

Figure 2.Top panel highlights the time-course in skeletal muscle EPA/DHA content following omega-3 fatty acid supplementation. Note that it could take up to 6 weeks for peak omega-3 fatty acid content to occur. Bottom panel, potential therapeutic outcomes of omega 3 supplementation in differing populations. Note that the differing populations may benefit in different ways to omega-3 fatty acid supplementation. MPS = muscle protein synthesis, MPB = muscle protein breakdown. Adapted from McGlory et al (2019) [3]

omega-3 fatty acids on training-induced adaptations or athletic performace in both women and men is now needed.

Can omega-3 fatty acids influence recovery from injury?

Perhaps the most exciting area of omega-3 fatty acid therapy is in recovery from injury. Unlike resistance exercise (which is a potent stimulus for muscle growth) periods of muscle unloading or limb immobilization result in a reduction in rates of muscle protein synthesis and muscle-disuse atrophy. Initial work in rodents has shown that the provision of omega-3 fatty acids protected against muscle-disuse atrophy, which was linked to activation of signals known to regulate muscle protein synthesis.[30] There is now evidence that omega-3 fatty acid ingestion may also alleviate immobilization-induced muscle loss in young women.[20] Specifically, 4 weeks of 5g/d omega-3 fatty acid supplementation (~3g EPA+ ~2g DHA) reduced losses in muscle mass and MRI-measured muscle size in response to 2 weeks of single leg immobilization in young women. The protective effect of omega-3 fatty acids towards skeletal muscle was linked to reduced losses in mitochondrial protein content and respiration kinetics.[31] Critically, those in the omega-3 fatty acid group recovered these losses after 2 weeks of return to normal activity whereas those in the control group were only partially recovered. These studies[3,20,31] suggest that supplementation with omega-3 fatty acids could mitigate decrements in muscle mass/size during injury and promote return to play. These studies were conducted in healthy young women in the absence of a hyper-inflammatory state, which often accompanies injury/surgery. Whether these effects are the same in men or following injury in the presence of a pro-inflammatory state remains unknown.

What are the risks of taking omega-3 fatty acid supplements?

In large-scale reviews, risks of omega-3 fatty acid supplementation are mild and only occur in a small portion of the study sample.[25,26] Mild gastrointestinal effects that could occur include belching, fishy taste, and nausea.[16,32,33] In contrast to popular belief, there is no increased risk of bleeding during or after surgery even with high-dose omega-3 fatty acid supplementation.[34,35] Another anecdotal side effect of omega-3 fatty acid supplementation is an increase in overall calorie intake and the potential for body mass gain. However, supplementation with omega-3 fatty acids is unlikely to contribute to body mass gain due to the small overall calorie contribution (5g/d ~45 kCal). It is also important to consider supplement quality since a sample of 70% of fish oil supplements in the United States do not contain the amounts of EPA and DHA that are stated on the label.[36] Similarly, some supplements may also be contaminated by toxic ingredients and controlled substances that are prohibited according to the World Anti-Doping Agency guidelines. Athletes competing under doping regulations should be aware of the risk of consuming low-quality supplements and always seek advice from suitably qualified practitioners prior to engaging in any supplementation protocol and ensure that all supplements are independently batch-tested for contaminants. It should also be noted that it can take up to 6 weeks for peak EPA / DHA content to occur following omega-3 supplementation (Figure 2) which should be taken into consideration when evaluating the effects of omega-3 supplementation.

Conclusion

Omega-3 fatty acids are essential nutrients that contribute to the optimal functioning of the heart, nervous system, and skeletal muscle with therapeutic potential in many population groups (Figure 2). Omega-3 fatty acid sources include fish such as mackerel, salmon, or herring, or plant-based sources such as flax and hemp seeds. Recent evidence suggests that some atheltes may not be consuming the AI for omega-3 fatty acids, increasing the risk of deficiency. Two servings of fish per week should provide an adequate intake of ALA, EPA and DHA for healthy adults. For athletes, supplementation with omega-3 fatty acids likely provides no benefit to sports performance. In scenarios of injury recovery that require periods of immobilization, increasing omega-3 fatty acid intake may help decrease the rate of muscle loss.

Author bio

Lana Ramić B.Sc

Lana Ramić is a recent graduate of the School of Kinesiology and Health Studies at Queen's University. She is currently working with Dr. McGlory on projects related to omega-3 fatty acids and muscle protein. Lana is interested in investigating the effects of omega-3s in athletic, adult, and elderly populations. In September 2020, she will be starting at the University of Ottawa's School of Medicine to pursue her medical degree.

Chris McGlory Ph.D

Dr. Chris McGlory is currently an Assistant Professor at Queen's University, Canada having completed Postdoctoral Fellowships with Prof. Stuart Phillips at McMaster University, Canada. Chris' lab focuses on how dietary protein and fatty acid intake modulate the adaptive response of skeletal muscle to exercise and periods of muscle-disuse. Chris has published over 50 scientific papers related to this work and has delivered numerous invited national and international presentations at many prestigious scientific meetings (American College of Sports Medicine, European Society for Clinical Nutrition and Metabolism, Gatorade Sports Science Institute, Europhysiology).

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