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The role of omega-3 fatty acids in cardiovascular health

Miguel A Costa
Department of Biomedical Sciences, University of São Paulo, São Paulo, Brazil

Abstract
Omega-3 fatty acids are polyunsaturated fatty acids that play a critical role in human health, particularly in cardiovascular health. This review paper explores the sources, mechanisms, and clinical benefits of omega-3 fatty acids, focusing on their impact on cardiovascular disease (CVD) prevention and management. The paper examines the biochemical properties of omega-3 fatty acids, their anti-inflammatory and anti-thrombotic effects, and the outcomes of major clinical trials. Additionally, it discusses dietary recommendations, potential risks, and future research directions in the field of omega-3 fatty acids and cardiovascular health.

Keywords: Eicosanoids, cardiovascular, alpha-linolenic

Introduction
Cardiovascular diseases (CVDs) are the leading cause of mortality worldwide. Among various dietary components, omega-3 fatty acids have garnered significant attention for their potential cardioprotective effects. Omega-3 fatty acids, particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), are primarily found in fatty fish and fish oil supplements. Alpha-linolenic acid (ALA), another omega-3 fatty acid, is present in plant sources like flaxseeds and walnuts. This review aims to provide a comprehensive overview of the role of omega-3 fatty acids in cardiovascular health.

Main objective
The main objective of this paper is to comprehensively review the role of omega-3 fatty acids in cardiovascular health, including their biochemical properties, dietary recommendations, potential risks, and future research directions.

Biochemical Properties of Omega-3 Fatty Acids
Omega-3 fatty acids are essential polyunsaturated fatty acids that are critical for human health, particularly in relation to cardiovascular function, brain health, and inflammation. They are characterized by the presence of multiple double bonds in their chemical structure, with the first double bond located at the third carbon atom from the methyl end of the fatty acid chain. The most biologically significant omega-3 fatty acids include alpha-linolenic acid (ALA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA). ALA, an 18-carbon fatty acid with three double bonds (18:3n-3), is primarily found in plant oils such as flaxseed, soybean, and canola oils. It is considered an essential fatty acid because the human body cannot synthesize it de novo, meaning it must be obtained through the diet. ALA serves as a precursor to the longer-chain omega-3 fatty acids, EPA and DHA, though the conversion rate of ALA to these more biologically active forms is relatively low in humans. This conversion is limited by several factors, including the availability of enzymes such as delta-6-desaturase and elongase, which are also required for the metabolism of omega-6 fatty acids, leading to competition between these pathways. EPA, a 20-carbon fatty acid with five double bonds (20:5n-3), is predominantly found in marine sources such as fatty fish (salmon, mackerel, sardines) and fish oil supplements. EPA is involved in the production of eicosanoids, which are signaling molecules that play vital roles in inflammation and immunity. EPA-derived eicosanoids, including prostaglandins, thromboxanes, and leukotrienes, are generally less inflammatory compared to those derived from arachidonic acid, an omega-6 fatty acid. This shift in the balance of eicosanoid production is one mechanism by which omega-3 fatty acids exert their anti-inflammatory effects. DHA, a 22-carbon fatty acid with six double bonds (22:6n-3), is also found in marine sources and is particularly abundant in fish oils. DHA is a critical component of cell membranes, especially in the brain and retina, where it contributes to membrane fluidity and function. DHA is involved in the production of neuroprotective and anti-inflammatory mediators known as docosanoids, which include resolvins, protectins, and maresins. These specialized pro-resolving mediators (SPMs) help to terminate inflammatory responses and promote tissue repair and regeneration, highlighting the importance of DHA in maintaining neural health and resolving inflammation. The structural features of omega-3 fatty acids, such as their multiple double bonds, confer distinct physical properties. For instance, the presence of these double bonds makes omega-3 fatty acids more prone to oxidation, which can be both beneficial and detrimental. On the one hand, the oxidized metabolites of omega-3 fatty acids, such as SPMs, play crucial roles in resolving inflammation. On the other hand, excessive oxidation can lead to the formation of harmful free radicals and lipid peroxides, necessitating the need for antioxidants in the diet to mitigate these effects. Omega-3 fatty acids are incorporated into phospholipids in cell membranes, influencing membrane fluidity, receptor function, and the activity of membrane-bound enzymes. This incorporation is vital for various physiological processes, including signal transduction, gene expression, and cellular communication. For example, DHA is highly concentrated in the phospholipids of the brain and retinal cells, where it supports cognitive function and visual acuity. The bioavailability and metabolism of omega-3 fatty acids can be influenced by several factors, including the form in

which they are consumed. Omega-3 fatty acids in the form of triglycerides, as found in fish and fish oils, are more efficiently absorbed compared to ethyl ester forms commonly found in some supplements. Once absorbed, omega-3 fatty acids are transported in the bloodstream by lipoproteins and are selectively taken up by tissues based on their metabolic needs. In summary, omega-3 fatty acids possess unique biochemical properties that contribute to their significant roles in human health. The structural characteristics of ALA, EPA, and DHA allow them to participate in various biochemical pathways, producing anti-inflammatory and neuroprotective mediators and integrating into cell membranes to influence cellular functions. Understanding these properties and their physiological implications underscores the importance of adequate omega-3 fatty acid intake through diet or supplementation for optimal health, particularly in the prevention and management of cardiovascular diseases and inflammatory conditions.

Dietary Recommendations

Omega-3 fatty acids are essential polyunsaturated fatty acids known for their significant health benefits, particularly in cardiovascular health. Given their importance, several health organizations have established dietary recommendations to ensure adequate intake of these nutrients. These recommendations are based on extensive research and vary depending on the population group and individual health conditions.

For the general population, the American Heart Association (AHA) recommends consuming fatty fish at least twice a week. This translates to an intake of approximately 500 milligrams (mg) per day of combined eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), the two most crucial omega-3 fatty acids found predominantly in marine sources. Fatty fish such as salmon, mackerel, sardines, and herring are particularly rich in EPA and DHA. In addition to marine sources, plant-based sources such as flaxseeds, chia seeds, walnuts, and canola oil provide alpha-linolenic acid (ALA), another omega-3 fatty acid that can be partially converted to EPA and DHA in the body, although this conversion rate is relatively low.

The Dietary Guidelines for Americans suggest a daily intake of about 1.1 grams of ALA for adult women and 1.6 grams for adult men. While ALA is beneficial, direct consumption of EPA and DHA is more effective in ensuring the body's omega-3 needs are met due to the limited conversion efficiency of ALA to EPA and DHA. Therefore, incorporating both plant-based and marine sources into the diet is recommended to achieve a balanced intake of omega-3 fatty acids.

Pregnant and lactating women have specific nutritional needs, particularly for DHA, which is crucial for fetal brain and eye development. Studies have shown that adequate DHA intake during pregnancy is associated with better visual and cognitive outcomes in infants. Health organizations, including the AHA, recommend that pregnant and lactating women consume at least 200-300 mg of DHA daily. This can be achieved through the consumption of DHA-rich foods like fish and DHA-fortified products, or through supplementation if dietary intake is insufficient.

Individuals with existing cardiovascular conditions or those at high risk for cardiovascular disease may benefit from higher intakes of omega-3 fatty acids. Clinical studies have demonstrated that omega-3 fatty acids can significantly reduce the risk of cardiovascular events such as heart attacks and strokes. For example, the GISSI-Prevenzione trial and the JELIS trial both reported significant reductions in cardiovascular mortality and major coronary events with omega-3 supplementation. Consequently, the AHA suggests that individuals with coronary heart disease consume about 1 gram per day of EPA and DHA combined, preferably from fish. For those with elevated triglyceride levels, higher doses ranging from 2 to 4 grams per day of EPA and DHA may be recommended under medical supervision.

For vegetarians and vegans, who may not consume fish or other marine sources of omega-3s, achieving adequate intake can be challenging. Plant-based sources of ALA, such as flaxseeds, chia seeds, and walnuts, are important dietary components. However, due to the low conversion rate of ALA to EPA and DHA, algae-based supplements that provide direct sources of EPA and DHA are highly recommended for these populations. Research has shown that these supplements can effectively raise blood levels of EPA and DHA, similar to fish oil supplements.

Incorporating omega-3 fatty acids into the diet can be done through various practical approaches. Regular consumption of fatty fish, inclusion of ALA-rich plant foods, and the use of omega-3 supplements when necessary are all effective strategies. Additionally, many food products are now fortified with omega-3s, providing convenient options to boost intake.

While omega-3 fatty acids are generally safe and beneficial, it is important to be aware of potential risks associated with excessive intake. High doses of omega-3 supplements, particularly those exceeding 3 grams per day, can increase the risk of bleeding, especially in individuals taking anticoagulant medications. Additionally, some fish oil supplements may contain contaminants like mercury and polychlorinated biphenyls (PCBs). Therefore, choosing high-quality, purified supplements is essential to minimize these risks.

In conclusion, omega-3 fatty acids play a critical role in maintaining cardiovascular health and overall wellness. Dietary recommendations emphasize the importance of consuming a variety of sources, including fatty fish and plant-based options, to ensure adequate intake. Specific populations, such as pregnant women and individuals with cardiovascular disease, may require higher intakes to meet their unique health needs. By following these recommendations and incorporating practical dietary strategies, individuals can effectively enhance their omega-3 fatty acid intake and enjoy the associated health benefits. Continued research will further refine these recommendations, ensuring they are based on the latest scientific evidence.

Conclusion

Omega-3 fatty acids play an indispensable role in promoting cardiovascular health and overall well-being. Extensive research has elucidated the biochemical properties of omega-3 fatty acids, particularly EPA and DHA, highlighting their anti-inflammatory, anti-thrombotic, and lipid-lowering effects. These mechanisms underpin the significant cardioprotective benefits observed in numerous clinical studies, where omega-3 supplementation has been associated with reductions in cardiovascular events, improved lipid profiles, and enhanced endothelial function.

The dietary recommendations for omega-3 fatty acids emphasize the importance of incorporating both marine and plant-based sources to achieve a balanced intake. Health organizations recommend consuming fatty fish at least twice a week, alongside ALA-rich plant foods, to ensure adequate levels of EPA and DHA. Specific populations, such as pregnant and lactating women, individuals with cardiovascular disease, and those following vegetarian or vegan diets, have tailored recommendations to address their unique needs.

Despite the clear benefits, the optimal dosage and form of omega-3 supplementation remain areas of ongoing research. Discrepancies in clinical trial outcomes suggest that factors such as baseline dietary intake, dosage, and study population characteristics can influence the efficacy of omega-3 interventions. Additionally, potential risks associated with high-dose supplementation, such as bleeding complications, necessitate careful consideration and guidance from healthcare professionals.

Future research should focus on refining our understanding of the dose-response relationships of omega-3 fatty acids, exploring the genetic factors that influence individual responses, and investigating the long-term effects of omega-3 supplementation. Moreover, advancements in biotechnology and food science hold promise for developing more effective and sustainable sources of omega-3s, such as algae-based supplements and genetically modified crops.

In summary, omega-3 fatty acids are a vital component of a heart-healthy diet. By adhering to dietary recommendations and integrating omega-3-rich foods and supplements into daily routines, individuals can significantly reduce their risk of cardiovascular diseases and enhance their overall health. As the scientific community continues to unravel the complexities of omega-3 fatty acids, these insights will pave the way for more personalized and effective dietary strategies, ultimately improving public health outcomes worldwide.

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