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Review

Stearidonic acid as a supplemental source of ω-3 polyunsaturated fatty acids to enhance status for improved human health

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ABSTRACT

There is substantial evidence to show that consumption and increased blood levels of the very long-chain (VLC) ω-3 polyunsaturated fatty acids (ω-3 PUFAs) eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are associated with health benefits. The consumption of oily fish is an effective way of increasing EPA and DHA intake and status, but intake in most Western countries remains below the levels recommended for optimal health. The reasons for this include not liking the taste, a concern about sustainability of fish supplies, or potential chemical and heavy metal contamination. Alternative dietary sources of ω-3 fatty acids to enhance EPA and DHA status in the body would therefore be beneficial. There are many non-fish food sources of the essential plant-derived ω-3 fatty acid α-linolenic acid, but conversion from this to longer-chain EPA and especially to DHA is poor. Stearidonic acid (SDA) is an intermediate fatty acid in the biosynthetic pathway from α-linolenic acid to VLC ω-3 PUFAs and the conversion from SDA is more efficient than from α-linolenic acid. However, there are few food sources rich in SDA. Oil crops naturally rich in SDA or enriched through genetic modification may offer an alternative supplemental oil to boost the population status of VLC ω-3 PUFAs. This review discusses the currently available evidence that increased SDA consumption can increase red blood cell EPA content, although this is less than the effect of supplementation directly with EPA. There is now a need for trials specifically designed to assess whether an increased SDA consumption would translate into improved human health outcomes.

Introduction

A large body of evidence from epidemiologic studies and randomized controlled trials (RCTs) has indicated that a high consumption of the very long-chain (VLC) ω-3 polyunsaturated fatty acids (PUFAs) eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) lowers cardiovascular disease (CVD) morbidity and mortality [1–3]. It may also improve inflammatory conditions such as arthritis [4] and aid in eye and brain development [5]. The best dietary source of these fatty acids is oily fish [6]. However, oily fish consumption in the UK [7] and most other Western countries [8] remains low. α-Linolenic acid (ALA), the most abundant non-fish ω-3 fatty acid, can be converted in the body into EPA and DHA. However, conversion, especially to DHA, appears to be poor [9,10]. Evidence is emerging that another plant-based ω-3 fatty acid, stearidonic acid (SDA), is more efficiently converted to EPA in the body than ALA [11–13] and may therefore provide a superior strategy than ALA to increase levels of EPA in the body. This review discusses the gap between EPA and DHA intake and the levels required for optimal human health and considers SDA as a potential supplemental source of ω-3 fatty acids to increase levels of VLC ω-3 PUFA, especially EPA.

How much VLC ω-3 PUFAs should we consume?

Evidence from many prospective cohort-based studies has pointed to a beneficial effect of ω-3 PUFAs, especially VLC ω-3

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PUFAs, with increased intake [14–16]. A systematic review of 11 prospective cohort studies found that increasing fish consumption decreased the risk of coronary heart disease mortality in a dose-dependent manner such that each increment of 20 g/d of fish consumed could lower mortality rates by 7% [17]. This was extended in a population of high fish consumers from Japan (highest quintile at least eight portions/week), which found a strong inverse association between fish intake and cardiac events, such that those who consumed at least eight portions of fish per week had an approximately 40% lower risk of fatal and non-fatal coronary heart disease [18]. In a population-based case–control study, the risk of primary cardiac arrest was significantly decreased by an incremental increase in dietary intake of VLC ω-3 PUFAs up to a level that equated to one portion of oily fish per week, and this was reflected in a significant risk decrease with an incremental increase in red blood cell VLC ω-3 PUFAs [19]. A meta-analysis of cohort and RCT data concluded that 0.25 g of VLC ω-3 PUFAs (equivalent to less than one serving of fish per week) was sufficient to decrease the risk of coronary artery disease [20]. In some trials a minimum dose of 1 g/d has been suggested for a demonstrable decrease in other CVD risk factors [7], although a meta-analysis of RCTs was unable to detect a dose–response for a decrease in CVD events [21]. In a systematic review of RCTs investigating the triacylglycerol-lowering effects of VLC ω-3 PUFAs, an approximately linear dose–response effect was observed up to an intake of 3 g/d [22].

This brief overview of the scientific literature highlights the discrepancies in the amounts of VLC ω-3 PUFAs that are estimated to be required for optimum health benefits. Current dietary recommendations in the UK advocate consumption of at least two portions of fish per week, one of which should be oily [7]. This equates to a minimum VLC ω-3 PUFA intake of 0.45 g/d [7]. The European Food Standards Authority (EFSA) used a value of 0.25 g/d as the reference intake value for the VLC ω-3 PUFAs (EPA + DHA), from which the food labeling regulations for the European Union were set [23]. An increased proportional intake of ALA, the most common ω-3 PUFA in the diet, is also recommended based on apparent benefits for cardiovascular health and neurodevelopment [24,25]. An ALA value of 2 g/d was used by the EFSA as the reference intake value on which the labeling guidelines for ω-3 fatty acids were based [26]. The World Health Organization and the 2010 Dietary Guidelines of the US have recommended a minimum VLC ω-3 PUFA intake of 0.25 g/d [27]. However, any increase in VLC ω-3 PUFA intake at the population level is anticipated to produce health benefits such as a decrease in population coronary heart disease incidence [7].

Consumption of VLC ω-3 PUFAs

The average consumption of fish in adults (19–64 y old) in the UK is 37 g/d, of which 11 g/d is oily fish. This equates to ∼0.2 g/d of VLC ω-3 PUFAs. Intakes are much lower in children, with average fish consumptions of 20 g/d in 4- to 10-y-olds and 13 g/d in 11- to 18-y-olds, of which 3 and 2 g/d (respectively) are oily fish. This equates to ∼0.04 g/d of VLC ω-3 PUFAs, which, on a population level, is below that recommended for optimal health [7,28]. However, the mean intake of VLC ω-3 PUFAs may not be very representative of the overall consumption in the population because only 23% of adults (19–64 y old), 8% of children 11 to 18 y old, and 11% of children 4 to 10 y old reported consuming oily fish in the most recent National Diet and Nutrition Survey (NDNS) for the UK [28]. However, these data were collected using 4-d food diaries, and it is difficult to accurately capture fish intake over such a short period of recording because of the sporadic nature of its consumption. It is even harder to estimate VLC ω-3 PUFA intake because of the large variability between species of fish, between farmed and wild fish, diet of the fish, and seasonality [29–33], as illustrated in Figure 1. Australian data showed a mean intake of EPA and DHA in adults of 188 mg/d with a median intake of 29 mg/d, reflecting the skewed distribution of intake [34].

The low consumption of oily fish and, hence, of VLC ω-3 PUFAs may be due to overall food habits; 2% of children and adults surveyed in the recent NDNS were classified as vegetarian or vegan [28] or simply because consumers do not like the taste of fish, in particular oily fish. Consumers may also lack the skills to prepare and cook fish. Some may be concerned about the potential contamination of oily fish with polychlorinated biphenyls and heavy metals [7,35,36], particularly sensitive individuals such as women who are pregnant or in children [7,35].

There are also concerns about the sustainability of fish supplies. It is recognized that current supplies of wild and farmed fish may be inadequate to meet the recommended VLC ω-3 PUFA intakes for Europe and Northern America [27]. This extends not only to human consumption of fish and fish oil but also fish products (fish meal and fish oil) used as feed components for farmed fish. Almost half of all fish consumed is currently supplied by aquaculture [37] and a decreasing supply of fish oil and fish meal has meant exploring non-fish alternatives for farmed fish feed. In Norway and the UK, up to 25% of farmed fish meal is of vegetable origin [38] and vegetable oils are used as partial replacement of fish oil. This in turn can result in a lower VLC ω-3 PUFA content of farmed fish [39,40]. Concerns about sustainability may also influence fish consumption because 79% of surveyed European consumers rated the environmental impact an important influence on seafood purchasing practices, although this was secondary to 91% who rated the health benefits of fish consumption as an important positive influence [36,41].

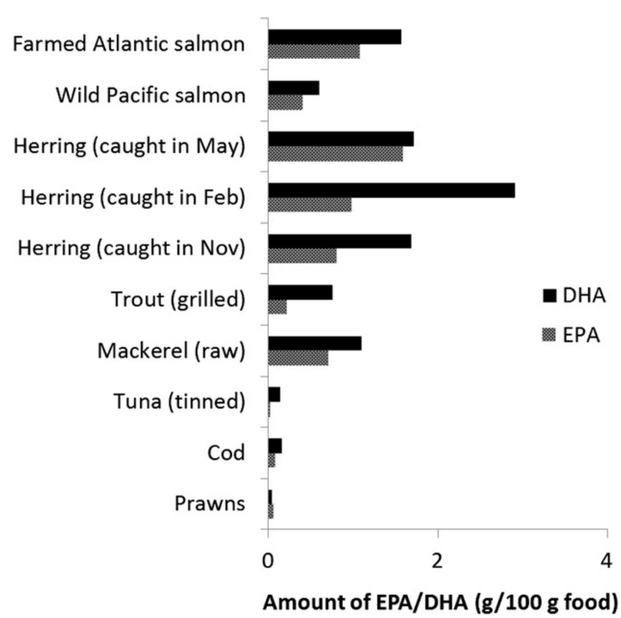

Fig. 1. Example of variation of EPA and DHA by type of fish, season of fish catch, and wild versus farmed fish using data obtained from sources [29,31,33]. DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid.