The Omega-3 Index in Athletes

Brief Review

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Abstract

Introduction: The omega-3 index (O3i), the amount of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) as a percentage of total fatty acids within erythrocytes, has emerged as a potentially important biomarker for sport. The purpose of this review is to quantify the O3i in athletes across various sporting contexts.
Methods: Two databases (PubMed, Google Scholar) were searched for cross-sectional studies reporting the O3i in athletes. Simple pooled mean analyses were used to quantify the O3i in all studies and by subgroup (i.e., sex and sport).
Results: Based on 18 studies (25 observations) comprised of 1,452 athletes, the combined O3i was 4.43 ± 0.59% and ranged between 2.98% and 5.19%. According to studies that reported the O3i proportion within their sample, less than 1% of all athletes had an O3i > 8%, whereas 32% of athletes had an O3i < 4%. The O3i mean difference between all subgroups (sex and sport activity) was within ± 1%.
Conclusions: Athlete programs should make a concerted effort to: 1) routinely test the O3i, 2) provide education from nutrition professionals on the potential benefits and sources of *n*-3 fatty acids and, 3) provide meal options comprised of rich sources of EPA and DHA at least three times per week and consider providing supplementation as needed, if allowed by governing organizations.

Key Words: Biomarker, performance, sports nutrition, eicosapentaenoic acid, docosahexaenoic acid

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Introduction

The omega-3 index (O3i) has emerged as a potentially important biomarker for sport.[1,2] The O3i is the amount of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) expressed as a percentage of total fatty acids within erythrocytes[3] and can easily be assessed via dried blood spot.[4] Meta-analyses of epidemiologic studies and clinical trials have demonstrated that the O3i, or blood levels of EPA and DHA, are associated with a significant reduction in cardiovascular disease (CVD) risk and outcomes.[5–8] From similar observations, the O3i risk zones were developed, such that, < 4% is high risk, 4-8% is moderate risk, and > 8% is low-risk for CVD. While improved cardiovascular dynamics may be beneficial to athletes, most of this research has been conducted in and applied to clinical populations.

More recently, reviews have suggested that *n*-3 fatty acids (i.e., EPA and DHA) may enhance sport performance, recovery, and confer prophylactic protection from head impacts.[9–13] A systematic review in athletes determined that fish oil supplementation, a common source of EPA and DHA, improved reaction time, mood, cardiovascular dynamics, recovery from training or muscle damage, and reduced proinflammatory cytokines.[9] Although preliminary in nature, a recent meta-analysis suggested that *n*-3 fatty acid supplementation, primarily as DHA, significantly reduced a serum marker of head trauma in athletes commonly exposed to repetitive subconcussive head impacts (i.e. American football).[12] While it is unclear if the aforementioned O3i risk zones are appropriate for sport, accumulating evidence suggest that the O3i represents a viable biomarker to monitor as a part of a comprehensive physiological and biochemical analysis to optimize athlete health and performance. Given the evidence to date, it is rather striking that O3i status in athletes, as reported in the literature, remains below the optimal range (> 8%). In fact, blood EPA and DHA values in athletes are closer to 4%. According to two large studies in athletes, the average O3i was 4.3%[14] and 4.4%[15] in which 36% of athletes (252 out of 702) presented values < 4%.

Considering the potential importance of *n*-3 fatty acids, a detailed evaluation of the O3i in athletes is warranted. To this end, the purpose of this narrative review is to quantify and describe the O3i in athletes across various sports.

Methods

Articles were identified from searches using PubMed, Google Scholar, and the Global Organization for EPA & DHA Omega-3s Clinical Study Database.[16] Cross-sectional studies that reported the O3i and allowed for the calculation of the O3i using EPA and DHA in athletes were included. Studies reporting fatty acid values in other blood fractions (e.g., plasma) were converted to equivalent erythrocyte fatty acid values using validated equations.[17] Athletes were identified using the classification system established by McKay et al.[18], such that studies were only included if the athlete caliber was defined as Tier 3 (highly trained/national), Tier 4 (elite/international), or Tier 5 (world-class). Studies reporting the O3i in mixed caliber athletes were assigned based on the lowest Tier level. For example, a cohort with Tier 3 and Tier 4 athletes was categorized as Tier 3.

Statistical Analysis

Data are reported as mean and standard deviation. Simple pooled mean analysis using Excel was conducted to determine the combined O3i for all athletes, with sample size adjustments (i.e., weighted means). Subgroup analyses were conducted for sex and sport. Only subgroups with observations > 1 were included.

Results

Eighteen cross-sectional studies (25 observations) reported the O3i in athletes.[14,15,19–34] Most studies reported observations by sex with the majority being male athletes, were among Tier 4 athletes, and 16 of the 18 studies obtained n-3 tissue samples from erythrocytes or whole blood. Additional details are available in Table 1.

Table 1. Cross-sectional studies reporting the omega-3 index (O3i) in athletes.

Study	Sport	*n*	Sex	Location	Athlete caliber	*n*-3 tissue sampled	Proportion of athletes in each O3i category (%)		
							< 4%	4-8%	> 8%
Tepsic, 2009	Soccer	24	M	Serbia	Tier 3	Erythrocyte	-----	-----	-----
	Basketball	23							
Arsic, 2012	Soccer	19	F	Serbia	Tier 3	Erythrocyte	-----	-----	-----
	Water Polo	15							
Tepsic, 2013	Boxing	16	M	Serbia	Tier 3	Erythrocyte	-----	-----	-----
Von Schacky, 2014	Mixed	106	Both	Germany	Tier 4	Erythrocyte	99		1
Wilson, 2016	Basketball	9	M	USA	Tier 4	Whole Blood	11	89	0
	Mixed	49	F				16	84	0
Wilson, 2017	Mixed	54	F	USA	Tier 4	Whole Blood	-----	-----	-----
Anzalone, 2019	Am Football	404	M	USA	Tier 4	Erythrocyte	34	66	0
Arsic, 2020	Handball	15	M	Serbia	Tier 3	Plasma	-----	-----	-----
		17	F						
Ritz, 2020	Mixed	298	Both	USA	Tier 4	Whole Blood	38	62	0
Armstrong, 2021	Rugby	19	M	Canada	Tier 4	Erythrocyte	27	73	0
		15	F				60	27	13
Davis, 2021	Basketball	119	M	USA	Tier 4	Whole Blood	21	77	2
Kunces, 2021	Am. Football	30	M	USA	Tier 4	Erythrocyte	97		3
Essman, 2022	Soccer	31	F	USA	Tier 4	Whole Blood	48	52	0
Lyudinina, 2022	Skiing	36	M	Russia	Tier 4	Plasma	-----	------	-----
Heileson, 2023	Mixed	12	M	USA	Tier 4	Whole Blood	23	77	0
		18	F						
Hooks, 2023	Mixed	40	F	Ireland	Tier 4	Whole Blood	3	97	0
Zhang, 2023	Mixed	24	M	China	Tier 4	Erythrocyte	38	58	4
		30	F				20	77	3
Fujibayashi, 2024	Rugby	29	M	Japan	Tier 3	Whole Blood	48	52	0

Abbreviations: *n*-3, omega-3; USA, United States of America; -----, not reported.

The pooled mean O3i across 25 observations comprised of 1,452 Tier 3 and 4 athletes was 4.43 ± 0.59% and ranged from 2.98% to 5.19%. Of the observations that reported the proportion of athletes within the O3i risk categories (Table 1, *n* = 15), the highest proportion of athletes had an O3i from 6-8%, whereas less than 1% (8 of 1,233 athletes) reported an O3i > 8%. Only 13 of the observations reported high-risk and moderate-risk categories separately (*n* = 1,097). Of those, approximately 32% (*n* = 350) of athletes had O3i < 4%. Figure 1 displays the O3i for each observation. Of note, 28% of the observations (*n* = 7) reported an average O3i < 4%, indicating the high-risk category (below red dashed line), while the remaining observations fell within the moderate risk range (4 to 8 %; below green dashed line). No observations reached the optimal threshold of 8% (above the green dashed line), indicating a general insufficiency across sports.

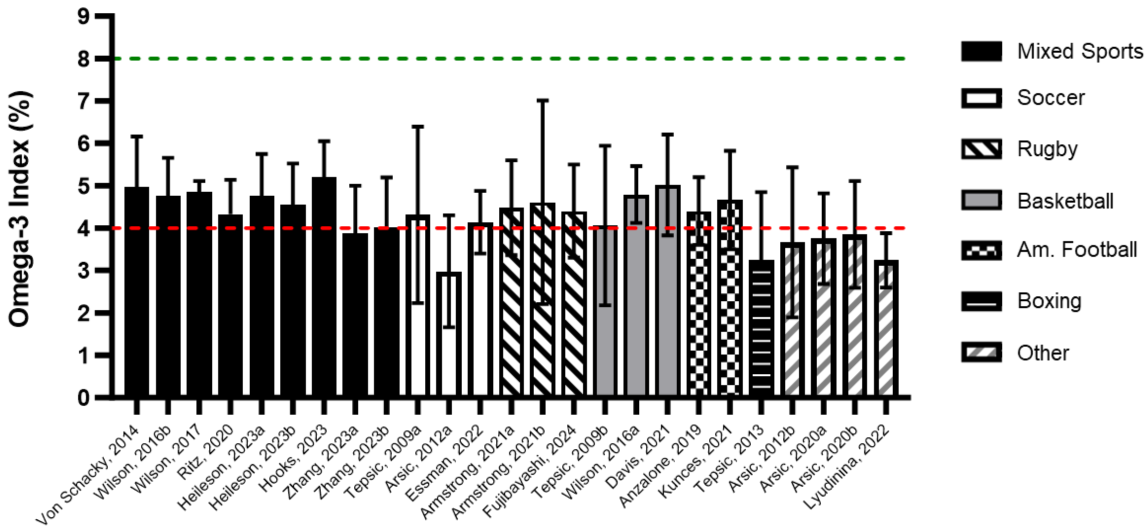

Figure 1. The omega-3 index (O3i) for athletes across all observations (*n* = 25) and arranged by sport. The green dashed line represents the optimal threshold (>8%), indicating the lowest risk for cardiovascular disease, while the red dashed line marks the suboptimal threshold, below which athletes are at higher risk, thereby suggesting insufficiency. An O3i between 4 and 8% is considered "moderate risk". The "Other" sport category included water polo, handball, and skiing. Data are mean ± SD. *Abbreviations*: Am. Football = American Football

As indicated on Table 2, the average O3i was within ± 1% of EPA+DHA across sex and sport activity.

Table 2. Pooled mean omega-3 index (O3i) based on sex and sport.

	Observations	Sample Size (*n*)	O3i
Sex			
Male	13	760	4.23 ± 0.57
Female	10	288	4.26 ± 0.66
Sport			
Mixed	9	631	4.59 ± 0.44
Soccer	3	74	3.81 ± 0.72
Rugby	3	63	4.50 ± 0.11
Basketball	3	151	4.62 ± 0.50
Am. Football	2	434	4.53 ± 0.18
Handball	2	32	3.80 ± 0.07

Data are mean ± SD.

Discussion

This review encompassed 25 observations across 1,452 athletes from diverse sporting disciplines, and reveals that athletes, globally, exhibit suboptimal O3i, with a mean value of 4.43 ± 0.59%. This falls significantly below the recommended threshold of > 8% associated with a low cardiovascular risk in clinical populations. The inadequacy of O3i status appears consistent across athletes, with no notable differences between sex and sport (mean differences of ± 1%). Less than 1% of athletes achieved an O3i > 8%, while the vast majority remaining within the moderate (4-8%)

or high-risk (<4%) categories. In fact, athletes have similar O3i levels to that of amateur athletes following vegan dietary patterns that are absent of long-chain *n*-3 fatty acids.[35] The suboptimal O3i likely stems from variations in dietary habits, training demands and supplementation practices, and highlight the need for targeted nutritional interventions. While it remains unclear whether the same O3i thresholds apply to elite athletes, evidence suggests that EPA and DHA contribute to physiological adaptations and enhance recovery from exercise due to their anti-inflammatory properties.[9–11,13,36]

Insufficient consumption of marine-derived *n*-3 fatty acids is a primary contributor to suboptimal O3i levels. Dietary EPA and DHA consumption accounts for approximately 25% of O3i variability[37], with inadequate seafood intake being prevalent among athletic populations. This has been supported by a study of professional basketball players from 13 different teams across the United States, which revealed that 61% consumed less than the recommended amounts of fish per week (≥2 servings), while 31% reported no fish consumption.[27] These findings demonstrate that *n*-3 fatty acid status is influenced by multiple factors extending beyond regional seafood availability (e.g., established dietary habits, nutrition education level, and personal food preferences). For example, elite female athletes in Ireland reported that the main obstacles to meeting fish dietary recommendations included sensory issues related to taste and smell, inadequate cooking skills, and insufficient knowledge regarding the benefits of *n*-3 fatty acids.[32]

Beyond insufficient *n*-3 intake, excessive *n*-6 fatty acid consumption exacerbates suboptimal O3i levels by disrupting the *n*-6: *n*-3 ratio. Research on athletes in Japan[34], China[33], and the United States[38] has documented patterns consistent with high-levels of *n*-6 consumption. This imbalance has significant physiological consequences because both fatty acid families compete for the same metabolic enzymes. Higher *n*-6 intake correlates with elevated levels of pro-inflammatory markers, including interleukin-6 and C-reactive protein[39], creating an environment that may require increased *n*-3 intake to maintain homeostasis. For athletes, EPA and DHA play essential roles in influencing cellular signaling pathways and attenuating exercise-induced cellular stress.[40] When present in adequate amounts, these fatty acids interact with pro-inflammatory *n*-6 fatty acids, particularly arachidonic acid, affecting multiple physiological systems including cardiovascular, muscular, connective, and neurological tissues, thereby modulating tissue restoration and adaptation.[41,42] Consequently, excessive consumption of refined oils (e.g., soybean oil, corn oil) and highly processed foods rich in *n*-6 fatty acids may create a pro-inflammatory environment that heightens athletes' *n*-3 requirements.[43]

Paradoxically, even athletes who meet established *n*-3 dietary guidelines exhibit lower O3i levels compared to the general population. For example, collegiate Rugby players in Japan, despite adhering to dietary recommendations and consuming more *n*-3 fatty acids than non-athletes (3.4 vs. 2.4 g), had an O3i 1.8% lower than their non-athlete counterparts (4.4% vs. 6.2%)[34] and over 5% lower than the general population.[44] Similarly, even with *n*-3 supplementation, the O3i in athletes from the United States and Canada was approximately 0.5% lower than non-athletes from the same country.[26,31,44,45] Recent investigations found only modest correlations[14] or no correlations[34] between dietary *n*-3 intake and blood *n*-3 levels in athletes, suggesting that the standard dietary guidelines (250-500 mg EPA+DHA) may be inadequate for this population. This discrepancy appears connected to exercise-induced alterations in fatty acid metabolism, as even a single training session impacts enzymatic pathways involved in the uptake of *n*-3 and *n*-6 fatty acids.[34] Additionally, both training intensity[2] and weekly volume, particularly higher running mileage[42] have been proposed to contribute to O3i variability, suggesting that athletes may require higher *n*-3 intake during periods of intense training or competition. Consequently, traditional dietary assessments may inadequately predict O3i status in athletes, highlighting the need for blood analysis for precise evaluation.[14,34]

Given that dietary intake alone often fails to meet optimal *n*-3 needs, supplementation plays a crucial role in achieving optimal O3i in athletes. The International Olympic Committee (IOC) recommends 2 grams of *n*-3 daily for elite athletes, substantially exceeding the general population guidelines of 250-500 mg. While targeted *n*-3 supplementation is essential, its effectiveness varies considerably and depends on dosage, chemical formulation, duration, frequency, adherence, and individual metabolic responses. For example, while earlier research suggests supplementation accounts for only 15% of O3i variability[37], recent studies have determined that *n*-3 dose alone or *n*-3 dose with baseline O3i and chemical formulation account for the vast majority of the variance in O3i response (~60-70%).[46,47] Regarding chemical formulation, triglyceride-based supplements increased O3i by approximately 1% point more than ethyl ester products on a gram-per-gram basis.[47] Additionally, in Canadian rugby athletes, the only athletes who achieved an optimal O3i (>8%) reported *n*-3 supplementation.[26] However, despite 73% of female and 63% of male athletes reporting *n*-3 supplement use and meeting the 500 mg recommendation, most failed to attain the optimal threshold, indicating that standard supplementation protocols may be insufficient for many athletes.[26] Additionally, Spanish summer sport athletes who supplemented with either 760 mg or 1140 mg of EPA+DHA for four months experienced O3i increases of only 1.8% to 2.1%, respectively.[41] In a more recent 12 week study, trained endurance athletes were provided either 772.9 mg EPA+DHA from fish oil (*n* = 8) or 615.3 g EPA+DHA from algal oil (*n* = 8). Regardless of *n*-3 type, the O3i increased by less than 2%.[48] Although long-term studies are lacking in athletic populations, extended supplementation periods and higher dosages appear necessary to achieve meaningful O3i improvements. However, current supplementation practices among athletes often lack consistency and structure. For instance, in an investigation of professional basketball players, only 10% reported *n*-3 supplementation, with variations in dosage (0.5 to 3.0 g) and frequency (from daily to three times weekly).[27] Similarly, Ritz et al. found that athletes consuming *n*-3 supplements were unable to specify their brand, dosage, or intake frequency.[14] This inconsistency reflects the need for standardized supplementation guidelines and structured protocols to achieve the recommended optimal O3i in athletic populations.

Effectively addressing suboptimal O3i in athletes requires consideration of biological variability and practical implementation challenges. O3i may be influenced by factors beyond dietary intake and exercise patterns, such as genetics (accounts for ~24% of O3i variation[37]), body weight, baseline O3i, age, physical activity, and sex, which collectively, explain an additional 10%.[46] These differences highlight the need for personalized *n*-3 intake guided by routine O3i assessments.[49] However, economic barriers, such as current retail prices for O3i testing, may limit this implementation. Despite these constraints, O3i testing remains feasible, as it requires a quick, minimally invasive finger-prick test and a small dried blood sample. Therefore, for athletic programs already conducting other biomarker assessments, adding *n*-3 measurements may not pose significant logistical burdens. As indicated in Figure 2, a cost-effective approach to integrating O3i testing could include: (1) conducting baseline assessments, (2) providing *n*-3-rich meals and targeted supplementation based on assessments, and (3) retesting every 3-6 months or at key training phases. In fact, even for programs without access to routine testing, dietary and educational interventions can support *n*-3 optimization. Although not directly included in the decision matrix, each decision point is an opportunity to intervene via nutrition education on LC *n*-3 PUFAs for sport-specific and general health.

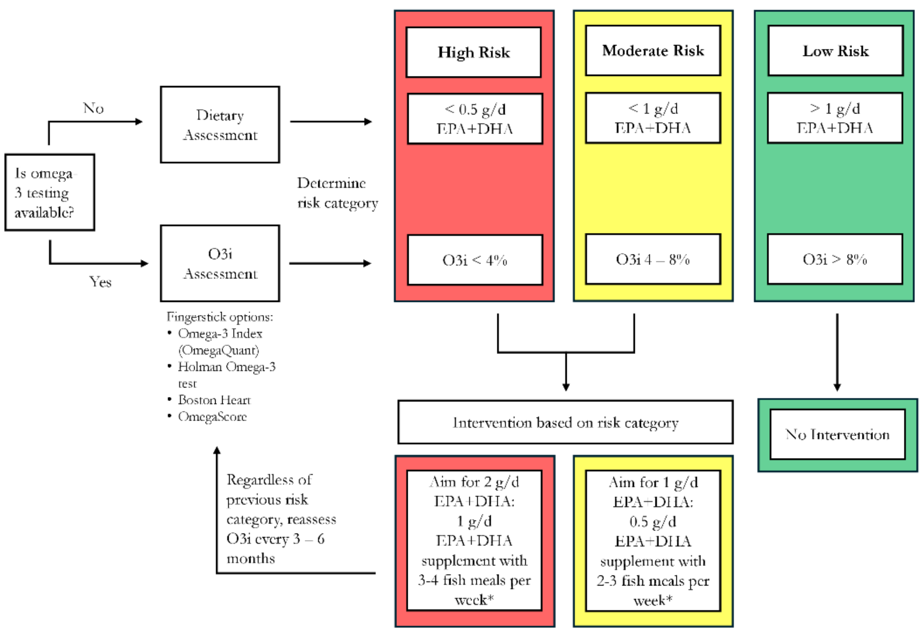

Figure 2. An evidence-based decision matrix to optimize the omega-3 index (O3i).
* If no fish is consumed, the recommended supplement amount should be doubled to achieve optimal O3i levels.

Given that regular O3i assessments may not be feasible for all institutions, structured dietary interventions are an accessible approach for improving *n*-3 status. These strategies should prioritize regular fatty fish consumption alongside individualized EPA+DHA supplementation as needed. Whole food sources, such as salmon, sardines, anchovies, herring and tuna provide long-chain *n*-3 fatty acids alongside high-quality protein and micronutrients.[50,51] While Dietary Guidelines for Americans recommends at least 8 ounces of seafood per week, providing approximately 500 mg of EPA+DHA[52], research indicates this intake may be insufficient for optimizing O3i in athletes.[46,53] Ritz et al.[14] reported a dose-dependent relationship between seafood intake and O3i, with each additional weekly serving of seafood correlating with a 0.27% increase in the O3i. However, as relying solely on dietary sources can be challenging, Jackson et al.[53] recommends a more aggressive approach: consuming at least three 3-ounce servings of fatty fish per week plus *n*-3 supplementation to achieve an O3i > 8%. This combined approach provides approximately 835 mg of EPA+DHA per week, a value that exceeds standard dietary guidelines.[52] For athletes with low O3i, evidence supports higher supplementation doses, including 1.5-2 $g\cdot day^{-1}$ EPA+DHA for at least 16 weeks[41], a dosage that aligns with the IOC recommendations (2 $g\cdot day^{-1}$).[54] The effectiveness of combining education with supplementation access was demonstrated in Rugby players, who experienced an average O3i improvement of 2.5% in 10 weeks, with ~30% achieving an optimal O3i by the end of the study.[55] This real-world application confirms that despite the challenges in improving O3i status, targeted nutritional programs that include both education and practical access to appropriate foods and supplements can effectively enhance EPA and DHA status in athletes.

Limitations

The literature review was thorough but may not have been exhaustive. Given the systematic nature of our literature search, it is possible that our review captured the majority of the extant literature. However, several limitations should be considered when interpreting our findings. While our analysis encompassed a range of sporting disciplines, certain sports were represented more comprehensively than others. While some investigations included individual sports within the mixed sports category, separate mean O3i values for specific disciplines such as swimming, cycling, combat sports beyond boxing, gymnastics, athletics, etc., were not calculated due to insufficient sample sizes. Nevertheless, given the consistency of O3i values across the examined sports (±1% mean differences), we have reasonable confidence that our findings are generalizable to athletic populations not specifically represented in this review. Lastly, this review includes studies predominantly from North America, Europe, and parts of Asia, leaving uncertain the O3i status of athletes from other regions. However, considering that athletes in Japan, a region with traditionally high fish consumption, also failed to meet optimal O3i thresholds[34], the O3i patterns observed likely reflect a global phenomenon. Despite these limitations, the consistency of findings across diverse populations demonstrates that suboptimal O3i levels are prevalent among competitive athletes globally.

Conclusions

Athlete programs should make a concerted effort to conduct *n*-3 testing, provide education from nutrition professionals on the potential benefits and sources of *n*-3 fatty acids and, if possible, provide meals comprised of rich sources of EPA and DHA at least three times per week. For athletes with an O3i < 4% or those that do not respond with increased fatty fish intake, consider providing EPA+DHA supplementation, if allowed by governing organizations.

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