# Total Long-Chain n-3 Fatty Acid Intake and Food Sources in the United States Compared to Recommended Intakes: NHANES 2003-2008

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**Running header:** total long-chain n-3 fatty acid intake from dietary sources and supplements, NHANES 2003-2008

**Abbreviations:** AHA, American Heart Association; ALA, alpha-linolenic acid; CVD, cardiovascular disease; DGA, Dietary Guidelines for Americans; DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid; FNDDS, Food and Nutrient Database for Dietary Studies; NCHS, National Center for Health Statistics; NHANES, National Health and Nutrition Examination Survey; SDA, stearidonic acid; USDA, United States Department of Agriculture; WWEIA, What We Eat in America;

# Abstract

The American Heart Association recommends consuming fish (particularly oily fish) at least 2 times per week, which provides ≈ 0.5 g/d of eicosapentaenoic acid (EPA) + docosahexaenoic acid (DHA) for cardiovascular disease risk reduction. Previous analyses indicate that this recommendation is not being met; however, few studies have assessed different ethnicities, subpopulations requiring additional n-3 fatty acid intake (i.e., children and pregnant and/or lactating women), or deciles of intake. Data from the National Health and Nutrition Examination Survey 2003-2008 was used to assess n-3 fatty acid intake from foods and supplements in the US population, according to age, sex, and ethnicity. A unique "EPA-equivalents" factor, which accounts for potential conversion of shorter-chain n-3 fatty acids, was used to calculate total long-chain n-3 fatty acid intake. Data are reported for 24,621 individuals. Over 90% consumed less than the recommended 0.5 g/d from food sources (median = 0.11 g/d; mean = 0.17 g/d). Among the top 15% of n-3 fatty acid consumers, fish was the largest dietary contributor (71.2%). Intake was highest in males 20+ years, and lowest in children and women who are or may become pregnant and/or are lactating. Among ethnicities, intake was lowest in Mexican Americans. Only 6.2% of the total population reported n-3 fatty acid supplement use, and this did not alter median daily intake. Additional strategies are needed to increase awareness of health benefits (particularly among Mexican Americans and women of child-bearing age) and promote consumption of oily fish or alternative dietary sources to meet current recommendations.

# Introduction

Long-chain n-3 fatty acids play a crucial biological role in health [1]. The long-chain n-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are recommended to reduce the risk of cardiovascular disease (CVD), which remains the leading cause of death in the United States (US) [2]. For instance, to reduce CVD risk in the general population, the American Heart Association (AHA) recommends consuming fish (particularly oily fish) at least twice per week to provide ≈ 0.5 g/d of EPA+DHA [3, 4]. The 2015-2020 Dietary Guidelines for Americans (DGA) similarly recommends consuming 8 ounces per week of a variety of fish to obtain at least 0.25 g/d of EPA+DHA [5]. Because DHA is essential for neurologic development, oily fish consumption (up to 12 ounces per week) is also recommended for children and women who are of child-bearing age or who are pregnant and/or lactating [5, 6].

Based on these recommendations and the health benefits associated with n-3 fatty acid intake, it is important to assess the usual n-3 fatty acid intake of the US population. Current evidence indicates that the US diet falls short of meeting recommendations for EPA and DHA intake. For instance, another analysis of National Health and Nutrition Examination Survey (NHANES) data (2003-2008) found that in US adults the mean intake of oily fish (0.15 ounces/d), as well as EPA and DHA from foods (0.02 g/d and 0.06 g/d) and foods plus supplements (0.04 g/d and 0.07 g/d), was far below the recommended amount [7]. Previous analyses of n-3 fatty acid intake in the US have reported similarly concerning EPA and DHA intake from foods [8, 9]. To our knowledge, only one study has examined intakes in groups who may require additional n-3 fatty acid intake or be at increased risk for deficient n-3 fatty acid intake (i.e., children and pregnant and/or lactating women) [10]. It is particularly important to assess n-3 fatty acid intake in women who are or may become pregnant because pre- and post-natal maternal DHA consumption is the primary source of DHA required for optimal visual and neural development in infancy and early childhood [11, 12]. Furthermore, previous analyses have typically focused on mean and median intakes, which provide less insight into the proportions of the US population meeting specified target intakes. Assessing deciles of intake could provide additional information about which subgroups of the total US population have the largest shortfall in n-3 fatty acid intake and are therefore in greatest need of additional strategies to promote increased n-3 fatty acid intake.

The objective of the current analysis was to build upon previous analyses of n-3 fatty acid intake in the US population using data from NHANES 2003-2008. We assessed n-3 fatty acid intake from foods and supplements (individually and combined) in the total US population, and by age, sex, and ethnicity. Furthermore, we used a unique "EPA-equivalents" factor in the calculation of total n-3 fatty acid intake to account for potential endogenous, albeit limited, conversion of shorter-chain n-3 fatty acids. In addition to assessing n-3 fatty acid intake, we also identified the foods that contributed most to n-3 fatty acid intake in both high and low n-3 fatty acid consumers in the US population.

# Methods

At the request of PEW Charitable Trusts (PEW), Exponent, Inc. (Exponent) used NHANES data to estimate the total daily intake of long-chain n-3 fatty acids for the total US population and the following age/sex subpopulations: children 1-6 years (y), children 7-12 y, males 13-19 y, non-pregnant and/or non-lactating females 13-19 y, males 20+ y, non-pregnant and/or non-lactating females 20+ y, pregnant and/or lactating females 13+ y, and seniors 55+ y. In addition, Exponent estimated intakes for the following ethnicities: Mexican Americans, Hispanics, Non-Hispanic whites, Non-Hispanic blacks, and Other (including multi-racial). It should be noted that the National Center for Health Statistics (NCHS) recommends analysis of the Mexican American subgroup rather than the Hispanic subgroup for the 2003-2006 and 2005-2008 survey periods due to NHANES sampling methodology (i.e., oversampling of the Mexican American subgroup from 1999-2006 with subsequent under sampling of non-Mexican American Hispanics, and oversampling of all Hispanic persons from 2007-2010) [13].

*Study population*

NHANES is a cross-sectional survey conducted by the NCHS, under the Centers for Disease Control and Prevention, using a complex multistage probability sample that is designed to be representative of the national civilian US population [14]. As part of the "What We Eat in America" (WWEIA) component of the NHANES examination, trained dietary interviewers collected detailed information on all foods and beverages consumed by respondents in the previous 24-hour time period (midnight to midnight). A second dietary recall was administered by telephone 3 to 10 days after the first dietary interview, but not on the same day of the week as the first interview. Survey participants were also asked if they had taken a dietary supplement in the past 30 days, how long they had been taking it, how many days it was taken in the past 30 days, the amount that was taken on those days, and the reason(s) that they were taking it. Label information such as supplement name, manufacturer and/or distributor, serving size, form of serving size, and ingredients and amounts were recorded by NCHS for each supplement reported by participants. The current analysis of n-3 fatty acid intake was conducted using combined data on 24-hour dietary intake and 30-day dietary supplement use collected in 2003-2004, 2005-2006, and 2007-2008 survey periods (NHANES 2003-2008). Analyses were limited to participants who provided two complete and reliable 24-hour dietary recalls. The combined sample included 24,621 individuals.

*Determination of daily total long-chain n-3 fatty acid intake*

Total long-chain n-3 fatty acid intake was defined as the sum of EPA, DHA, and EPA-equivalents. EPA-equivalents were estimated from the conversion of alpha-linolenic acid (ALA; 5%; [15-17]) and stearidonic acid (SDA; 33%; [18, 19]) to EPA. Intake from foods was calculated by PEW based on US Department of Agriculture (USDA) National Nutrient Database for Standard Reference, Release 22 (SR22) [20]. The SR22 database provides food composition and nutrient data that directly correspond with nutrient values reported in the USDA Food and Nutrient Database for Dietary Studies (FNDDS), 4.1 [21], and also processed for foods reported as consumed by participants in WWEIA, NHANES 2007-08. Exponent used their

Foods and Residues Evaluation Program (FARE® version 9.95) software to calculate intake in the total US population and the specified age, sex, and ethnicity subpopulations. Statistically weighted values from the survey were used in order to compensate for variable probabilities of selection, adjust for non-response, and provide intake estimates that are representative of the US population.

Baseline n-3 fatty acid intake was estimated by multiplying the reported intake of foods from the 24-hr recall with the n-3 fatty acid concentrations provided by PEW, and dividing the cumulative sum over the two 24-hr recalls by two. n-3 fatty acid intake from supplements was estimated by Exponent using a database providing the n-3 fatty acid content per serving of specified supplements. In the supplement database, ingredient descriptions were used to identify n-3 fatty acids (e.g., ALA, DHA, EPA, EPA/DHA, n-3 fatty acids, etc.) or ingredients that may contain them (e.g., fish oil). In several cases, both the amount of the n-3 fatty acid containing ingredient (i.e., fish oil) and the amount of specific n-3 fatty acids (i.e., EPA and/or DHA) were specified. In these cases, the specified amount of EPA and DHA was used to calculate n-3 fatty acid intake. When only the n-3 fatty acid containing ingredient (e.g., flaxseed oil, fish oil, cod liver oil) was provided with no breakdown of EPA or DHA content, Exponent imputed the n-3 fatty acid content based on a conservative estimate of the proportion of n-3 fatty acids in each ingredient (e.g., 0.2 g EPA+DHA per 1.0 g of fish oil, based on menhaden oil composition) or the proportion of n-3 fatty acids in each ingredient specified on the supplement label. n-3 fatty acid intake from each supplement was calculated as the amount of n-3 fatty acids in the supplement multiplied by the quantity of the supplement consumed multiplied by the number of days the supplement was taken over the past month. Daily n-3 fatty acid intake for each individual was then calculated as the sum of n-3 fatty acids from each supplement. If a participant took more than one supplement containing n-3 fatty acids, the amount was summed to obtain the total daily n-3 fatty acid intake from dietary supplements. The daily intake of n-3 fatty acids from foods plus supplements was estimated for each participant by summing the 2-day average from food and the daily intake from supplements.

# Results

The baseline daily intake of long-chain n-3 fatty acids—defined as EPA + DHA + EPA-equivalents accounting for potential conversion from ALA and SDA—from foods and foods plus supplements, is presented as the mean, median, maximum, deciles ($10^{th}$ to the $90^{th}$ percentile), and $99.9^{th}$ percentile of intake in grams per day (g/d). In all cases, the median daily intake of n-3 fatty acids was lower than the mean daily intake. Estimated daily n-3 fatty acid intake from supplements is presented in Supplemental Table 1.

*Total US Population*

Long-chain n-3 fatty acid intake (i.e., EPA + DHA + estimated EPA-equivalents) for the total US population is presented in Table 1. From 2003-2008, the baseline median daily intake from food was 0.11 g/d, while the mean daily intake was slightly higher at 0.17 g/d (Table 1). Only 6.2% of the total population surveyed reported n-3 fatty acid supplement use; thus, n-3 fatty acid intake from supplements represented a very small proportion of total n-3 fatty acid intake. Furthermore, among the total US population (including both supplement users and non-supplement users), accounting for n-3 fatty acid supplement use only marginally increased the total mean daily intake of n-3 fatty acids to 0.22 g/d, and did not alter the median intake (Table 1; Figure 1). Only among the higher deciles of intake did n-3 fatty acid supplement use increase the total daily n-3 fatty acid intake, and even then over 90% of the total US population remained below the recommended 0.5 g/d.

*Age and Sex Subpopulations*

Daily long-chain n-3 fatty acid intake (i.e., EPA + DHA + estimated EPA-equivalents) among age and sex subgroups of the total US population is presented in Table 2. Median and mean daily intake from foods was highest in males 20+ y, at 0.14 g/d and 0.23 g/d, respectively

(Table 2). In all age and sex subpopulations, over 90% of individuals consumed less than the recommended 0.5 g/d from food sources, even after accounting for potential conversion of plant-based n-3 fatty acids (i.e., ALA and SDA). Supplement use was uncommon among both men and women of all ages, and largely did not alter median n-3 fatty acid intake. Supplement use was highest among individuals 55+ y, males 20+ y, and non-pregnant/non-lactating females 20+ years. Only in these subgroups did 10% of individuals meet or exceed the recommended daily intake of 0.5 g/d when considering both dietary sources, potential conversion of plant-based n-3 fatty acids, and supplements.

Median daily n-3 fatty acid intake was low among populations with greater n-3 fatty acids requirements (i.e., children as well as women who are or may become pregnant and/or lactating). In children 1-6 and 7-12 y, median daily intake from food was 0.06 g/d and 0.09 g/d, respectively. In pregnant and/or lactating women, as well as and females 20+ y who were not pregnant/lactating, median and mean daily intake from foods was 0.11 g/d and 0.17 g/d, respectively. n-3 fatty acid supplement use was minimal among pregnant and/or lactating women, and lower than the n-3 fatty acid supplement use reported by non-pregnant/non-lactating women 20+ years. When accounting for supplement use, median daily n-3 fatty acid intake did not increase from 0.11 g/d and mean daily intake increased marginally by 0.02 g/d, for a total intake of 0.19 g/d in pregnant and/or lactating females.

*Race/Ethnicity Subpopulations*

Daily long-chain n-3 fatty acid intake (i.e., EPA + DHA + estimated EPA-equivalents), subdivided by race/ethnicity (Mexican American, Non-Hispanic White, Non-Hispanic Black, and Other), is presented in Table 3. Mean and median daily intake was lowest in Mexican Americans and highest in individuals categorized as “Other” (≈ 4% of total population) (Table 3). The “Other” category was the only ethnicity in which at least 10% of individuals met the 0.5 g/d recommendation from food sources alone or foods plus supplements. Supplement use was most common among Non-Hispanic Whites (≈ 7%) and lowest in Mexican-Americans (≈ 2%).

*Main Dietary Contributors to n-3 Fatty Acid Intake*

The proportion of total long-chain n-3 fatty acid intake contributed by 10 broad food groups among low and high n-3 fatty acid consumers is depicted in Figure 2. Among high n-3 fatty acid consumers, fish was the largest contributor to dietary n-3 fatty acid intake (71.2%). Food sources of n-3 fatty acids were much more varied in low n-3 fatty acid consumers, with “grain products” (36%) and “meat, poultry, and mixtures” (21.5%) being the largest contributors rather than fish (0.6%).

# Discussion

This analysis of NHANES 2003-2008 data demonstrates that even after accounting for supplement intake and potential conversion of plant-based n-3 fatty acids, daily long-chain n-3 fatty acid intake (defined as EPA + DHA + EPA-equivalents) from foods and supplements is well below the 0.5 g/d recommended by the AHA [3] and the 0.25 g/d recommended by the 2015-2020 DGA [5] for a large proportion of the general population—especially in Mexican Americans, young children, and women who are pregnant and/or lactating. From 2003-2008, only 20% of individuals in the total US population consumed more than 0.21 g/d from foods, and over 90% consumed less than 0.34 g/d from foods. Low n-3 fatty acid intake from foods was uniformly found in 90% of individuals in all age, sex, and ethnicity subgroups except the small category termed “Other”—which may be due to Asian American individuals who consume a culturally traditional diet higher in fish. n-3 fatty acid supplement use was uncommon and did not largely alter median n-3 fatty acid intakes. Only among higher deciles of n-3 fatty acid intake did supplement use increase total daily intake—indicating that individuals who use n-3 fatty acid supplements are already consuming dietary sources of long-chain n-3 fatty acids (i.e., oily fish), while non-fish consumers tended not to use n-3 fatty acid supplements.

Our findings are consistent with previous analyses demonstrating very low long-chain n-3 fatty acid intake in the US population. For instance, Papanikolaou et al. reported that median EPA and DHA intake from foods was 0.02 g/d and 0.05 g/d, respectively in adults over 19 years of age from NHANES 2003-2008 (n = 14,338) [7]. The sum of EPA and DHA from the analysis by Papanikolaou et al. is nearly two-thirds of the 0.11 g/d median n-3 fatty acid intake that we found in the total US population from NHANES 2003-2008. This may be due, in part, to our use of EPA-equivalents that account for the conversion of ALA and SDA to EPA. Although the conversion rate of these plant-based n-3 fatty acids to EPA is very low (particularly for ALA) [15, 16], because median daily ALA intake is much higher (1.4 g/d; [7]), this could substantially increase estimates of n-3 fatty acid intake—particularly in individuals who are not oily fish consumers. In the most recent NHANES data from WWEIA 2011-2012, the mean amount of EPA and DHA consumed by men and women over the age of 2 was 0.03 ± 0.002 g/d and 0.05 ± 0.004 g/d, respectively [22]. However, mean intake values are more susceptible to skewing from a small number of individuals with very high n-3 fatty acid intake (particularly when accounting for supplement use), whereas median intake values are a better reflection of "typical" intakes. For example, in the current study population, there was at least one individual in the 55+ y subgroup whose n-3 fatty acid intake from supplements was 16 g/d (Supplemental Table 1). This extreme outlier in the 99.9$^{th}$ percentile is not representative of the general population and artificially inflates the estimated mean intake. Thus, median EPA and DHA intakes in NHANES 2011-2012 were likely even lower. Regardless of minor differences in the absolute values reported by different analyses, it is evident that long-chain n-3 fatty acid intake in the US is far below recommended amounts [3, 5] and has not improved in recent years.

Daily n-3 fatty acid intake was also particularly low in children, women who are pregnant/lactating, and women of childbearing potential – all of whom may have additional n-3 fatty acid requirements. Among pregnant/lactating women, 70% consumed less than 0.15 g/d of n-3 fatty acids from foods, and n-3 fatty acid supplement use was rare. Previous assessments of dietary intake in pregnant women have reported similarly low n-3 fatty acid and/or fish consumption [10, 23-26]. For instance, Nordgren et al. recently reported that mean EPA+DHA intake was 0.09 g/d in pregnant women and women of childbearing age, which was significantly lower than the average intake by men in the same age range (0.12 g/d) [10]. This may potentially be due to concerns about methylmercury contamination that often predominate and overtake messages about the maternal and fetal health benefits of fish and n-3 fatty acids [23, 27-30]. Children (1-6 and 7-12 y) and females of childbearing potential (13-19 and 20+ y) also consumed very little n-3 fatty acids, with mean intakes of 0.08 g/d, 0.12 g/d, 0.12 g/d, and 0.17 g/d, respectively. Given that our n-3 fatty acid intake calculations include EPA-equivalents that account for the conversion of ALA and SDA to EPA, this is consistent with a previous report of EPA + DHA intake in 2-18 year olds from NHANES 2003-2010 in which mean intake was ~0.05 g/d [31]. Similarly, mean intake of EPA and DHA was ~0.01 g/d and ~0.02 g/d, respectively, in children aged 12-60 months from NHANES 2003-2008 [32]. The DHA content of the maternal diet is the primary determinant of the amount of DHA transferred to the fetus via the placenta and the amount of DHA secreted in breastmilk [33, 34], and greater maternal long-chain n-3 fatty acid consumption is associated with better visual and neural development [11, 35]. Uptake of DHA into these tissues is greatest during the third trimester and the first 2 years of life; therefore, sufficient maternal DHA consumption is critical during the pre- and post-natal periods [11, 12]. Thus, in addition to the effects on cardiovascular and general health, low n-3 fatty acid intake in these groups also has additional implications for childhood development [34].

With regard to food sources contributing to long-chain n-3 fatty acid intake, as expected, we found that oily fish was the predominant source of n-3 fatty acid intake among individuals in the upper 85$^{th}$ percentile of n-3 fatty acid intake. Conversely, individuals with low n-3 fatty acid intake consumed very little oily fish and obtained trace amounts of n-3 fatty acids from other food groups, such as grains, meats, and dairy. However, it should be noted that these foods primarily provide ALA and SDA, rather than EPA and DHA. Although our assessment of n-3 fatty acid intake included EPA-equivalents to account for the limited amount of conversion to EPA, conversion to DHA is minimal (≤ 0.05%) [15]; thus, these values may be an overestimation of intake, particularly for DHA. Similarly, among adults 19+ years of age in NHANES 2003-2008, median intake of seafood and fish rich in n-3 fatty acids was 0.43 and 0.07 ounces per day, respectively [7]. This seafood consumption is approximately 38% of the 2015-2020 DGA recommendation to consume 8 ounces of a variety of seafood per week [5], and only 6% of the recommendation to consume 8 ounces of oily fish per week given by the AHA [3]. Oily fish consumption is also very low among US children [32], with non-fish foods being the largest contributors to n-3 fatty acid intake [31]. Therefore, although oily fish is a good source of n-3 fatty acids, insufficient n-3 fatty acid intake among the US population is likely due, in part, to the lack of oily fish consumption by a large proportion of the population.

Taken together, our results and previous assessments of n-3 fatty acid intake in the US demonstrate the need for additional strategies to address this deficiency and increase n-3 fatty acid intake in all segments of the US population. Although oily fish is the primary dietary source of long-chain n-3 fatty acids, numerous barriers may prevent individuals from adopting dietary recommendations to regularly consume oily fish. These include personal preferences (e.g., ethical or environmental concerns, aversion to eating fish) as well as other factors such as unfamiliarity with seafood preparation and cooking methods, cost and/or availability in the local food environment, food allergies, a vegetarian or vegan dietary pattern, and a perceived risk of pollutants. In these cases, alternative sources of n-3 fatty acids may be necessary, such as n-3 fatty acid supplements and/or food products enriched with long-chain n-3 fatty acids. Based on the historic reluctance of Western populations to increase oily fish intake, fortification of commonly consumed foods with long-chain n-3 fatty acids may offer a feasible solution [36]. Dietary recommendations may also need to be directed to specific groups that are likely to have very low n-3 fatty acid intake (e.g., vegetarians and vegans, Mexican Americans) and/or are in greater need of adequate n-3 fatty acid stores (i.e., children and women of childbearing potential). Although the neurodevelopmental harm associated with excessive methylmercury consumption should not be ignored, most authorities agree that the benefits of fish consumption far outweigh the potential risk from consuming small amounts of contaminants in low mercury seafood [37, 38]. Unfortunately, this message has not always been effectively conveyed to the public [39], and messages about risk often predominate [27] and can quickly overtake the message that greater fish consumption is beneficial for fetal development [28]. Clearer and more effective messages are needed to ensure that an unnecessarily negative perception of fish, which further prevents pregnant women from obtaining n-3 fatty acids, is not created [23]. Furthermore, higher poverty and less educational attainment have been associated with lower n-3 fatty acid intake in pregnant women and women of childbearing age [10]; thus, nutritional interventions may need to be designed to specifically target socioeconomically disadvantaged populations. In light of the ethical and environmental concerns regarding both wild fisheries and aquaculture production, there is also growing interest in plant-based sources of n-3 fatty acids, including microalgae and SDA-enriched soybean oils.

*Strengths and Limitations*

This assessment was conducted using a large, representative sample of the US population. Furthermore, age, sex, and ethnicity subgroups were analyzed. However, future studies are needed to determine whether the overall pattern of intake by age and sex is present within individual ethnicity categories. Additionally, analysis of n-3 fatty acid intake within ethnicity subcategories might be improved by restricting the analysis to adults so as not to include children who consume less calories overall, and consequently less EPA and DHA. It will also be important to update assessments of n-3 fatty acid intake using the most recent NHANES cycles to evaluate whether consumption patterns change and to continue to compare them to dietary recommendations. The estimates of n-3 fatty acid intake from supplements used in this analysis were calculated using a factor of 0.2 for the proportion of EPA + DHA in fish oil-based supplements, while fish body oils are typically 30% EPA + DHA; therefore, these values are likely an underestimation of n-3 fatty acid intake from supplements. Nonetheless, had a slightly higher factor (i.e., 0.3) been used, this would only have affected values for individuals in the 99.9$^{th}$ percentile of total intake and would not have changed the overall conclusion that the majority of the total US population is consuming insufficient amounts of n-3 fatty acids. The 24-hour dietary recall method is considered sufficient for accurately measuring mean dietary intake on the population level as it produces less systematic error and is less likely to alter eating behavior (compared to a Food Frequency Questionnaire), is less burdensome, relies only on short-term memory, and can overcome random error associated with day-to-day fluctuations in intake if days of the week are evenly represented in the data [40]. However, 24-hour recalls are not a reliable indicator of an individual's habitual dietary intake, may be prone to self-reporting bias (e.g., underreporting intake), and may not accurately capture the intake of foods that are consumed infrequently such as fish. The use of EPA-equivalents to account for potential conversion of ALA and SDA to EPA is a unique feature of the current assessment; however, metabolic conversion of ALA to EPA in humans is extremely limited (≈5%) and can vary according to numerous biological factors (e.g., sex) and dietary fatty acid intake [15, 16, 41]. The conversion rates used for our analysis represent an upper estimate of conversion efficiency [16, 18, 19]. Therefore, the absolute values for n-3 fatty acid intake reported herein may be an overestimation, albeit slight, compared to similar reports of EPA and DHA intake. Had a lower conversion rate been used, the estimated total n-3 fatty acid intake values would have been even lower. However, this does not alter our primary finding that n-3 fatty acid intake in the US is well below recommended amounts. Future analyses of the contribution of individual n-3 fatty acids (i.e., ALA, SDA, EPA, docosapentaenoic acid, and DHA) are needed to better characterize n-3 fatty acid intake in the US and design interventions to target specific populations and/or specific n-3 fatty acids.

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**Conflict of Interest**

The contents are solely the responsibility of the authors. All authors take responsibility for the manuscript's final content. All of the authors have no conflicts of interest to declare.

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**Fig. 1** Estimated n-3 fatty acid intake[1] from foods alone and the additive contribution from n-3 fatty acid supplements among deciles of the total US population

[1] Defined as EPA + DHA + EPA equivalents (5% conversion rate of ALA to EPA and 33% conversion rate of SDA to EPA).

**Fig. 2** Percent contribution of dietary sources of n-3 fatty acids[1] in (A) low and (B) high n-3 fatty acid consumers[2]

[1]Defined as EPA + DHA + EPA equivalents (5% conversion rate of ALA to EPA and 33% conversion rate of SDA to EPA).

[2]Values are based on a 2-day average. Low n-3 fatty acid consumers are individuals with total n-3 fatty acid intake at or below the 15th percentile of total n-3 fatty acid intake, while high n-3 fatty acid consumers are individuals with total n-3 fatty acid intake at or above the 85th percentile of total n-3 fatty acid intake.

**Table 1** Estimated daily intake of n-3 fatty acids[1] from foods and foods plus supplements in the total US population[2]

| | Sample size | Mean | Median | Max | Percentiles | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 10th | 20th | 30th | 40th | 50th | 60th | 70th | 80th | 90th | 99.9th |
| n-3 fatty acid intake from foods (g/d) | 24536 | 0.17 | 0.11 | 4.28 | 0.04 | 0.06 | 0.07 | 0.09 | 0.11 | 0.13 | 0.16 | 0.21 | 0.34 | 2.76 |
| n-3 fatty acid intake from foods + ***supplements*** (g/d)* | 24168 | 0.22 | 0.11 | 16.98 | 0.04 | 0.06 | 0.08 | 0.09 | 0.11 | 0.13 | 0.17 | 0.25 | 0.45 | 5.59 |

[1] Defined as EPA + DHA + EPA equivalents (5% conversion rate of ALA to EPA and 33% conversion rate of SDA to EPA).
[2] Values represent a 2-day average from 24,621 individuals in the NHANES 2003-2008 survey period with 2 complete 24-hour dietary recalls.
*Sample size decreased because the analysis was restricted to supplement users who also provided two complete and reliable 24-hour dietary recalls.

**Table 2** Estimated daily intake of n-3 fatty acids[1] in age and sex subgroups of the US population[2]

| Population | Sample size | Mean | Median | Max | Percentiles | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 10th | 20th | 30th | 40th | 50th | 60th | 70th | 80th | 90th | 99.9th |
| **Children 1-6 years** | | | | | | | | | | | | | | |
| n-3 fatty acid intake from foods (g/d) | 3354 | 0.08 | 0.06 | 1.38 | 0.03 | 0.04 | 0.05 | 0.05 | 0.06 | 0.07 | 0.08 | 0.10 | 0.14 | 0.96 |
| n-3 fatty acid intake from foods + ***supplements*** (g/d)* | 3313 | 0.08 | 0.06 | 1.38 | 0.03 | 0.04 | 0.05 | 0.05 | 0.06 | 0.07 | 0.08 | 0.10 | 0.15 | 1.34 |
| **Children 7-12 years** | | | | | | | | | | | | | | |
| n-3 fatty acid intake from foods (g/d) | 2846 | 0.12 | 0.09 | 1.52 | 0.04 | 0.05 | 0.06 | 0.08 | 0.09 | 0.10 | 0.11 | 0.15 | 0.20 | 1.37 |
| n-3 fatty acid intake from foods + ***supplements*** (g/d) | 2846 | 0.12 | 0.09 | 5.82 | 0.04 | 0.05 | 0.06 | 0.08 | 0.09 | 0.10 | 0.12 | 0.15 | 0.21 | 1.37 |
| **Males 13-19 years** | | | | | | | | | | | | | | |
| n-3 fatty acid intake from foods (g/d) | 2125 | 0.16 | 0.11 | 2.70 | 0.04 | 0.06 | 0.08 | 0.09 | 0.11 | 0.13 | 0.16 | 0.19 | 0.28 | 1.54 |
| n-3 fatty acid intake from foods + ***supplements*** (g/d)* | 2123 | 0.16 | 0.11 | 2.70 | 0.04 | 0.06 | 0.08 | 0.09 | 0.11 | 0.13 | 0.16 | 0.20 | 0.28 | 1.54 |
| **Females 13-19 years (not pregnant and not lactating)** | | | | | | | | | | | | | | |
| n-3 fatty acid intake from foods (g/d) | 2071 | 0.12 | 0.09 | 1.88 | 0.04 | 0.05 | 0.06 | 0.07 | 0.09 | 0.10 | 0.12 | 0.15 | 0.23 | 1.55 |
| n-3 fatty acid intake from foods + ***supplements*** (g/d)* | 2069 | 0.13 | 0.09 | 1.88 | 0.04 | 0.05 | 0.06 | 0.08 | 0.09 | 0.10 | 0.12 | 0.15 | 0.24 | 1.55 |
| **Males 20+ years** | | | | | | | | | | | | | | |
| n-3 fatty acid intake from foods (g/d) | 6113 | 0.23 | 0.14 | 4.10 | 0.06 | 0.08 | 0.10 | 0.12 | 0.14 | 0.17 | 0.21 | 0.28 | 0.47 | 2.85 |
| n-3 fatty acid intake from foods + ***supplements*** (g/d)* | 6106 | 0.28 | 0.15 | 9.89 | 0.06 | 0.08 | 0.10 | 0.12 | 0.15 | 0.18 | 0.24 | 0.34 | 0.60 | 8.24 |
| **Females 20+ years (not pregnant and not lactating)** | | | | | | | | | | | | | | |
| n-3 fatty acid intake from foods (g/d) | 6139 | 0.17 | 0.11 | 4.28 | 0.04 | 0.06 | 0.07 | 0.09 | 0.11 | 0.12 | 0.15 | 0.21 | 0.34 | 2.33 |
| n-3 fatty acid intake from foods + ***supplements*** (g/d)* | 6136 | 0.23 | 0.11 | 16.98 | 0.05 | 0.06 | 0.08 | 0.09 | 0.11 | 0.13 | 0.17 | 0.26 | 0.50 | 6.65 |
| **Pregnant/Lactating Females 13+ years** | | | | | | | | | | | | | | |
| n-3 fatty acid intake from foods (g/d) | 723 | 0.17 | 0.11 | 1.66 | 0.05 | 0.07 | 0.09 | 0.09 | 0.11 | 0.12 | 0.15 | 0.23 | 0.34 | 1.66 |
| n-3 fatty acid intake from foods + ***supplements*** (g/d) | 723 | 0.19 | 0.11 | 1.66 | 0.05 | 0.07 | 0.09 | 0.10 | 0.11 | 0.13 | 0.16 | 0.24 | 0.39 | 1.66 |
| **Seniors 55+ years** | | | | | | | | | | | | | | |
| n-3 fatty acid intake from foods (g/d) | 5326 | 0.19 | 0.11 | 3.66 | 0.05 | 0.06 | 0.08 | 0.09 | 0.11 | 0.14 | 0.17 | 0.24 | 0.40 | 2.85 |
| n-3 fatty acid intake from foods + ***supplements*** (g/d)* | 5321 | 0.29 | 0.12 | 16.98 | 0.05 | 0.07 | 0.08 | 0.10 | 0.12 | 0.16 | 0.22 | 0.36 | 0.64 | 16.98 |

[1]Defined as EPA + DHA + EPA equivalents (5% conversion rate of ALA to EPA and 33% conversion rate of SDA to EPA).
[2]Values represent a 2-day average from 24,621 individuals in the NHANES 2003-2008 survey period with 2 complete 24-hour dietary recalls.
*Sample size decreased because the analysis was restricted to supplement users who also provided two complete and reliable 24-hour dietary recalls.

**Table 3** Estimated daily intake of n-3 fatty acids[1] among ethnicity subgroups of the US population[2]

| Ethnicity | Sample size | Mean | Median | Max | Percentiles | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 10th | 20th | 30th | 40th | 50th | 60th | 70th | 80th | 90th | 99.9th |
| **Mexican American**[3] | | | | | | | | | | | | | | |
| n-3 fatty acid intake from foods (g/d) | 6027 | 0.16 | 0.09 | 2.68 | 0.04 | 0.05 | 0.07 | 0.08 | 0.09 | 0.11 | 0.14 | 0.18 | 0.30 | 2.15 |
| n-3 fatty acid intake from foods + ***supplements*** (g/d)* | 5861 | 0.17 | 0.10 | 6.67 | 0.04 | 0.05 | 0.07 | 0.08 | 0.10 | 0.12 | 0.14 | 0.19 | 0.34 | 2.68 |
| **Non-Hispanic White** | | | | | | | | | | | | | | |
| n-3 fatty acid intake from foods (g/d) | 10044 | 0.17 | 0.11 | 4.10 | 0.04 | 0.06 | 0.07 | 0.09 | 0.11 | 0.13 | 0.16 | 0.21 | 0.34 | 2.33 |
| n-3 fatty acid intake from foods + ***supplements*** (g/d)* | 9937 | 0.22 | 0.11 | 16.98 | 0.05 | 0.06 | 0.08 | 0.09 | 0.11 | 0.14 | 0.17 | 0.25 | 0.47 | 8.24 |
| **Non-Hispanic Black** | | | | | | | | | | | | | | |
| n-3 fatty acid intake from foods (g/d) | 5960 | 0.18 | 0.11 | 4.28 | 0.04 | 0.06 | 0.08 | 0.09 | 0.11 | 0.14 | 0.17 | 0.23 | 0.36 | 2.97 |
| n-3 fatty acid intake from foods + ***supplements*** (g/d)* | 5910 | 0.19 | 0.11 | 9.89 | 0.04 | 0.06 | 0.08 | 0.09 | 0.11 | 0.14 | 0.17 | 0.24 | 0.38 | 4.28 |
| **Other** | | | | | | | | | | | | | | |
| n-3 fatty acid intake from foods (g/d) | 1035 | 0.23 | 0.12 | 3.66 | 0.04 | 0.06 | 0.08 | 0.10 | 0.12 | 0.15 | 0.18 | 0.27 | 0.51 | 2.85 |
| n-3 fatty acid intake from foods + ***supplements*** (g/d)* | 1014 | 0.26 | 0.12 | 4.31 | 0.05 | 0.06 | 0.08 | 0.10 | 0.12 | 0.16 | 0.20 | 0.30 | 0.57 | 4.31 |

[1]Defined as EPA + DHA + EPA equivalents (5% conversion rate of ALA to EPA and 33% conversion rate of SDA to EPA).
[2]Values represent a 2-day average from 24,621 individuals in the NHANES 2003-2008 survey period with 2 complete 24-hour dietary recalls.
[3]Analysis of the Mexican American subgroup rather than the Hispanic subgroup is strongly recommended by NCHS for NHANES 2003-2006 and 2005-2008 survey periods due to sampling methodology used during those time periods [13].
*Sample size decreased because the analysis was restricted to supplement users who also provided two complete and reliable 24-hour dietary recalls.