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Food Sources of EPA and DHA in the Diets of American Children, NHANES 2003-2010

Sibylle Kranz1, Lyndsey R. Huss2 and Jennifer Dobbs-Oates3

1Senior Lecturer, Centre for Exercise, Nutrition, and Health Sciences, University of Bristol; formerly Associate Professor, Department of Nutrition Science, College of Health and Human Sciences, Purdue University, 700 W. State Street, West Lafayette, Indiana 47907-2059, USA
2Associate Nutritionist, Nestle Nutrition R&D Centers, Inc., Product Technology Center, 445 State Street, Fremont, Michigan 49413, USA; formerly Graduate Student, Department of Nutrition Science, College of Health and Human Sciences, Purdue University, 700 W. State Street, West Lafayette, Indiana 47907-2059, USA
3Clinical Assistant Professor, Department of Human Development and Family Studies, College of Health and Human Sciences, Purdue University, West Lafayette, Indiana 47907-2059, USA

Abstract

Objective

Dietary eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are found in the highest concentrations in fish and seafood. As important nutrients for brain and eye development and function, their consumption levels are of public health interest, especially in children. This study was conducted to examine children’s reported consumption of fish and shellfish as well as EPA and DHA intake.

Methods

Secondary analysis of dietary intake (24-hour recall) and Food Frequency Questionnaire (FFQ) data ascertaining habitual fish and seafood intake of 2-18 year olds (N=13,441) participating in the 2003-2004, 2005-2006, 2007-2008, and 2009-2010 National Health and Nutrition Examination Survey (NHANES). All analyses were survey design corrected and weighted (one-day dietary intake weight) and conducted for the total sample by age group (2-5, 6-11, 12-18 year olds); analysis was conducted for EPA and DHA combined.

Results

Less than 50% of the children consumed fish (49.0%) or shellfish (35.9%) and only 0.3% of the population consumed fish high in EPA and DHA. Children consumed, on average, less than 25% of the recommended amount of EPA and DHA. The foods that contributed the highest average of EPA and DHA to the diet were canned sardines, cooked salmon, and fried carp. The EPA and DHA-containing foods consumed by at least one child in the population with the highest EPA and DHA densities were sturgeon roe, baked/broiled mackerel, and sardines.

Conclusions

Results of this nationally representative study of 2-18 year olds show that children had suboptimal consumption of fish and shellfish, and EPA and DHA reported intakes were much below the recommended amounts. Further research is needed to examine the barriers to higher fish and shellfish consumption and to develop effective ways to increase children’s dietary intake of EPA and DHA.

Introduction

The human body has the ability to elongate and desaturate alpha-linolenic acid (ALA) to the long chain omega-3 polyunsaturated fatty acids (n-3 PUFAs) eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) [1-3]. However, Western diets are low in n-3 PUFAs, specifically ALA found in plant oils and EPA and DHA found in oily fish [4-6]. In the United States (US), the mean intake of n-3 PUFAs is 0.7% of total energy consumed [7], and intake in adults is very low with a median intake of EPA and DHA only contributing 0.05% of total dietary energy [7,8]. Even individuals with low fish consumption have greater n-3 PUFA status than those individuals who do not consume any fish [9]. Western diets low in n-3 PUFAs and high in n-6 PUFAs contribute to poor brain development and function [4,10]. It is uncertain if the rate of DHA synthesis in the human body is sufficient to support optimal brain and retinal development, and these PUFAs should ideally be provided in the diet [11]. DHA is the major n-3 PUFA esterified in glycerophospholipids through the action of acyl-CoA synthases and acyl-CoA:lysophospholipid acyltransferases [12], that forms the structural matrix of brain grey matter and retinal membranes [13,14]. In addition, dietary intake of n-6 PUFAs play a role since n-6 PUFAs interact and compete with n-3 PUFAs in the fatty acid metabolic pathway [15-21].

*Corresponding author: Sibylle Kranz, Senior Lecturer, Centre for Exercise, Nutrition, and Health Sciences, University of Bristol and formerly Associate Professor, Department of Nutrition Science, College of Health and Human Sciences, Purdue University, Indiana 47907-2059, USA, E-mail: sibylle.kranz@bristol.ac.uk

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In the National Health and Nutrition Examination Survey (NHANES) 1999-2006, a food frequency questionnaire (FFQ) specifically designed to assess habitual fish consumption over a 30-day period was used. Tran et al. [22] found that the three most frequently consumed fish are tuna, salmon, and breaded fish. According to NHANES 2003-2008 dietary intake data, the food groups that contributed the greatest amount of DHA to the diets of American children were fish and shellfish (46.3%), poultry and poultry dishes (24.5%), eggs and egg dishes (19.6%), and pasta, rice and other grain dishes (2.2%) [23]. In children of all ages, racial groups, and ethnic groups (Non-Hispanic white or black and Mexican American) examined, the type of fish children most frequently consumed was white fish, followed by shellfish, and then oily fish. Young children in the US had the lowest reported EPA (6 mg/d) and DHA (20 mg/d) intake compared to children in Australia, Belgium, Canada, and China (mean ranges of 17-60 mg/d EPA and 23-96 mg/d DHA) [23, 24]. At the same time, US children had a greater mean intake of total n-6 PUFAs (8.6 g/d) compared to Australia, Canada, and China (6.20-7.60 g/d, 7.40-7.74 g/d, and 2.14-2.32 g/d, respectively) [23]. Multiple factors influence the n-3 PUFA content of the natural dietary sources of EPA and DHA. Even within each food type, variations in fatty acid content are based on factors, such as location, season, water temperature, age, sex, and diet[25]. Other natural sources of EPA and DHA are fatty animal tissue (with fatty fish being the best dietary source) [4], products of select marine sources (e.g. fish oil, krill oil, and algal oil) and other meats (e.g. poultry, eggs, beef, and pork) [26-28]. In addition to the natural food sources of n-3 PUFAs, numerous alternative sources are available in the US food market. Food production companies incorporate n-3 PUFAs into breads and pastas, milk, eggs, processed meats, salad dressings, margarine, mayonnaise, peanut butter, pizza, nutrition bars, cereal, yogurt and juices [27-31]. Incorporating n-3 PUFAs into commonly consumed foods (that do not naturally contain n-3 PUFAs) provides a cost-effective, sustainable venue to increase n-3 PUFA consumption, specifically EPA and DHA [32, 33]. Although the ALA, EPA, and/or DHA used in the fortification of foods is primarily from plant (ALA) or marine sources (EPA and DHA), the bioavailability and usefulness of these forms is currently understudied.

The 2010 Dietary Guidelines for Americans recommend that Americans consume seafood at least twice a week with "an intake of 8 or more ounces per week (less for young children)" that will provide a mean of 250 mg per day of EPA and DHA [34]. Furthermore, the Joint Food and Agriculture Organization (FAO) and World Health Organization (WHO) Expert Consultation on Fats and Fatty Acids in Human Nutrition provided recommendations for adequate intake levels of EPA and DHA for children and adults [35]. Although national and international public health organizations, professional organizations, and expert committees have made dietary recommendations for fish consumption or EPA and DHA intake [8, 36-38], to date, the Institute of Medicine has not established dietary reference intakes (DRIs) for EPA and DHA [39]. To develop effective public health nutrition policy, more specific EPA and DHA target intake levels (i.e. DRIs for EPA and DHA) must be established. There is a critical need for public health guidance on EPA and DHA intakes because substantial evidence indicates that these dietary fatty acids have many health benefits.

| Population characteristics of children 2-18 year old with diet records, NHANES 2003-2010† | 2-18 year olds (n=13441) | 2-5 year olds (n=3380) | 6-11 year olds (n=4185) | 12-18 year olds (n=5876) |
| --- | --- | --- | --- | --- |
| % | | | | |
| Male | 50.7 | 51.8 | 50.4 | 50.4 |
| Ethnicity | | | | |
| Mexican American | 13.4 | 15.6 | 13.9 | 11.8 |
| Non-Hispanic White | 60.2 | 56.0 | 59.4 | 63.0 |
| Non-Hispanic Black | 14.4 | 14.2 | 14.5 | 14.4 |
| Other Race | 12.1 | 14.2 | 12.2 | 10.8 |
| Income | | | | |
| <1.30 PIR | 32.0 | 36.8 | 32.1 | 29.2 |
| 1.30-1.84 PIR | 11.1 | 12.0 | 12.1 | 9.8 |
| 1.85-3.49 PIR | 25.5 | 25.1 | 24.8 | 26.2 |
| 3.50-5.00 PIR | 31.4 | 26.1 | 31.0 | 34.7 |

†Data are presented as percentages
‡Family PIR frequency missing=793
§Family PIR frequency missing = 206
∥Family PIR frequency missing = 220
¶Family PIR frequency missing = 367
[39] and play important roles in heart health [40], brain [11, 41-47] and eye development [48-51].

The overall goal of this project was to describe the reported consumption levels and food sources of fish and shellfish as well as EPA and DHA reported intake in the diets of American children, thereby advancing public health policy.

Methods

Dietary intake and socio-economic data including sex, race/ethnicity, and poverty income ratio (PIR) (Table 1) from children (n=13,441) ages 2-18 years in the NHANES 2003-2010 were extracted. PIR is the ratio of family income to the appropriate poverty threshold [52]. Ratios below 1.00 indicate that the family income is below the poverty threshold whereas a ratio of 1.00 or greater indicates income above the poverty threshold. Households with a PIR <1.3 are eligible for the United States Department of Agriculture (USDA) Supplemental Nutrition Assistance Program (SNAP); households with a PIR ≤1.85 PIR are eligible for participation in the USDA Women, Infants, and Children (WIC) Program; households with a PIR of 1.86-3.49 are defined as medium income; households with a PIR of 3.50-5.00 are defined as high income with all values >5.00 truncated to five [53].NHANES data are publicly available, de-identified data, thus, this study was "exempt" by the Institutional Review Board for Human Research.

Nutritional Variables

To code the nutrient and food-level data intakes, the USDA's Food and Nutrient Database for Dietary Studies (FNDDS), 5.0 (2012) [54] was used. The USDA food coding system was used to group foods into food groups with shared characteristics, such as "fish and shellfish", "meat, poultry, and fish with non-meat items", or "frozen and shelf-stable plate meals, soups, and gravies". Dietary intake data was provided by 24-hour recalls, which were used to rank-order (highest to lowest) the foods reportedly consumed by 2-18 year old children by EPA and DHA density (mg/g of food) and to calculate average EPA and DHA intake amounts. The nutrients EPA and DHA were analyzed as combined variable (EPA+DHA).

Since the goal of this study was to examine the nutrients critical for brain and eye development, EPA and DHA content of food and their consumption levels were combined to account for the bioconversion from EPA to DHA in the human body. Consumption of EPA and DHA was examined to determine tertiles of the total diet EPA and DHA density (mg/100g of food consumed) to identify and describe three levels of EPA and DHA consumers. Food-level data was analyzed using three approaches: a) the density of EPA and DHA in the foods (mg/100g of food), b) mean intake of EPA and DHA from foods (mg/d and number of children reportedly eating the food), and c) food list of all foods containing at least some EPA and DHA (more than zero mg/100g of food) and the number of children eating the food. To assess the effect of fish and shellfish intake on EPA and DHA intake, the responses to the FFQ assessing habitual fish intake were used to discern those children who ate fish or shellfish in the past 30 days from those who were classified as "not fish or shellfish consumers".

Statistical Analysis

All analyses were corrected for survey design and weighted (using the standard one-day dietary weight) to maintain the nationally representative character of the data and conducted in SAS V9.3 (SAS Institute Inc., Cary, NC, USA). Proc Survey Freq in SAS was used to estimate the percentage of the population in each race/ethnic, PIR, and sex category and to estimate the proportion of children who ate fish or shellfish in the past 30 days (FFQ responses). To determine the foods with the highest EPA and DHA density, all reported food items were identified and rank-ordered descending order of EPA and DHA density (mg/100g of food). Total EPA and DHA intake was calculated by multiplying EPA and DHA density with amount of food eaten. The mean intake of each food item and each food group was calculated. Also, the number of children reporting each food item with EPA or DHA was ascertained. Consumption data are reported as mean ± standard error or as percentages.

Results

This study included a nationally representative sample of children whose sociodemographic characteristics reflect the demographic profiles of the American population with approximately 50.7% of the children male, 60.2 non %Hispanic white, and 32.0% from a household with a PIR < 1.30 (Table 1). The foods with the highest EPA and DHA density (mg/100g food) reportedly consumed by children ages 2-18 years old are reported in (Table2) and separated by age group (Supplemental Table 1). To directly compare the EPA and DHA density of food items consumed by age group, refer to Figures 1-4. Analysis showed that 19 of the top 20 foods with the highest EPA and DHA density were from the fish and shellfish food group, with the exception of cooked brains (consumed by one child); the greatest densities were found in sturgeon roe, baked/ broiled mackerel, and skinless, boneless, water-packed sardines. Analysis of the top 20 food source of the highest contributors to dietary EPA and DHA in 2-18 year olds (Table 3) showed that all of those foods were fish or shellfish and were eaten by only small numbers of children, i.e. only three children consumed sardines or cooked salmon, one child ate fried carp, but 16 children ate battered fish (fish not specified) and 34 children consumed baked or broiled salmon. The data are presented by age group (2-5, 6-11, and 12-18 year olds in Supplemental Table 2).

Overall, the mean EPA and DHA intake was 48 ± 0.002 mg/d. This value varied by age group with 37 ± 0.002 mg/d, 45 ± 0.003 mg/d, and 58 ± 0.003 mg/d of EPA and DHA in 2-5, 6-11, and 12-18 years old, respectively [Figure 5]. However, when children not consuming dietary EPA and DHA were excluded from the calculation, the mean daily intake of EPA and DHA increased to 59 ± 0.002 mg/d for 2-18 year old children, 44 ± 0.003 mg/d for 2-5 year old children, 53 ± 0.004 mg/d for 6-11 year old children, and 72 ± 0.004 mg/d for 12-18 year old children. Furthermore, when only those children who were identified as "fish and shellfish eaters" using the FFQ were included in the calculations, the mean EPA and DHA intake further increased to an average of 64 ± 0.003 mg/d for 2-18 year olds (62.0% consumed seafood) and 49 ± 0.004 mg/d for 2-5 year olds (63.4% consumed seafood), 61 ± 0.006 mg/d.
for 6-11 year olds (63.7% consumed seafood), and 77 ± 0.004 mg/d for 12-18 year olds (59.8% consumed seafood).

When EPA and DHA from all sources were considered, the tertiles of total dietary EPA and DHA density in the foods were <5 mg/100g in the lowest tertile, 5-21 mg/100g in the medium tertile, and >21 mg/100g in the highest consumption tertile. The USDA food groups contributing most to the daily EPA and DHA intake (mg/d) were calculated and reported in (Table 4), it at least one of the food items in each food group was reportedly consumed and if at least 15 children reported eating food items from this food group. Fish and shellfish contributed the most EPA and DHA, followed by “meat, poultry, and fish with non-meat items”, and “frozen and shelf-stable plate meals, soups, and gravies”. Results

| Food Rank | Main food description | EPA and DHA density (mg/100g food) | Main food description | EPA and DHA density (mg/100g food) | Main food description | EPA and DHA density (mg/100g food) |
|-----------|-----------------------|-------------------------------------|-----------------------|-------------------------------------|-----------------------|-------------------------------------|
| 1         | Sardines, skinless, boneless, water-packed | 2150                               | Squid, dried          | 1848                               | Roe, sturgeon          | 6548                               |
| 2         | Herring, pickled      | 1389                               | Salmon, canned        | 1587                               | Mackerel, baked/broiled | 2351                               |
| 3         | Salmon, steamed/poached | 1256                              | Salmon, baked/broiled | 1079                               | Sardines, skinless, boneless, water-packed | 2149                               |
| 4         | Salmon, baked/broiled | 1088                               | Salmon, cooked, cooking method NS | 1052                               | Herring, baked/broiled  | 2024                               |
| 5         | Trout, baked/broiled | 1009                               | Salmon, floured/breaded, fried | 987                               | Mackerel, floured/breaded, fried  | 1607                               |
| 6         | Sardines, cooked      | 982                                | Sardines, canned in oil | 983                               | Salmon, canned          | 1587                               |
| 7         | Mussels, steamed/poached | 875                               | Mussels, steamed/ poached | 875                               | Sardines with tomato-based sauce (mixture) | 1396                               |
| 8         | Salmon, battered, fried | 863                               | Salmon, battered, fried | 863                               | Trout, baked/broiled     | 1083                               |
| 9         | Sea bass, steamed/poached | 741                               | Trout, breaded/battered, baked | 765                               | Salmon, baked/broiled     | 1077                               |
| 10        | Sea bass, baked/broiled | 731                               | Sea bass, baked/broiled | 742                               | Salmon, cooking method NS | 1056                               |
| 11        | Trout, floured/breaded, fried | 717                               | Pompano, baked/broiled | 681                               | Sardines, cooked         | 983                                |
| 12        | Pompano, baked/broiled | 715                                | Trout, floured/breaded, fried | 665                               | Sardines, canned in oil  | 981                                |
| 13        | Swordfish, floured/breaded, fried | 687                               | Trout, battered, fried  | 650                               | Salmon, steamed/ poached | 948                                |
| 14        | Trout, battered, fried | 651                                | Salmon cake or patty   | 632                               | Mussels, steamed/ poached | 875                                |
| 15        | Salmon cake or patty  | 634                                | Fish, type NS, baked/ broiled | 608                               | Brains, cooked           | 847                                |
| 16        | Sea bass floured/breaded, fried | 564                               | Sea bass, floured/breaded, fried | 585                               | Salmon, floured/breaded, fried | 834                               |
| 17        | Fish, type NS, baked/broiled | 515                               | Fish, cooked, type and cooking method NS | 584                               | Sea bass, baked/broiled | 723                                |
| 18        | Fish, type NS, smoked | 512                                | Squid, baked, broiled  | 583                               | Pompano, baked/broiled   | 702                                |
| 19        | Shrimp, cooked, cooking method NS | 508                               | Oysters, raw           | 560                               | Trout, floured/breaded, fried | 695                                |
| 20        | Fish, cooked, type and cooking method NS | 505                               | Oysters, floured/breaded, fried | 534                               | Oysters, steamed         | 695                                |

1Data are presented as mg/100g of food item
Table 2: The food items with the highest EPA and DHA density (mg of EPA and DHA per 100 g food) consumed by children ages 2-18 years old.

| Food Ranking | Main Food Description                                      | EPA and DHA density (mg/100g food) |
|--------------|------------------------------------------------------------|-----------------------------------|
| 1            | Roe, sturgeon                                              | 6548                              |
| 2            | Mackerel, baked/broiled                                   | 2351                              |
| 3            | Sardines, skinless, boneless, water-packed                 | 2149                              |
| 4            | Herring, baked/broiled                                    | 2024                              |
| 5            | Squid, dried                                               | 1848                              |
| 6            | Mackerel, floured/breaded, fried                           | 1607                              |
| 7            | Salmon, canned                                            | 1587                              |
| 8            | Sardines with tomato-based sauce (mixture)                 | 1396                              |
| 9            | Herring, pickled                                           | 1389                              |
| 10           | Salmon, baked/broiled                                      | 1079                              |
| 11           | Salmon, cooked, cooking method NS                         | 1056                              |
| 12           | Salmon, steamed/poached                                    | 1050                              |
| 13           | Trout, baked/broiled                                       | 1009                              |
| 14           | Sardines, canned                                          | 983                               |
| 15           | Sardines, cooked                                          | 982                               |
| 16           | Mussels, steamed/poached                                   | 875                               |
| 17           | Brains, cooked                                             | 847                               |
| 18           | Salmon, floured/breaded, fried                             | 834                               |
| 19           | Trout, breaded/battered, baked                             | 765                               |
| 20           | Sea bass, steamed/poached                                  | 741                               |

*Data are presented as mg of EPA and DHA per 100g of edible food.

also showed that the majority of 2-18 year old children (82.5%) had at least some dietary EPA and DHA intake (any intake greater than zero). Examination of the EPA and DHA densities of all foods consumed showed that the proportion of children reportedly eating fish or shellfish in the previous 30 days was calculated using the data from the supplementary FFQ on habitual fish and seafood intake. Only 35.9% of participants reportedly consumed shellfish and 49% reportedly consumed fish. Since child’s age may have an effect on fish and seafood intake, the sample was divided by age group and results showed that 31.6% and 54.5%, 35.9% and 52.3%, as well as 38.6% and 42.8% of 2-5, 6-11, and 12-18 year old children consumed shellfish and fish, respectively, in the past 30 days.

Considering EPA and DHA intake from all sources, the food items that provided the most EPA and DHA were "skinless, boneless,
Table 3: Highest contributors\(^1\) to mean EPA and DHA dietary intake of children ages 2-18 years old and the number of children reported eating the food item

| Food Ranking | Main Food Description                                      | Mean EPA and DHA intakes (mg/d) | Number of children reporting food |
|--------------|-----------------------------------------------------------|---------------------------------|----------------------------------|
| 1            | Sardines, skinless, boneless, water-packed               | 2093                            | 3                                |
| 2            | Salmon, cooked, NS as to cooking method                  | 1724                            | 3                                |
| 3            | Carp, floured or breaded, fried                          | 1538                            | 1                                |
| 4            | Fish, NS as to type, battered, fried                     | 1224                            | 16                               |
| 5            | Salmon, steamed or poached                               | 1148                            | 3                                |
| 6            | Salmon, baked or broiled                                 | 1124                            | 34                               |
| 7            | Trout, breaded or battered, baked                        | 1050                            | 1                                |
| 8            | Shrimp creole, with rice                                 | 987                             | 4                                |
| 9            | Salmon, floured or breaded, fried                         | 935                             | 2                                |
| 10           | Sardines with tomato-based sauce (mixture)               | 932                             | 1                                |
| 11           | Haddock, floured or breaded, fried                        | 903                             | 1                                |
| 12           | Sea bass, baked or broiled                               | 895                             | 3                                |
| 13           | Oysters, canned                                          | 877                             | 1                                |
| 14           | Mackerel, floured or breaded, fried                       | 868                             | 1                                |
| 15           | Sea bass, floured or breaded, fried                       | 858                             | 3                                |
| 16           | Mussels, steamed/poached                                 | 804                             | 3                                |
| 17           | Squid, dried                                             | 776                             | 1                                |
| 18           | Swordfish, floured/breaded, fried                         | 731                             | 2                                |
| 19           | Herring, pickled                                          | 690                             | 3                                |
| 20           | Scallops, baked/broiled                                  | 675                             | 1                                |

\(^1\)Contribution of EPA and DHA calculated as EPA and DHA content of the food multiplied by the amount of the food item reportedly consumed
Supplemental Table 2: Highest contributors\(^1\) to mean EPA and DHA dietary intake of children by age-group and the number of children reported eating the food item\(^1\)

| Food Group                                                                 | 2-5 years old | 6-11 years old | 12-18 years old |
|----------------------------------------------------------------------------|---------------|----------------|-----------------|
| Fish and shellfish                                                         | 282           | 309            | 491             |
| Frozen & shelf-stable plate meals, soups & gravies                         | 51            | 48             | 67              |
| Egg mixtures                                                               | 51            | 32             | 59              |
| Meat, poultry, fish with nonmeat items                                     | 33            | 41             | 44              |
| Eggs                                                                       | 24            | 30             | 40              |
| Poultry                                                                    | 20            | 28             | 34              |
| Grain mixtures, frozen plate meals, soups                                   | 11            | 14             | 19              |
| Pancakes, waffles, French toast, other grain products                       | 11            | 8              | 11              |
| White potatoes and Puerto Rican starchy vegetables                          | 6             | 5              | 7               |

\(^1\)Data are presented as mean intake of EPA and DHA intake in mg/d, rank-ordered by EPA and DHA intake with n = number of children reportedly consuming food
Table 4: The USDA food groups contributing most dietary EPA and DHA to the diets of children ages 2-18 years old, NHANES 2003-2010

| Food Group                                                                 | EPA+DHA intake (mg/d) | Number of children reporting food¹ |
|---------------------------------------------------------------------------|-----------------------|------------------------------------|
| Fish and shellfish                                                        | 373                   | 785                                |
| Meat, poultry, fish with nonmeat items                                    | 53                    | 2248                               |
| Frozen & shelf-stable plate meals, soups & gravies                       | 47                    | 304                                |
| Egg mixtures                                                              | 40                    | 1611                               |
| Poultry                                                                   | 32                    | 3156                               |
| Eggs                                                                      | 30                    | 625                                |
| Grain mixtures, frozen plate meals, soups                                 | 16                    | 2168                               |
| Pancakes, waffles, French toast, other grain products                     | 8                     | 1134                               |
| Organ meats, sausages and lunchmeats, and meat spreads                    | 6                     | 1116                               |
| White potatoes and Puerto Rican starchy vegetables                        | 6                     | 260                                |
| Other vegetables                                                          | 5                     | 85                                 |
| Cereals, not cooked or NS as to cooked                                    | 5                     | 1546                               |
| Quick breads                                                              | 4                     | 329                                |
| Salad dressings                                                           | 4                     | 63                                 |
| Beef                                                                      | 4                     | 463                                |
| Cakes, cookies, pies, and pastries                                        | 4                     | 2199                               |
| Cheeses                                                                   | 3                     | 545                                |
| Milk desserts, sauces, gravies                                            | 3                     | 1723                               |
| Pork                                                                      | 3                     | 78                                 |
| Crackers and salty snacks from grain products                             | 3                     | 598                                |

¹Data are presented as mean and SE of EPA and DHA intake (mg/d), rank-ordered by EPA and DHA amounts.

2Number of children reportedly consuming at least one food item from the food group. Food groups with less than 15 children reportedly consuming at least one food item from the USDA food group are not shown.

Discussion

This study provides new data on fish and shellfish as well as EPA and DHA consumption of American children ages 2-18 years old. Results showed that the majority of children had at least some dietary EPA and DHA intake. Food sources of EPA and DHA included nutrient dense foods, such as fish and shellfish, but also high fat, sweet desserts and salty snacks (i.e. ice cream and chips). On average, only 35.9% of the children consumed shellfish and 49% consumed fish; with increasing age, more children ate shellfish but less children had fish.

The foods with the greatest EPA and DHA density (mg/100g food) that were consumed by any 2-18 year old child were roe, mackerel, and sardines and other fish and shell fish, however these EPA and DHA-rich foods were not commonly consumed by the majority of children. This might be due to barriers such as lack of food access (i.e. ability to obtain or retrieve food from local stores), lack of availability (i.e. the quantity and quality of food that is provided by caretakers and caretakers' knowledge and ability to prepare fish) [55], and the social context in which the food is encountered such as role models not eating seafood and/or habitual consumption i.e. the children are not used to the odor or flavor of these food sources [56].

The weighted mean EPA and DHA intake of children per day were 37 mg, 45 mg, and 58 mg for 2-5, 6-11, and 12-18 year olds, respectively – much below the intake recommendations by the Joint FAO and WHO Expert Consultation on Fats and Fatty Acids in Human Nutrition Adequate Intake levels of 100-150 mg for 2-4 year olds, 150-200 mg for 4-6 year olds, 200-250 mg for 6-10 year olds, and 250-2000 mg for people 10 years and older [35] as Figure 5 shows.
This finding is alarming since, especially in younger children, EPA and DHA are critical nutrients to promote healthy brain and eye development and function. Based on the food sources identified in this study, the dramatic under-consumption of dietary EPA and DHA may be due to the low proportion of children consuming fish and shellfish, which were the most EPA- and DHA-dense foods consumed by the children. The proportion of children consuming these foods was 1: 34 children or < 0.3% of the sample population (N=13,441).

The majority of children were not consuming the foods highest in EPA and DHA and further analysis showed that consumption of foods contributing any EPA and DHA was too low to meet the intake recommendations, i.e. total daily contribution of ice cream was 3.6 mg (which was the single most consumed EPA and DHA-containing food) and that of egg omelet or scrambled egg was 39.0 mg (highest contribution to daily EPA and DHA intake but only consumed by 537 children). Tuna salad, commonly served in childcare centers and schools, ranked only thirty-eighth place and contributed small amounts of EPA and DHA to children’s diets.

Not surprisingly, fish and shellfish was the food group contributing the largest amount of EPA and DHA to 2-18 year olds diets. However, as the analysis of consumption amounts and frequency showed, very few children consumed these foods (0.3% of the population). Thus, it appears that an important public health policy should be to increase the proportion of the pediatric population consuming these foods. Previous research to examine acceptability of fatty fish meals in 2-5 year old children has shown that young children accepted oily fish when it was incorporated into familiar foods such as macaroni-and-cheese and wraps [57], thereby significantly increasing EPA and DHA intakes.

The present study had several strengths and limitations. The strengths include, but are not limited to, the large sample size and representation of the US population, the use of validated instruments to estimate EPA and DHA intake, and the pooling of four NHANES survey years (2003-2004, 2005-2006, 2007-2008, and 2009-2010). One limitation of the analysis was that the dietary intake estimates were based on one single 24-hour dietary recall. The 24-hour dietary recall is one of the most commonly used dietary intake estimation methods, especially in large nutrition surveys and has been validated for adults and children in the US.

### Table 5: The food items containing any EPA and DHA, the number of 2-18 year old children reportedly consuming the food, and the mean contribution of the food items to children daily EPA and DHA intake

| Food Description                                      | Number of children reporting food | EPA and DHA consumed (mg/d) | Mean | SE  |
|------------------------------------------------------|----------------------------------|-----------------------------|------|-----|
| Ice cream, regular, flavors other than chocolate     | 989                              | 3.6                         | <0.001 |
| Salty snacks, corn or cornmeal base, tortilla chips  | 581                              | 2.4                         | <0.001 |
| Egg omelet or scrambled egg, fat added in cooking   | 537                              | 39.0                        | 0.002 |
| Chicken or turkey loaf, prepackaged or deli, luncheon meat | 501                              | 7.4                         | 0.001 |
| Pancakes, plain                                      | 409                              | 1.2                         | <0.001 |
| Waffle, plain                                        | 395                              | 12.1                        | 0.001 |
| Chicken patty, fillet, or tenders, breaded, cooked  | 354                              | 4.5                         | <0.001 |
| Egg, whole, fried                                    | 353                              | 31.8                        | 0.001 |
| Spaghetti with tomato sauce and meatballs, meat sauce, or meat sauce and meatballs | 328                              | 3.5                         | <0.001 |
| Cheerios                                              | 325                              | 6.0                         | <0.001 |
| Froot Loops                                           | 297                              | 1.7                         | <0.001 |
| Chicken, drumstick, coated, baked or fried, prepared with skin, skin/coating eaten | 281                              | 35.0                        | 0.002 |
| Chicken, wing, coated, baked or fried, prepared with skin, skin/coating, eaten | 275                              | 45.6                        | 0.003 |
| Bread, white                                          | 240                              | 1.1                         | <0.001 |
| Egg omelet or scrambled egg, fat not added in cooking | 234                              | 42.0                        | 0.002 |
| Roll, sweet, cinnamon bun, frosted                   | 229                              | 2.3                         | <0.001 |
| Chicken, NS as to part and cooking method, NS as to skin eaten | 227                              | 40.5                        | 0.003 |
| Cheese, processed, American or Cheddar type          | 226                              | 3.9                         | <0.001 |
| Corn dog (Frankfurter or hot dog with cornbread coating) | 225                              | 3.5                         | <0.001 |
| Egg omelet or scrambled egg, NS as to fat added in cooking | 210                              | 40.7                        | 0.003 |

\(^1\)Data are presented as mean and SE of EPA and DHA intake in mg/d, rank-ordered by the number of children consuming the food.
dietary sources of EPA and DHA may have to be explored.

However, one day of intake does not provide a good estimate of usual intake especially of rarely consumed foods such as fish and shellfish, and children’s diets might not be accurately captured in a single 24-hour recall. However, some of this variation was accounted for by the use of the FFQ assessing fish and seafood consumption over a 30-day period.

**Conclusions**

This study provides important information on the food sources and the dietary intake of EPA and DHA, which are important essential fatty acids for brain and eye development and function, in 2-18 year old American children. Results indicate that fish and shellfish provide the highest EPA and DHA density, but are not commonly consumed foods. Accordingly, estimated average EPA and DHA intake amounts were dramatically below the current intake recommendation levels. Higher consumption levels of EPA and DHA would be beneficial and should be recommended, however, as data from this study show, fish and shellfish are not well accepted in children ages 2-18 years old. Future research should investigate the barriers (e.g. fish consumption advice, availability of and accessibility to oily fish, preparation ability by parents, parental eating habits, and cost) to elucidate why so many children are not consuming fish and shellfish. In addition, healthy alternative dietary sources of EPA and DHA may have to be explored.

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