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Dietary intake of long-chain ω-3 polyunsaturated fatty acids: contribution of meat sources

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Abstract

Objective: We examined the relative contributions of meat and fish to the dietary intakes of long-chain ω-3 polyunsaturated fatty acids (LCn3PUFAs).

Methods: A database detailing 4550 foods and 4298 recipes recorded in the 1995 Australian National Nutrition Survey (NNS95) was updated with new fatty acid compositional data then used to determine intakes from 24-h dietary recalls of 13 858 individuals. This approach was validated with food frequency questionnaires from 8321 of these individuals.

Results: Fatty acid intakes were comparable to our previous estimates from NNS95 except for LCn3PUFAs, which were considerably higher. Mean intakes in adults estimated from the 24-h recalls were 75, 71, and 100 mg/d for eicosapentaenoic acid, docosapentaenoic acid (DPA), and docosahexaenoic acid, respectively, giving a total of 246 mg/d. This is 30% greater than our previously published estimate of LCn3PUFA intake, the difference being attributable to inaccuracies in pre-existing data on the fatty acid composition of certain foods, particularly the DPA content of meats. We estimate that 43% of the LCn3PUFAs consumed by adults in the NNS95 survey originated from meat, poultry, and game compared with 48% from fish and seafood. Steak and kidney pies and other meat-containing cereal-based products accounted for an additional 4%. Beef and lamb contributed 28% of the total LCn3PUFA intake, whereas pork and poultry contributed 4% and 10%, respectively. Food frequency questionnaires produced similar results.

Conclusion: Meat is a major source of LCn3PUFA, particularly DPA, for most Australians. When DPA is included in the definition of LCn3PUFAs, almost half the average adult intake of LCn3PUFA appears to originate from meat sources.

Keywords: Omega-3; Docosapentaenoic acid; Red meat; Dietary intakes

Introduction

There is increasing recognition of the health benefits of regular consumption of the long-chain ω-3 polyunsaturated fatty acids (LCn3PUFAs) present in fish and other seafood [1–3]. These benefits extend from developmental roles, especially in the nervous system, during infancy to the attainment and maintenance of optimal mental and physical health status throughout adult life [4]. In the latter case, attention has focused largely on evidence for cardioprotective and anti-inflammatory effects of LCn3PUFAs, resulting in public health recommendations for regular consumption of fatty fish [2,5].

Although seafood is the major dietary source of LCn3PUFA, a rapidly increasing variety of alternative food sources is being developed, encouraged by the introduction of nutritional and health claims for functional foods rich in LCn3PUFAs [1,6]. These include processed foods enriched with LCn3PUFA from microalgal and other sources and meat, milk, and eggs from livestock fed ω-3–rich diets [7]. Hence, professional associations and health authorities are recognizing the need to express dietary recommendations in terms of absolute amounts of LCn3PUFA rather than servings of fatty fish [1,6,8].

Development of recommendations should take account

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of existing population intakes of LCn3PUFAs. In many cases, however, the information on intakes currently available from population surveys is fairly rudimentary. This is due largely to limitations in the precision of fatty acid compositional data for foods, e.g., the U.S. Department of Agriculture (USDA) National Nutrient Database [9], and lack of detail in descriptions of the food items consumed, e.g., the extent of trimming of fat from cuts of meat or the species of fish used in a take-away meal. We took these issues into account in our recent analysis of the 1995 Australian National Nutrition Survey (NNS95) in which we applied a newly developed database on the fatty acid composition of foods [10] to determine the dietary sources and intakes of PUFAs [11]. This enabled us to estimate for the first time the average LCn3PUFA intake of the Australian adult population as 190 mg/d [11], which was comparable to the average intake for adults in the United States (140 mg/d) as estimated from the Continuing Survey of Food Intakes of Individuals [12], but an order of magnitude lower than that of habitual fish-eating countries such as Japan, where the intake has been estimated to be approximately 1600 mg/d [13].

Interestingly, we noted that the meat, poultry, and game category of foods was a significant source of LCn3PUFAs, accounting for at least one-fifth of the average intake of Australians [11,14]. This is not surprising, considering that, as in the United States, consumption of meat in Australia is comparatively high. The mean daily intake of meat, poultry, and game for adults in the NNS95 was 158 g compared with only 26 g for the fish and seafood category [15]. Thus the modest amounts of PUFA in muscle tissue phospholipids of lean meat need to be taken into account when determining dietary PUFA intakes, whereas previous estimates of LCn3PUFA have often been based on consumption of seafood only [16]. Importantly, the predominant LCn3PUFA in meats is docosapentaenoic acid (DPA) [17], the functional and nutritional attributes of which are largely unknown.

Recognizing the potential significance of meat consumption as a contributor to dietary intakes of LCn3PUFA, particularly DPA, we sought to further refine the NNS95 analysis by using a revised database with greater detail on the meat products consumed. This has enabled us to refine our estimates of LCn3PUFA intakes and further delineate the food sources.

Methods and materials

Survey data

The NNS95 survey was conducted jointly by the Australian Bureau of Statistics and the Department of Health and Family Services, with representation from rural and urban areas of all Australian states and territories [15]. Food intakes were surveyed in 13 858 individuals who were interviewed in their homes by qualified nutritionists using a 24-h recall method; 8321 of them also completed a food frequency questionnaire (FFQ). Interview schedules were randomized across subjects, thus ensuring that all 7 d of the week were covered equally. Individual descriptions of all foods consumed in the previous 24 h were recorded, as were the time of consumption and the amount consumed as estimated with the aid of food models. The 24-h recall questionnaire was based on material developed by the USDA. The FFQ comprised a qualitative questionnaire on the usual consumption of 107 foods and 11 vitamin/mineral supplements over the preceding 12 mo. Respondents returned the completed FFQ by mail to the Australian Bureau of Statistics.

Databases

The NNS95 survey data were compiled into a database package that was made available on compact disk to research institutions on request. The package contained confidentialized unit record files, i.e., unidentified information from each individual in the study, which included the individual's identity number and demographic descriptors (e.g., age and gender), amounts of each encoded food consumed by the individual in the 24-h recall, and, for most respondents, FFQ data. It also contained data on the nutrient composition of foods and recipes described in the confidentialized unit record files, which had been sourced from published and unpublished data on Australian foods held by the Australia & New Zealand Food Authority or, when Australian data was not available, from overseas sources such as the official food tables of the United Kingdom and the United States [15].

For our previous estimation of LCn3 PUFA intakes [11], we used a newly developed database with fatty acid compositions of approximately 1100 foods [10], which nevertheless contained limited data on meat. It has since been extensively updated with approximately 350 new analyses of lean and fatty portions of red meats (unpublished data of Prof. A. Sinclair and colleagues, which was provided by Meat & Livestock Australia). This food composition database was then merged with data that had been previously extracted by CSIRO Australia (Adelaide, Australia) from the NNS95 database package. When fatty acid composition data for a particular food were unavailable, this information was obtained from the USDA food composition tables [9]. This occurred mainly with infrequently consumed, low-volume foods (e.g., chicory). The NNS95 database package was used to calculate fatty acid compositions for foods based on recipes. It included details on 4550 base foods; 1286 of these had recipes supplied in the confidentialized unit record files. Another 3012 recipes were supplied for modified versions of the base foods (e.g., egg, fried in lard). A total of 589 food items contained meat. Values for any foods without fatty acid data were imputed by using data from similar foods. Validation checks were performed to compare fat composition supplied in the NNS95 with other published values. Particular consideration was given to 1) the extent of trimming of meat, 2) meat in products classified as cereal products and dishes, and 3) the likely nature of unspecified fish used in fish dishes.

Once the cross-links for foods were determined, data were exported to a relational database management system (SIR 2002, SIR Pty Ltd, Terrey Hills, NSW, AUSTRALIA). This database also contained the food recipes and all data from each participant in the NNS95. Fatty acid content of recipe foods and modified foods was computed for each food consumed and then intakes were calculated for each survey participant.

Analysis of 24-h recalls

Merged fatty acid data were used to calculate fatty acid intakes for each 24-h recall. Intakes were tabulated by age and gender. Contributions of various food groups to LCn3PUFA intakes were also determined. Contributions from red meat, pork, and poultry were compared with those from fish/seafood.

Analysis of FFQ

The FFQ was intended as a broad tool to monitor food consumption habits, with nine frequency categories available for each food item: never or less than once a month, one to three times per month, once a week, two to four times per week, five to six times per week, daily, two to three times a day, four to five times a day, and more than six times a day. Each item in the FFQ was intended to represent a generic group of foods (e.g., cheddar and other cheeses). However, the 24-h recalls contained data for a number of generic foods composed of weighted averages of the most popular foods; these composite data were used in the FFQ analyses. When composite items were not available, the relative popularity of all relevant foods consumed by adults in the 24-h recall was ranked, and the most popular food was used. Median serving sizes for each gender were calculated for each item in the FFQ by using the 24-h recall data for adults. Fatty acid profiles were calculated for each food in the FFQ from averaged compositional data of similar foods in the 24-h recall and used to estimate the customary dietary intakes of PUFA.

Statistical analysis

Distributions, medians, means, and standard errors of the mean were computed from 24-h recall data and FFQ data using the SIR database system.

Results

Table 1 presents the distribution of the study population; 78% were adults and 48% were male.

Table 1
Numbers of subjects in the 1995 Australian National Nutrition Survey 24-h recall

	Total	Male	Female
All ages	13 858	6616	7242
2–11 y	1921	971	950
12–18 y	1086	564	522
19–24 y	1060	485	575
25–64 y	7831	3694	4137
≥65 y	1960	902	1058
Adults (≥19 y)	10 851	5081	5770

The data for average intakes (g/d) of total ω-6, total ω-3, and total LCn3PUFA and for selected individual ω-6 and ω-3 PUFAs estimated from the 24-h recalls are listed in Table 2. With the exception of eicosapentaenoic acid (EPA) and particularly DPA, the values are comparable with those reported in our previous preliminary analysis of the NNS95 [11]. However, the reassessed intakes of EPA (75 mg/d) and DPA (71 mg/d) are higher than previously estimated (56 and 26 mg/d, respectively). As discussed below, this is a direct result of previous underestimation of the LC ω-3 content of certain foods, particularly red meat products. In the present analysis, we also estimated customary intakes of PUFA from the FFQ and found a very close agreement between mean and median data derived by the two methods (Fig. 1).

The mean LCn3PUFA intake in Australian adults (males and females, 19 y and older) was found to be 246 mg/d (Table 2) compared with our previous estimate of 189 mg/d [11]. There was little variation in adulthood, although women had lower intakes than men, proportional to their lower total energy and PUFA intakes. Children, however, had substantially lower LCn3PUFA intakes, even in proportion to their total PUFA intake.

The median PUFA intakes were approximately 80% of the corresponding mean intake values except for LCn3PUFAs, where the median value of 121 mg/d was approximately half of the mean value of 246 mg/d (Fig. 1). This is particularly evident for EPA and docosahexaenoic acid (DHA) but less so for DPA. One might argue that this is an artifact of assessing the intake of a food eaten relatively infrequently, namely fish, from a single 24-h recall. However, when food intakes were quantified from the FFQ using estimates of serving sizes derived from 24-h recalls of the same individuals, almost identical estimates were obtained for the mean (247 mg/d) and median (119 mg/d) intakes of LCn3PUFA in adults (Fig. 1). Hence, the difference between mean and median intakes, particularly of EPA and DHA, is likely to reflect a less common consumption of fish (i.e., a small proportion of the population eating large quantities of fish), rather than being an artifact of low frequency of consumption by individuals in the 24-h recall.

Table 3 presents the contributions of various food sources to LCn3PUFA intakes. In our previous estimates, fish and seafood accounted for 70% of LC ω-3 intake,

Table 2
Intakes of selected PUFAs (mg/d) for all subjects from 24-h recall*

	Total (all ages)	2–11 y	12–18 y	19–24 y	25–64 y	≥65 y	All adults (≥19 y)	Adults (men only)	Adults (women only)
Total PUFA	11 870 ± 70	9418 ± 120	12 760 ± 220	14 020 ± 250	12 410 ± 100	10 050 ± 160	12 230 ± 80	14 540 ± 130	9990 ± 90
Total ω-6 PUFA	10 600 ± 60	8470 ± 120	11 380 ± 200	12 600 ± 230	11 080 ± 90	8880 ± 150	10 920 ± 80	12 970 ± 120	8930 ± 80
18:2-ω-6	10 340 ± 60	8320 ± 120	11 110 ± 200	12 280 ± 230	10 790 ± 90	8680 ± 150	10 640 ± 70	12 610 ± 120	8720 ± 80
20:4-ω-6	141 ± 1	81 ± 2	142 ± 4	174 ± 4	159 ± 2	11 ± 3	153 ± 2	191 ± 2	117 ± 2
Total ω-3 PUFA	1270 ± 10	950 ± 10	1380 ± 30	1420 ± 30	1330 ± 10	1170 ± 20	1310 ± 10	1580 ± 20	1060 ± 10
18:3-ω-3	1050 ± 10	840 ± 10	1180 ± 20	1170 ± 20	1080 ± 10	950 ± 20	1070 ± 10	1280 ± 10	870 ± 10
20:5-ω-3	67 ± 1	32 ± 2	57 ± 4	77 ± 4	76 ± 2	69 ± 4	75 ± 2	91 ± 3	60 ± 2
22:5-ω-3	64 ± 1	32 ± 1	63 ± 2	81 ± 2	73 ± 1	54 ± 2	71 ± 1	90 ± 1	52 ± 1
22:6-ω-3	90 ± 2	46 ± 3	75 ± 7	94 ± 6	102 ± 3	96 ± 6	100 ± 3	117 ± 5	83 ± 3
Total LCn3PUFA	221 ± 4	110 ± 6	195 ± 12	253 ± 11	251 ± 6	219 ± 10	246 ± 5	298 ± 8	195 ± 5

LCn3PUFA, long-chain ω-3 polyunsaturated fatty acid; PUFA, polyunsaturated fatty acid
* Mean ± standard error of the mean.

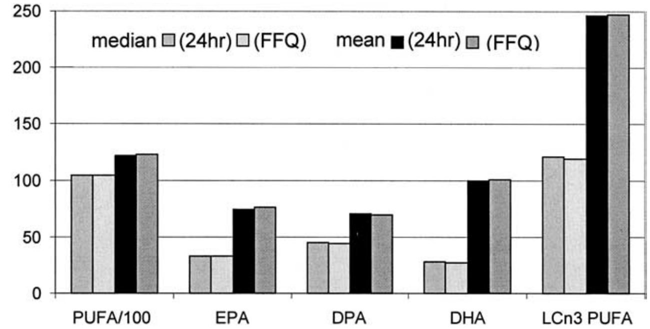

Fig. 1. Comparison of median and mean intakes (mg/d) of ω-3 PUFAs and total PUFAs (×0.01) estimated from 24-h recalls and FFQ. DHA, docosahexaenoic acid; DPA, docosapentaenoic acid; EPA, eicosapentaenoic acid; FFQ, food frequency questionnaire; PUFA, polyunsaturated fatty acid.

whereas meat, poultry, and game contributed 20% [11]. However, Australian adults consume six times as much meat, poultry, and game as fish and seafood, so it is not surprising that the contributions of these two food groups to LCn3PUFA intakes are similar, i.e., 48.0% for fish and seafood and 42.7% for meat, poultry, and game. If the meat content of meat pies and other cereal-based products (contributing 3.9% of LC ω-3 intake) is taken into consideration, almost half of LCn3PUFA consumed by adults would appear to come from meat, poultry, and game sources. This major variation from our previous estimate can be attributed to the inherent underestimates of LCn3PUFA contained in meat due to the imprecision of previous data on fatty acid composition.

A clearer indication of the relative contributions of meat and fish/seafood to LCn3PUFA consumption can be obtained by comparing weighted averages of the concentrations of LCn3PUFA in various food categories, bearing in mind that the concentrations can vary markedly between different species of fish or between different cuts of meat. Thus the average values for LCn3PUFA concentrations of meats and fish shown in Fig. 2 have been weighted in accordance with the frequency of consumption of each item of meat or fish. It can be seen that red meat, particularly beef and lamb, is a modest source of DPA and, to a lesser extent, EPA, whereas fish is a far richer source of LCn3PUFA, particularly DHA.

In summary, our estimate of the average adult LCn3PUFA intake (246 mg/d) comprises 75, 71, and 100 mg/d from EPA, DPA, and DHA, respectively. The major variation from our previously estimated intakes [11] is a three-fold higher value for DPA, originating primarily from red meat (Fig. 2). Of the various meat categories, beef was the greatest contributor to LCn3PUFA intake (22.3% for adults), whereas lamb, pork, and poultry contributed 5.9%, 3.9%, and 10.0%, respectively. In each category, most LCn3PUFA was consumed from fresh cuts of meat, with very little from sausages and processed foods. A more

Table 3
Percentage contributions of major food groups* to the average intakes (mg/d) of total PUFAs and individual LCn3PUFAs in adults

Major food group	Examples of foods within major food groups	Total PUFA	EPA	DPA	DHA	LCn3PUFA
Fats and oils	Butter, margarine, oils, copha	23.1	0.0	0.0	0.0	0.0
Cereals and cereal products	Bread, English muffins, rice, pasta, breakfast cereals	12.7	0.4	0.6	0.1	0.4
Cereal-based products and dishes	Biscuits, cakes, pies, fried rice, pizza, vol au vents, quiche, gnocchi, lasagna, commercial hamburgers, croissants, pancakes	12.0	4.5	8.9	4.4	5.7
Egg products and dishes	Eggs, omelette with cheese, spinach souffle	1.7	0.0	0.7	5.1	2.3
Fish and seafood products and dishes	Fish, prawns, canned tuna, fish with pasta, paella with seafood	3.5	49.7	15.4	69.9	48.0
Meat, poultry, and game products and dishes	Beef patty, rabbit, offal, ham, lamb casserole, chicken stir-fry	18.2	44.8	73.2	19.6	42.7
Milk products and dishes	Milk, yogurt, cream, cheese, ice cream, custard, soy milks, milkshakes	3.9	0.0	0.1	0.1	0.1
Savoury sauces and condiments	Gravy, satay sauce, cream and bacon pasta sauce, pickles, olives, mayonnaise, salad dressing, stuffing	4.5	0.0	0.0	0.1	0.1
Vegetables, legumes, and pulses†	Fresh vegetables, hot potato chips, sun dried tomatoes, coleslaw, canned mushrooms, vegetable curry, kidney beans, lentils, hummus, bakes beans, tofu, vegetarian sausages	11.8	0.0	0.1	0.1	0.1
Nut and seed products and dishes	Sesame seeds, cashew nuts, peanut butter, coconut cream	5.0	0.0	0.0	0.0	0.0
Snack foods	Potato crisps, pretzels, popcorn	1.2	0.0	0.0	0.0	0.0

DHA, docosahexaenoic acid; DPA, docosapentaenoic acid; EPA, eicosapentaenoic acid; LCn3PUFA, long-chain ω-3 polyunsaturated fatty acid; PUFA, polyunsaturated fatty acid

* See McLennan and Podger [15].

† Some dishes in the vegetables category contained small amounts of LCn3PUFA in meat or eggs, e.g., vegetables stuffed with rice and meat (vine leaves, capsicum, tomato, cabbage rolls), potato patties with added meat, bacon and/or cheese, egg dishes (caesar salad, potato salad with egg), battered vegetables (cauliflower, broccoli, vegetable tempura) or vegetables fried in egg and bread crumbs (hash browns, potato patties, corn fritters).

detailed account of the content and contribution of specific meat products will published elsewhere.

Discussion

The present reanalysis of NNS95 provides us with a more reliable assessment of dietary PUFA intakes, particularly LCn3PUFA, than was previously available. The most important outcome, however, is the recognition that meat is a far more substantial source of LCn3PUFA in our typical Western diet than was hitherto recognized.

From our previous assessment of NNS95, we reported that meat was a major source of LCn3PUFA, contributing approximately 20% of the average LCn3PUFA intake of

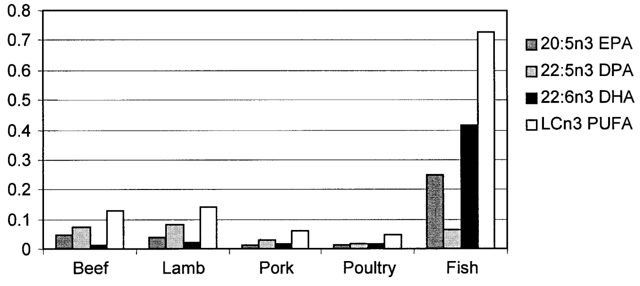

Fig. 2. LCn3PUFA content of cooked foods (g/ 100 g, weighted by consumption in the 1995 Australian National Nutrition Survey). DHA, docosahexaenoic acid; DPA, docosapentaenoic acid; EPA, eicosapentaenoic acid; LCn3 PUFA, long-chain ω-3 polyunsaturated fatty acid.

adult Australians [11]. Our re-evaluation of the same 24-h recall data using an updated fatty acid compositional database for foods and recipes, particularly those containing meat, currently shows that to be an underestimate. The present analysis indicates that meat, poultry, and game account for 43% of LCn3PUFA intake, whereas another 4% derives from the meat content of cereal-based foods such as steak and kidney pies. Hence, meat sources supplied almost half of the LCn3PUFA intake, equivalent to the contribution from fish/seafood.

This is not surprising, when one considers the relative consumption rates for meat and fish. Fish and other seafood are the richest food sources of LCn3PUFA, with concentrations 5 to 15 times higher than in meat or poultry (Fig. 2). However, Australians were consuming six times as much meat, poultry, and game as fish and seafood in 1995. At the same time, Americans were eating 12 times as much meat as fish [18]. Hence, intakes of LCn3PUFA in the United States and elsewhere may also be underestimated, especially because the contribution of meat to LCn3PUFA intakes is often ignored when assessing intakes from food records [16].

Several factors may account for this. First, examination of the USDA food composition tables [9] indicates little, if any, LCn3PUFA in meat and meat products. This may reflect imprecision in the fatty acid data available or, alternatively, real differences in the PUFA composition of meat between pasture-fed and grain-fed livestock. In Australia, ruminants are typically pasture fed and thus their meat has higher LCn3PUFA concentrations [17].

Second, and more importantly, analyses of LCn3PUFA intakes, intake recommendations, and health claims often omit DPA. DPA is an intermediate in the production of DHA from EPA, and, as we have observed, it is the predominant LCn3PUFA in meat and is a minor but significant component of the LCn3PUFA content of fish. Because meat is far more commonly consumed than fish, it is not surprising that the median intake is closer to the mean intake for DPA than for EPA or DHA, which are virtually confined to fish/seafood.

There is comparatively little DPA in fish oil and, because much of the evidence for health benefits of LCn3PUFA originates from intervention trials with fish oil supplementation, less is known about the physiologic role of DPA or its nutritional and health potentials. The limited information available on physiologic effects of DPA suggests that some of its effects may be similar to but quantitatively distinct from EPA and DHA. For example, the inverse association between dietary LCn3PUFA intakes and arterial intima/media thickness assessed by ultrasonography was greatest for DPA [19]. In addition, DPA has been shown to be a more potent inhibitor of platelet aggregation than EPA or DHA [20]. It is of interest that, in the Kuopio ischemic heart disease risk factor study [21], risk reduction correlated significantly with serum concentrations of DPA plus DHA in individuals whose mercury status was low. There was no risk reduction associated with EPA. Unfortunately, epidemiologic data on DPA are limited due to lack of inclusion of DPA in the nutrient databases used [16].

Dietary supplementation with fish or fish oil appears to have little effect on circulating DPA concentrations, indicating little conversion from EPA or DHA. It is of interest, however, that DPA appears to be a primary end point for the synthesis of LCn3PUFA from α-linolenic acid (LNA). Burdge et al. [22] found that the conversion of LNA was 7.9% to EPA and 8.1% to DPA in men, with hardly any further conversion (0% to 0.04%) through to DHA, although there was considerably greater conversion of DPA to DHA in women [22,23]. However, other studies have suggested that LNA conversion through to DHA does not occur, particularly during pregnancy. De Groot et al. [24] supplemented pregnant women with 2.8 g/d of LNA contained in a margarine spread. Plasma concentrations of EPA and DPA increased by 30% and 15%, respectively, but DHA did not differ between the LNA-supplemented and control groups. In a flaxseed oil supplementation trial in vegetarian men, consumption of 15.4 g/d of LNA resulted in 7-, 4.5-, and 1.5-fold increases of plasma LNA, EPA, and DPA, respectively, with no change in DHA [25]. In the same study, platelet phospholipid EPA and DPA increased 2.5- and 1.5-fold, respectively, after LNA consumption, whereas DHA was unaffected.

Thus, from a nutritional perspective, DPA is a potentially important LCn3PUFA and should be included in dietary intake assessments and recommendations for LCn3PUFA. Current U.S. intake recommendations and health claims define LCn3PUFA as the sum of EPA plus DHA, although DPA has been included in LCn3PUFA recommendations elsewhere [8,26,27]. Our present assessment of the average adult DPA intake is similar to that in France, where the consumption of meat is similar [27], although we find that DPA as a proportion of LCn3PUFA is lower than in France, where the consumption of fish is higher.

It is of interest that the mean intake of DPA reflects the median intake more closely than is the case for EPA and particularly DHA (Fig. 1). This may be attributed to a skewed distribution of fish consumption as observed previously [14], i.e., a small proportion of the population has a high intake of DHA-rich fish, whereas the majority eat relatively little. In contrast, meat, the primary source of DPA, tends to be eaten regularly by most of the population. The LCn3PUFA contents of pork, poultry, red meat, milk, and eggs can be increased to varying extents by supplementing livestock feeds with plant sources of LNA or marine sources of LCn3PUFA [28]. Thus there is the potential for even greater acquisition of LCn3PUFA through regular consumption of foods other than fish/seafood. Dietary recommendations for LCn3PUFA intake could better reflect these alternative options.

In conclusion, meat, particularly red meat, is an important dietary source of LCn3PUFA, in which DPA predominates. Further enrichment of the LCn3PUFA content of meat may be a practical alternative to increased consumption fish as a means of increasing population intakes of LCn3PUFA. However, more information on the nutritional and health benefits of DPA consumption is needed.

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