Global Estimates of Dietary Intake of Docosahexaenoic Acid and Arachidonic Acid in Developing and Developed Countries

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Key Words

Arachidonic acid · Docosahexaenoic acid · Global dietary intake · Infants · Adults

Abstract

Background/Aim: For international recommendations on docosahexaenoic acid (DHA) and arachidonic acid (ARA) dietary intake to be valid, there needs to be a greater understanding of dietary patterns across both the developed and developing world. The aim of this investigation was to provide a global overview of dietary intake of DHA and ARA. **Methods:** Food balance sheets from the Food and Agriculture Organisation Statistics Division and fatty acid composition data from Australian food composition tables in Nutrient Tables 2010 were utilised to generate median per capita intake estimates for DHA and ARA in 175 countries worldwide. **Results:** Estimated dietary intake per capita for DHA and ARA in 47 developed and 128 developing countries demonstrated that 48% of the 175 countries have an ARA intake of <150 mg/day and 64% have a dietary DHA intake of <200 mg/day. There was a direct relationship between dietary ARA and DHA intake and the per capita gross national income of the country. Regional analysis showed the lowest ARA and DHA dietary intake in Sub-Saharan Africa and Central and Southern Asian populations. **Conclusions:** This study demonstrates there are many populations worldwide that have ARA and DHA intake that do not reflect current inter-

national recommendations, and the public health consequences of this global inadequacy need to be urgently considered.

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Introduction

Long chain polyunsaturated fatty acids (LCPUFAs) attract considerable interest from scientists, clinicians and policymakers because of their roles in key metabolic processes that influence population health and well-being [1, 2]. The n-3 LCPUFAs influence cellular structure and function [3, 4], and docosahexaenoic acid (DHA) is especially important in the brain and retina, where it rapidly accumulates during the early years of life [5]. DHA is also the precursor of potent lipid mediators that play crucial roles in the prevention or treatment of common chronic diseases that may lead to significant morbidity and mortality.

The n-6 LCPUFAs, particularly arachidonic acid (ARA), are widely distributed throughout human cells and tissues. In addition to the central nervous system where ARA plays an essential structural and functional role, ARA is also a metabolic requirement for all cells as a precursor for eicosanoids which modulate a variety of biological processes, particularly those relating to cerebral, cardiovascular and immune functions [4].

However, despite their biological importance in health and development at all stages of the human life cycle, recommendations on specific dietary requirements for DHA and ARA are inconsistent, and at times controversial [6]. The current relevant scientific evidence is predominantly from surveys and scientific studies that have focused on the needs of populations located within developed countries, and as a consequence, there is a significant lack of information on dietary intake in populations from low-income countries. For global recommendations to be effective, the evidence needs to be inclusive and in particular, the needs of the most vulnerable populations have to be addressed.

There are 2 key components that may influence DHA and ARA status. First, there is the contribution of endogenous synthesis from the essential precursor 18-carbon n-3 and n-6 fatty acids, linoleic acid and alpha-linolenic acid, respectively; second, there is the contribution from preformed DHA and ARA sources in the diet.

Endogenous synthesis is directed through a metabolic pathway where the n-3 and n-6 fatty acids compete for a shared desaturation and elongation enzyme system. As a consequence, the balance in the intake of the essential 18-carbon n-3 and n-6 precursors can influence the levels of DHA and ARA derived from endogenous synthesis [7]. Moreover, it is now recognised that this metabolic pathway is relatively inefficient in converting n-3 and n-6 precursor fatty acids to DHA and ARA respectively, especially in early life when organ development is at its peak [8–13].

The competition between n-3 and n-6 fatty acids is particularly evident at the rate-limiting $\Delta 5$ - and $\Delta 6$ -desaturase steps in the metabolic pathway. It is now recognised that, in addition to substrate competition, the efficiency of the $\Delta 5$ - and $\Delta 6$ -desaturase steps is also dependent on the genotype of fatty acid desaturase (FADS) 1 and FADS2, both located on chromosome 11, and which encode $\Delta 5$ - and $\Delta 6$ -desaturase enzymes, respectively [7]. Several studies have reported associations between single nucleotide polymorphisms (SNPs) in the FADS genes and LCPUFA status, with carriers of the minor alleles of FADS SNPs being associated with lower red blood cell content of LCPUFAs, most notably of ARA [14, 15]. Moreover, there is emerging data to confirm that there is global variation in the prevalence of the minor alleles of FADS SNPs and this may contribute to population differences in LCPUFA status and subsequent health outcomes [16]. Although these metabolic and genetic factors may influence the LCPUFA status, and recommendations on dietary intake of n-3 and n-6 LCPUFAs need to be sensitive to their effects, the adequacy of the dietary intake will

play the dominant role in determining the LCPUFA status of a population [17].

In 2003, the World Health Organisation stated that in the general population diets should provide an adequate intake of PUFAs to prevent adverse outcomes, especially cardiovascular disease, and it was recommended that this should be in the range 6–10% of daily energy intake and that there should be an optimal balance between n-6 and n-3 PUFAs of 5–8 and 1–2% of daily energy intake per day, respectively [18]. In 2010, the European Food Safety Authority (EFSA), basing their recommendation in adults on cardiovascular considerations, indicated an adequate adult intake of 250 mg/day for eicosapentaenoic acid (EPA) plus DHA [19]. For pregnant and lactating women, they recommended an additional 100–200 mg DHA. EFSA also recommended an adequate intake of 100 mg DHA for older infants (>6 months of age) and young children below the age of 24 months. For children aged 2–18 years EFSA indicated that dietary advice for children should be consistent with that of the adult population (i.e., 1–2 fatty fish meals per week or ~250 mg of EPA plus DHA per day). The International Society for the Study of Fatty Acids and Lipids had previously recommended that at least 500 mg/day of EPA and DHA in the general adult population was required to maintain cardiovascular health [20]. In 2010, the Food and Agricultural Organisation (FAO) of the United Nations provided specific recommendations on n-3 LCPUFA for pregnant and lactating women indicating a requirement of 300 mg/day of DHA and EPA of which at least 200 mg/day should be DHA [21]. In relation to young children, FAO recommended that for 0–6 months, the requirement is 0.1–0.18% energy (equivalent to a mean of 102 mg/day) of DHA; for 6–24 months, DHA 10–12 mg/kg body weight; 2–4 years, DHA and EPA 100–150 mg/day; increasing to DHA and EPA of 200–250 mg at age 6–10 years.

Regarding ARA, the dietary recommendations are few, but food surveys report the intake of ARA to be between 50 and 300 mg/day for adults consuming western-style diets [22]. Recommendations for infants and children are also few with a recommendation of 140 mg ARA/day for infants during the first 6 months of life [23], and for young children, the Belgian Health Council [24] recommended that the ARA content of the diet should be 0.10–0.25% energy (102–258 mg/day), and DHA 0.10–0.40% energy (102–413 mg/day). However, a subsequent food survey indicated that children aged between 2.5 and 3 years in Belgium had a limited DHA intake of 45 mg/day and for ARA, 17 mg/day [25].

It is evident that for international recommendations on DHA and ARA dietary intake to be valid and repre-

Table 1. Weight percentage of food losses and waste at the retail (R) and consumption (C) level by type of food and geographical region (FAO, 2011)

Food	Region											
	Europe		North America and Oceania		Sub-Saharan Africa		North Africa, West and Central Asia		South and South-East Asia		Latin America	
	R	C	R	C	R	C	R	C	R	C	R	C
Fish/seafood	9	11	9	33	15	2	10	4	15	2	10	4
Meat	4	11	4	11	7	2	5	8	7	4	5	6
Milk and eggs	0.5	7	0.5	15	10	0.1	8	2	10	1	8	4

sentative of global populations, there needs to be a greater understanding of dietary patterns across both the developed and developing world.

The aim of this investigation is to provide a global overview of dietary intake of DHA and ARA, which will clarify the international variation in the LCPUFA diet, identify those countries that are most vulnerable to deficiency, and provide a baseline for the needs of the most vulnerable groups within populations.

Methods

Estimating Global Dietary Intake of DHA and ARA Consumption Data

The FAO of the United Nations has prepared food balance sheets (FBS) on regular intervals since the 1940s [26]. The objective of a FBS is to present a comprehensive picture of the pattern of a country's food supply during a specified reference period [27]. The FAO compiles yearly FBS data from 179 countries and includes more than 100 foods and agricultural products from country-level data on the production, use (e.g., seed, livestock feed, food processing, non-food uses and losses) and trade of food commodities. The FBS show national availability for each food item, that is, for each primary commodity and a number of processed commodities that is potentially available for human consumption. It also shows the sources of supply for these commodities and their utilization. The total quantity of foodstuffs produced in a country added to the total quantity imported and adjusted to any change in stocks that may have occurred since the beginning of the reference period gives the supply available during that period. On the utilization side, a distinction is made between the quantities exported, fed to livestock, used for seed, put to manufacture for food use and other uses, losses during storage and transportation, and food supplies available for human consumption. The per capita supply of each food item available for human consumption is then calculated by dividing the respective quantity by the related data on the population actually consuming the food items. Data on per capita food supplies are expressed in terms of quantity and by applying appropriate food composition factors for all primary and processed products, caloric value and protein and fat content can be determined.

The extent of intake of foods rich in DHA and ARA from a global perspective was estimated using per capita consumption data in FAOSTAT from 2009 through 2011 [27]. In order to account for variations from year to year in consumption and food availability, 3-year average consumption estimates were calculated. Data were available for Europe, North America, Australia and New Zealand, and Japan and China in the developed world, and for 4 regions (Africa, Asia, Latin America and Caribbean) and 128 countries in the developing world.

Wastage

It is important to note that the quantities of food available for human consumption, as estimated in the FAO FBS, relate simply to the quantities of food reaching the consumer and is not a direct measure of what is actually consumed. The amount of food actually consumed may therefore be lower than the quantity shown in the FBS depending on the degree of losses of edible food and nutrients at the stage of retail or within the household, for example, during storage, preparation, plate-waste, discarded or fed to domestic animals. Wastage occurring earlier in the food chain during production, distribution and processing is taken into consideration as an element in the FBS, but wastage occurring at retail and household levels is not included.

The Swedish Institute for Food and Biotechnology, on behalf of FAO has reconstructed mass flows of food for human consumption, from production to consumption, using available data, in order to specifically quantify food losses and wastage and they have estimated levels of wastage at consumer level for all the developed and developing countries included in this analysis [28]. This wastage data was therefore utilised to further refine the estimated levels of per capita consumption (table 1).

Fatty Acid Composition Data

Databases relating to the fatty acid composition of foods were evaluated, and it was noted that most databases represented the more affluent countries, and in these countries, the measurement of individual fatty acids was not included in the majority of the databases. The levels of ARA and DHA in foods are available in the US Department of Agriculture (USDA) Nutrient Database (NDB) for Standard Reference Release 27 [29]; however, a major limitation of using the USDA NDB data is that there was no reporting of differentiated omega-6 ARA levels in milk, poultry, eggs, fish, and other meats. In contrast, this data was available in the Australia Nutrient Tables (NUTTAB) database [30].

Table 2. Average levels of DHA and ARA in select food categories from the Australia NUTTAB database (FSANZ, 2011)

Food category, g/100 g food	Australia (2010)	
	ARA	DHA
Eggs	0.18	0.02
Fish, seafood	0.05	0.31
Bovine, meat	0.05	0.005
Mutton (goat), meat	0.08	0.01
Poultry, meat	0.07	0.01
Pig, meat	0.06	0.01
Meat, other	0.06	0.01
Offals, edible	0.13	0.07
Milk	0.002	0.00

Table 3. Median per capita daily consumption (g/day) of egg, fish, meat, and milk commodities based on 2009–2011 FAO FBS in developed and developing countries

Countries	Eggs	Fish, seafood	Bovine, meat	Mutton (goat), meat	Poultry, meat	Pig, meat	Meat, other	Total meat	Offal, edible	Milk (excl butter)
European Union	29.8	49.9	40.7	3.1	52.0	85.0	4.2	185.0	7.1	601
Australia and New Zealand	19.0	42.7	82.5	37.4	86.5	50.8	5.0	262.2	15.7	435
USA and Canada	30.3	36.9	80.3	1.7	102.0	62.7	1.1	247.8	2.1	577
China	45.3	75.5	11.9	7.1	31.7	87.9	2.8	141.4	8.4	83
Japan	51.3	130.0	22.4	0.5	45.5	50.6	0.3	119.3	6.2	195
Developing countries (GNI 2–4)	10.5	23.9	16.3	3.5	30.3	11.3	1.2	62.6	5.1	156

There are food composition databases relating to some developing countries; however, in the databases that contain fatty acid measurements, the number of foods that is included is limited and not sufficiently complete to provide a reasonable estimate of the total ARA and DHA intake from known dietary sources. It was concluded that the data from the Australian food composition database is the most detailed and inclusive and would allow global comparative analyses across developed and developing countries (table 2).

DHA is primarily found in animal tissue lipids, with the highest source being fish. ARA is also found in animal tissue lipids with the highest levels from beef, poultry, eggs and milk. The calculation of the average fatty acid levels in the selected food categories was limited to the raw forms of each food reported in NUTTAB 2010 [30]. There is no data on the cooking practices and this is bound to vary between countries. Since the FAO FBS data is based on availability of foods at the commodity level, fatty acid levels in the raw, unprocessed food was considered to be most applicable. Egg consumption levels were based on whole eggs.

Gross National Income Data

The relationship of the developmental status of the country to dietary intake was assessed using the measurement of per capita gross national income (GNI) [31], with the countries grouped as high income (GNI per capita greater than USD 12,276), upper-middle income (USD 3,976–USD 12,276), lower-middle income (USD 1,006–USD 3,975) and low income (less than USD 1,005 per capita).

Geographical Factors

As access to coastal areas may allow greater consumption of seafood and thus influence the DHA and ARA dietary intake of these countries, the effect of being bordered by coastline or being landlocked was investigated using coastline data from the Central Intelligence Agency [32].

Demographic Factors

Relevant demographic factors including population [33] and birth rate data [34] were considered in the analysis.

Data were analysed using IBM SPSS Statistics 22, and as key data did not have a normal distribution the relevant data are presented as the median and the minimum and maximum range.

Results

Dietary intake of DHA and ARA has been estimated for 175 countries worldwide, 47 classified as developed and 128 as developing. A summary of the per capita consumption estimates for food commodities that are sources of DHA and ARA and the calculated intake of DHA and ARA and percentage daily energy intake are provided in tables 3–5.

Table 4. Median per capita daily intake of ARA (mg/day) and percent of daily total energy intake (% energy) from food sources

Countries	Energy intake, kcal/day	Per capita daily intake of ARA from food sources, mg/day										ARA as % energy
		eggs	fish, seafood	bovine, meat	mutton (goat), meat	poultry, meat	pig, meat	meat, other	offals, edible	milk	total	
European Union	3,420	53.1	25.0	20.2	2.5	34.6	51.0	2.4	9.2	12.0	210	0.055
Australia and New Zealand	3,170	34.2	21.4	41.3	29.9	60.6	30.5	3.0	20.4	8.7	250	0.074
USA and Canada	3,650	54.5	18.5	40.2	1.4	71.4	37.6	0.7	2.7	11.6	239	0.061
China	2,970	89.3	38.8	6.0	5.7	22.2	52.7	1.7	11.6	1.7	230	0.069
Japan	2,810	92.3	65.0	11.0	0.4	31.4	29.9	0.2	7.9	3.9	242	0.078
Low-income countries (GNI 2–4)	2,643	20.5	12.0	8.2	2.9	21.2	6.8	0.7	6.6	3.1	82	0.029

Table 5. Median per capita daily intake of DHA (mg/day) and percent of daily total energy intake (% energy) from food sources

Countries	Energy intake, kcal/day	Per capita daily intake of DHA from food sources, mg/day									DHA as % energy
		eggs	fish, seafood	bovine, meat	mutton (goat), meat	poultry, meat	pig, meat	meat, other	offals, edible	total	
European Union	3,420	6.0	170.1	2.1	0.3	5.2	8.9	0.4	5.2	198	0.052
Australia and New Zealand	3,170	3.8	145.4	4.3	3.9	9.0	5.3	0.5	11.5	184	0.052
USA and Canada	3,650	7.1	187.6	4.7	0.2	11.9	7.3	0.1	1.8	221	0.055
China	2,970	10.0	267.3	0.6	0.8	3.4	9.4	0.3	6.3	298	0.090
Japan	2,810	10.3	446.9	1.2	0.1	4.8	5.3	0.1	4.6	473	0.152
Low-income countries (GNI 2–4)	2,643	2.3	84.5	0.9	0.4	3.2	1.2	0.1	3.7	96.3	0.033

In developed countries, the median daily intake of ARA is between 210 and 250 mg/day; however, the principal food sources vary with meat being the primary source of ARA in Europe, Australia, New Zealand, the United States and Canada, whereas in China and Japan, egg consumption is a major contributor to ARA intake. The median energy percentage of dietary ARA in the developed countries ranges from 0.055% in Europe to 0.078% in Japan (tables 3 and 4).

In 128 developing countries, the median ARA intake is 82 mg/day and this relates to the estimated low meat (62.6 g/day) and egg (10.5 g/day) consumption. The median energy percentage of dietary ARA is 0.029%, half of that reported for developed countries.

The dietary intake of fish and seafood was significantly lower in developing countries; however, there were several small island states that consumed exceptionally large quantities of seafood, especially Maldives. This dietary variation is reflected in the estimated DHA intake with the median intake in developing countries being 96 mg/day, and this contrasts with the range of 184–473 mg/day in the developed countries (tables 3, 5).

The relationship between the median intake of DHA and ARA and the per capita GNI of the country are shown in table 6. There is a direct relationship between the estimated dietary ARA and DHA consumption and the per capita GNI of the country. The 28 countries in the lowest income category had a median ARA and DHA intake of 43 and 47 mg/day, respectively, and this group represents a total population of nearly 740 million people (table 6). There was considerable regional variation with the lowest intake for both ARA and DHA being in Sub-Saharan Africa and Southern, Western and Central Asia (table 7).

In addition to economic factors, there was evidence of geographical and demographic relationships. There were 35 landlocked countries, and the median daily ARA and DHA intake were 88.2 and 47.4 mg/day, respectively, and these intake values are in contrast to the intake values of 28 small island developing countries that had a median ARA and DHA daily intake of 156.5 and 204.7 mg/day, respectively. With pregnant women and young children being a particularly vulnerable group to ARA and DHA deficiency, it is noted that across the 175 countries, there

Table 6. Estimated median (range) per capita ARA and DHA intakes in 172 countries classified by the GNI and total population

GNI	Daily ARA intake, mg/day	Daily DHA intake, mg/day	Population, millions	Birth rate, n/1,000 population
High income (n = 42)	227 (58–507)	192 (67–706)	1,088	10.8 (7.9–19.9)
Upper middle income (n = 49)	167 (78–345)	122 (31–1,371)	2,437	16.0 (8.9–34.5)
Lower middle income (n = 53)	93 (32–289)	134 (13–605)	2,788	22.8 (8.2–42.1)
Low income (n = 28)	43 (18–192)	47 (6–437)	740	35.1 (20–45.6)
Total (n = 172)	147 (18–507)	134 (6–1,371)	7,053	18.0 (7.9–45.6)

was a strong negative correlation between birth rate and ARA ($r = -0.730$; $p < 0.001$) and DHA ($r = -0.277$; $p < 0.001$; table 6).

Detailed data for individual countries on the estimated intake of DHA and ARA and percentage daily energy intake are presented for developed (GNI 1) and developing (GNI 2–4) countries in tables 8 and 9. In the 47 developed countries, the ARA and DHA intake was the greatest in Iceland and lowest in Bosnia and Herzegovina. In the 128 developing countries, the highest intake for ARA and DHA was estimated to be in Maldives, which had the highest DHA and the second highest ARA of all the countries assessed. Rwanda and Ethiopia had the poorest estimated ARA and DHA consumption rates.

Discussion

This global study demonstrates that across 175 countries, of which 128 are recognised as developing nations, there is marked variation in per capita dietary intake of DHA and ARA. The countries that have been analysed represent the diverse geographic, economic and cultural factors that underpin global populations. The economic status of the country was a key factor with the data showing a direct relationship of dietary DHA and ARA to the per capita GNI of the country. The DHA and ARA intake of countries with low GNI are several times lower than that of high-income countries, and the 28 countries in the lowest GNI category represent a population of nearly 740 million people.

Current recommendations on DHA and ARA requirements are predominantly underpinned by research data generated in high-income countries and therefore, the relevance of these recommendations to populations living in low-income developing countries is questionable. The presented data provides evidence to support this view.

Table 7. Per capita median daily dietary intake of ARA and DHA in low-income regions (GNI 2–4)

Region	ARA intake, mg/day	DHA intake, mg/day
North Africa	108.7 (34–134)	120.7 (41–184)
Sub-Saharan Africa	58.9 (18–187)	71.7 (6–294)
East Asia	155.6 (69–345)	302.5 (35–605)
Southern Asia	55.7 (32–307)	80.2 (23–1,371)
Western Asia	89.6 (53–134)	51.9 (32–102)
Central Asia	103.9 (40–255)	44.9 (8–184)
Caribbean and Central America	151.7 (41–284)	134.2 (28–561)
South America	186.0 (93–241)	81.6 (36–199)

Within any population, there are vulnerable groups and in relation to ARA and DHA, the optimal dietary intake of these fatty acids is particularly important in pregnant women, infants and young children. It is therefore notable that the DHA and ARA intake is the lowest in countries with the highest birth rates. It has previously been reported that maternal DHA status is reduced in multiparous women [35], and therefore, in the vulnerable low-income populations, the maternal and infant LCPUFA status will be susceptible to the dual adverse effects of multi-parity and poor maternal diet.

There are clear differences in dietary intakes of ARA and DHA food sources between high- and low-income countries and this is especially evident in the intake of seafood, eggs and poultry meat. Seafood is an important source of DHA in countries with access to a coastline, and in comparison to landlocked countries, significantly higher levels of DHA were noted in small developing islands even if they are low-income countries.

The strengths of the FAO FBS are that the data are readily available and up to date (through 2011), the data

is easy to access and use, and there is an element of consistency as the data collection follows similar procedures. The estimates of intake are therefore comparable between countries and the data can be organized in a way that allows the user to identify countries with high and low consumption of commodities of interest. Internal consistency checks are inherent in the accounting technique of the FBS and this is supported by external consistency checks that are based on related supplementary information, such as the results of surveys conducted in various parts of the world [26].

Limitations include the fact that the data do not directly measure food consumption but instead reflect the food supply in a country and may not accurately capture non-food uses such as wastage. However, in this study, adjustments were specifically made for wastage that may occur at the retail and household levels [28]. It has been suggested that the FBS consumption data may be an overestimate compared to measurements of consumption that are recorded in either household or individual surveys [36–38]. However, the latter also have limitations as they are often dependent upon short-term dietary histories that may not reflect the annual dietary intake. For example, in the United States, 50% of fish available for consumption are in the categories of crustaceans, cephalopods and molluscs [27], which may present as a variety of processed food commodities that may not be captured in household surveys. However, if it is assumed that there is an element of overestimation within the presented data, it is reasonable to conclude that the reported low intake of ARA and DHA in the most vulnerable populations will be even more of concern.

Applying food composition data from a developed country such as Australia to the entire list of developing countries throughout all regions of the world is a limitation, as it may not necessarily reflect a national or even regionally representative level of ARA and DHA in the population's food supply. However, while there are alternative food composition databases that are publically available, they were considered unsuitable, as the number of foods was not sufficiently complete to provide a comprehensive estimate of the total ARA and DHA intake from known dietary sources. Therefore, in order to conduct a global assessment and to be able to compare the fatty acid intake between countries, the complete database from NUTTAB 2010 was considered a satisfactory selection based on the data available [30]. Moreover, the evidence that the data reflected anticipated effects of economic, demographic and geographic variables provided some credence to the validity of the data.

Table 8. Estimated daily ARA and DHA intakes (with % energy) for countries in GNI 1 (in descending order of ARA intake)

Country	ARA intake, mg/day	ARA % energy	DHA intake, mg/day	DHA % energy
Iceland	350.8	0.095	793.4	0.214
Portugal	313.4	0.079	521.6	0.131
USA	313.2	0.075	219.7	0.053
Spain	307.2	0.085	396.8	0.109
Australia	303.6	0.086	260.9	0.074
New Zealand	299.7	0.086	259.5	0.074
France	299.4	0.076	335.1	0.085
Israel	285.5	0.073	216.7	0.055
Lithuania	285.2	0.075	402.7	0.106
Bermuda	282.8	0.102	163.7	0.058
Luxembourg	280.7	0.069	278.3	0.068
Austria	279.0	0.067	150.1	0.036
Belarus	270.7	0.079	192.4	0.056
Denmark	264.6	0.070	232.3	0.062
Italy	261.6	0.064	246.8	0.061
Canada	260.8	0.067	221.7	0.057
Japan	260.6	0.084	483.0	0.155
Norway	260.3	0.068	481.1	0.125
Malta	258.3	0.065	290.8	0.073
Sweden	258.0	0.074	290.7	0.084
Latvia	256.4	0.076	268.3	0.080
Ireland	252.8	0.065	228.1	0.058
Netherlands	249.6	0.069	226.2	0.063
China	249.4	0.076	306.7	0.093
Germany	245.2	0.063	153.0	0.039
Czech Republic	244.6	0.066	119.3	0.032
Belgium	243.7	0.059	241.8	0.059
Russian Federation	242.9	0.067	224.6	0.062
Finland	239.7	0.067	323.8	0.091
United Kingdom	238.8	0.063	192.7	0.050
Greece	236.1	0.057	201.3	0.049
Slovenia	235.5	0.066	127.2	0.036
Cyprus	228.2	0.064	223.6	0.063
Switzerland	228.0	0.060	178.6	0.047
Hungary	218.9	0.057	75.2	0.020
Poland	213.7	0.057	131.2	0.035
Estonia	211.4	0.060	159.8	0.046
Ukraine	207.8	0.058	149.0	0.042
Montenegro	201.6	0.067	114.7	0.038
Romania	201.2	0.052	82.6	0.021
Croatia	200.2	0.060	186.8	0.056
Slovakia	191.7	0.060	93.0	0.029
Bulgaria	174.3	0.057	83.3	0.027
Serbia	156.4	0.052	77.2	0.026
Republic of Moldova	146.9	0.045	139.0	0.043
Albania	145.9	0.042	70.7	0.021
Bosnia and Herzegovia	101.0	0.030	64.6	0.019

Table 9. Estimated daily ARA and DHA intakes (with % energy) for countries in GNI 2–4 (in descending order of ARA intake)

Country	ARA intake, mg/day	ARA % energy	DHA intake, mg/day	DHA % energy	GNI	Country	ARA intake, mg/day	ARA % energy	DHA intake, mg/day	DHA % energy	GNI
Maldives	331.0	0.112	1,409.3	0.475	2	Philippines	139.1	0.048	311.0	0.108	3
Antigua and Barbuda	307.1	0.119	583.0	0.226	3	Dominican Republic	135.9	0.049	137.0	0.049	2
French Polynesia	306.3	0.094	437.2	0.135	3	Cape Verde	135.2	0.048	116.4	0.041	3
Lithuania	285.2	0.075	402.7	0.106	2	Belize	133.2	0.044	88.0	0.029	2
Bahamas	277.2	0.092	268.0	0.089	2	Guyana	133.1	0.044	258.7	0.085	3
Belarus	270.7	0.079	192.4	0.056	2	Jordan	132.0	0.038	71.0	0.020	2
Samoa	270.1	0.084	439.5	0.137	3	Guatemala	128.5	0.047	28.4	0.010	3
Malaysia	265.7	0.082	530.3	0.164	2	Peru	125.5	0.043	208.9	0.072	2
Saint Vincent and the Grenadines	260.3	0.083	184.2	0.059	2	Egypt	121.0	0.031	192.2	0.049	3
Argentina	259.0	0.078	82.3	0.025	2	Morocco	118.1	0.032	129.0	0.035	3
Latvia	256.4	0.076	268.3	0.080	2	Iran (Islamic Republic)	118.0	0.035	80.0	0.024	2
Saint Lucia	254.9	0.084	222.8	0.073	2	Turkey	116.0	0.029	75.0	0.018	2
Republic of Korea	254.6	0.107	526.4	0.220	3	Tunisia	115.0	0.031	123.0	0.033	2
Russian Federation	242.9	0.067	224.6	0.062	2	Kyrgyzstan	112.7	0.036	32.6	0.010	4
New Caledonia	234.0	0.075	203.7	0.066	3	El Salvador	110.6	0.039	67.8	0.024	3
Mexico	233.4	0.069	130.9	0.039	2	Azerbaijan	107.8	0.032	33.1	0.010	2
Brazil	221.0	0.062	104.3	0.029	2	Sao Tome and Principe	102.4	0.035	247.9	0.084	3
Chile	212.4	0.065	141.1	0.043	2	Bosnia and Herzegovi	100.9	0.029	64.6	0.019	2
Mongolia	209.2	0.084	45.0	0.018	4	Honduras	99.4	0.034	35.6	0.012	3
Venezuela	208.9	0.072	136.0	0.047	2	Georgia	99.1	0.032	77.7	0.025	3
Ukraine	207.8	0.058	149.0	0.042	3	Mauritania	99.0	0.032	96.0	0.031	3
Grenada	207.4	0.077	265.6	0.099	2	Congo	93.9	0.039	206.5	0.086	3
Uruguay	205.1	0.065	85.2	0.027	2	Namibia	93.5	0.041	113.9	0.050	2
Romania	201.2	0.052	82.6	0.021	2	Indonesia	90.7	0.031	240.8	0.082	3
Kazakhstan	198.2	0.057	69.4	0.020	2	Uzbekistan	90.0	0.031	18.2	0.006	3
Gabon	193.2	0.064	298.7	0.098	2	Cambodia	89.4	0.033	310.2	0.116	3
Paraguay	190.1	0.065	37.7	0.013	3	Central African Republic	88.8	0.037	92.1	0.039	4
Trinidad and Tobago	188.2	0.059	192.2	0.061	2	Solomon Islands	88.0	0.033	319.3	0.118	3
Saint Kitts and Nevis	183.9	0.068	182.3	0.067	2	Nicaragua	86.6	0.031	55.8	0.02	3
Jamaica	183.4	0.058	237.1	0.075	2	Angola	83.8	0.039	137.0	0.063	3
Myanmar	176.8	0.065	447.0	0.165	4	Botswana	83.0	0.033	41.2	0.017	2
Bulgaria	174.3	0.057	83.3	0.027	2	Algeria	83.0	0.024	45.0	0.013	2
Viet Nam	171.3	0.056	311.4	0.101	3	Mali	80.3	0.026	85.1	0.027	4
Mauritius	168.0	0.051	200.8	0.061	2	Dominica	79.3	0.023	30.7	0.009	3
Panama	167.7	0.062	138.1	0.051	2	Senegal	78.4	0.029	224.2	0.083	3
South Africa	165.5	0.050	70.4	0.021	2	Sudan (former)	78.0	0.03	31.0	0.012	3
Costa Rica	163.3	0.052	113.7	0.036	2	Sierra Leone	77.0	0.03	298.2	0.117	4
Kiribati	161.7	0.050	620.6	0.193	3	Syrian Arab Republic	76.0	0.022	35.0	0.01	3
Turkmenistan	161.7	0.053	47.1	0.015	3	Ghana	73.7	0.023	219.3	0.069	3
Bolivia	160.6	0.066	37.3	0.015	3	Timor-Leste	73.5	0.032	35.6	0.016	3
Colombia	158.4	0.056	67.2	0.024	2	Lao People's Democratic Republic	73.5	0.030	153.4	0.062	3
Ecuador	157.4	0.058	86.6	0.032	2	Iraq	73.0	0.026	32.0	0.012	3
Fiji	156.4	0.046	308.2	0.092	3	Côte d'Ivoire	70.7	0.023	179.3	0.059	3
Serbia	156.4	0.052	77.2	0.026	2	Gambia	67.8	0.026	245.1	0.094	4
Armenia	155.7	0.062	46.6	0.019	3	Sri Lanka	66.0	0.024	216.0	0.079	3
Cuba	153.3	0.042	76.4	0.021	2	Swaziland	64.2	0.025	23.4	0.009	3
Republic of Moldova	146.9	0.045	139.0	0.043	3	Nigeria	61.4	0.020	138.4	0.046	3
Albania	145.9	0.044	70.7	0.021	2	Burkina Faso	59.3	0.020	56.6	0.019	4
Lebanon	145.3	0.042	104.6	0.030	2	Cameroon	59.1	0.021	154.5	0.055	3
Thailand	144.7	0.047	219.5	0.072	2	Pakistan	58.0	0.021	24.0	0.009	3
Libya	142.0	0.041	133.0	0.038	2						
Suriname	141.1	0.051	143.4	0.052	3						
Vanuatu	139.5	0.046	281.3	0.093	3						

Table 9. (continued)

Country	ARA intake, mg/day	ARA % energy	DHA intake, mg/day	DHA % energy	GNI	Country	ARA intake, mg/day	ARA % energy	DHA intake, mg/day	DHA % energy	GNI
Benin	57.3	0.020	119.2	0.042	4	Guinea	43.4	0.015	93.1	0.033	4
Yemen	57.0	0.024	34.0	0.014	3	Togo	39.6	0.015	61.4	0.023	4
Kenya	53.5	0.022	39.1	0.016	4	Guinea-Bissau	38.4	0.015	17.4	0.007	4
Zambia	52.9	0.025	67.5	0.032	3	Liberia	38.2	0.015	26.9	0.011	4
Djibouti	52.7	0.021	89.1	0.035	3	Chad	38.1	0.017	44.0	0.019	4
Uganda	52.5	0.021	118.9	0.047	4	Nepal	37.1	0.013	23.2	0.008	4
Lesotho	51.5	0.018	13.3	0.005	3	United Republic of Tanzania	33.6	0.014	57.1	0.024	4
Zimbabwe	51.0	0.021	26.0	0.011	4	India	33.5	0.012	52.1	0.019	3
Niger	50.1	0.018	27.0	0.010	4	Mozambique	32.0	0.013	68.2	0.027	4
Bangladesh	46.0	0.017	167.0	0.062	4	Malawi	31.3	0.012	47.7	0.018	4
Madagascar	44.4	0.019	55.7	0.024	4	Ethiopia	24.1	0.010	7.01	0.003	4
Tajikistan	44.0	0.019	8.3	0.004	4	Rwanda	19.1	0.008	20.2	0.008	4
Haiti	44.0	0.019	45.2	0.019	4						

A similar methodology has been used in previous studies including that of Hibbeln et al. [39], who utilised data from FAOSTAT to measure n-3 LCPUFA dietary intake in 38 predominantly developed countries and related their data to age-adjusted mortality due to cardiovascular disease, coronary heart disease and stroke. They determined that the greatest protection was provided by a total n-3 LCPUFA dietary intake of 750 mg/day, which most closely correlated with the dietary intake of the Japanese population. A detailed food survey by Kuriki et al. [40] reported that Japanese dieticians had a DHA dietary intake of 510–590 mg/day and an ARA intake of 150 mg/day. This data is consistent with the findings from the current study, with the estimated daily dietary intake for Japan being 473 mg/day for DHA and 242 mg/day for ARA.

Michaelsen et al. [41] utilised FAOSTAT data to estimate the availability of fat and fatty acids in 13 low-income and middle-income countries and reported that the total n-3 fatty acid supply is below or close to the lower end of the recommended intake range for infants and young children, and below the minimum recommended level for pregnant and lactating women in the 9 countries with the lowest gross domestic product (GDP). They also demonstrated that the availability of food sources for ARA was significantly reduced in the countries with the lowest GDP.

In conclusion, this study provides a comprehensive global perspective on the dietary intake of DHA and ARA in both developed and developing countries and demonstrates that there are many regions and populations that have an intake of DHA and ARA that does not reflect cur-

rent international recommendations. Within individual populations, vulnerable groups including pregnant women, infants and young children may be particularly at risk of the global diversity in LCPUFA intake and the potential public health consequences need to be urgently considered.

Disclosure Statement

Professor Forsyth undertakes consultancy work for DSM, and Mrs. Gautier and Dr. Salem are employees of DSM. DSM is a major producer of nutritional ingredients including arachidonic acid and docosahexaenoic acid.

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