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Estimated Dietary Intakes of Arachidonic Acid and Docosahexaenoic Acid in Infants and Young Children Living in Developing Countries

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Key Words
Arachidonic acid · Docosahexaenoic acid · Global dietary intakes · Infants · Young children

Abstract
Background/Aims: There are only few data on dietary arachidonic acid (ARA) and docosahexaenoic acid (DHA) intake in infants from developing countries, and current global recommendations on intake during early life may not reflect the needs of the world's most vulnerable infants. The aim of the study was to provide estimates of intake of ARA and DHA in infants and young children aged 6–36 months who live in developing countries. ***Methods:*** FAO Food Balance Sheets and fatty acid composition data from Australian food composition tables were utilized to generate mean per capita intake estimates for DHA and ARA in developing countries. The median daily intake of DHA and ARA in children age 6–36 months in each country was determined by combining the fatty acid composition of breast milk and complementary foods with the estimated intakes being weighted according to median duration of any breastfeeding. ***Results:*** The median daily dietary intake for ARA and DHA across 76 developing countries was 64.0 and 48.9 mg/day, respectively. The lowest complementary food intake of ARA and DHA was present in countries with the lowest gross national income and highest birth rates. ***Conclusion:*** Global recommendations on ARA and DHA in early life need to reflect the specific needs of infants and families living in low income countries, and country-specific food policies should address gaps between recommended and achieved intakes.

Introduction

The scientific evidence indicates that long-chain polyunsaturated fatty acids (LCPUFAs) play a key role in metabolic processes that can determine the health and development of infants and children [1, 2]. Both n-3 and n-6 LCPUFAs are integral components of cell membranes and their presence can influence cellular structure and function [3]. The n-3 LCPUFA docosahexaenoic acid (DHA) is especially important for the brain and retina, where it rapidly accumulates during the early years of life [4] and plays an important role in the development of visual and cognitive function [5]. The n-6 LCPUFA, arachidonic acid (ARA), is also rapidly accreted by the infant brain but, in addition, it is also widely distributed throughout other vital organs and tissues within the body. It is increasingly being recognized that both DHA and ARA are important precursors and messengers for a variety of biological processes particularly in relation to cerebral, cardiovascular and immune functions [6].

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Studies have shown that the endogenous synthesis of both DHA and ARA in early life may be insufficient [7, 8] and that blood and tissue concentrations decrease rapidly after birth if exogenous supplies are inadequate [4, 5, 9]. From a biological perspective, the dietary essentiality of these fatty acids at this time of life is reinforced by the well-documented evidence that these fatty acids are consistent and stable components of breast milk (BM) [10]. Intervention studies of infants fed infant formulas supplemented with ARA and DHA to achieve compositions more similar to BM have reported functional benefits in vision and some key cognitive functions including information processing, problem solving and attention control when compared to infants receiving formulas devoid of ARA and DHA [11].

However, most studies have focused on supplementation of infants with ARA and DHA during the first months of life and there is limited data on the LCPUFA requirements beyond the age of 6 months [12]. Moreover, there are only few data relating to infants from low income countries [13]. The limited data relating to the post 6 months period indicates that for many infants, the LCPUFA content of traditional complementary and toddler food is low, and therefore, these infants may be vulnerable to LCPUFA deficiency, especially if they are not receiving BM [14]. This vulnerability may be increased if the maternal LCPUFA diet is insufficient, as this leads to low transplacental transfer of LCPUFAs during pregnancy, and this in turn reduces LCPUFA status of the infant at birth [15]. Moreover, maternal diet relates to the LCPUFA content of BM, especially DHA, and low maternal DHA status is associated with low levels of DHA in BM [16]. The effect of genetic differences in the fatty acid desaturase gene cluster on individual and population LCPUFA status is increasingly being recognized as an important factor to be considered when developing recommendations on maternal and infant LCPUFA dietary intake [17–21].

Various international organizations have proposed global recommendations on dietary intakes for pregnant women, infants and young children. In 2003, the World Health Organization (WHO) stated that in the general population, diets should provide an adequate intake of PUFAs and it was recommended that this should be in the range 6–10% of daily energy intake [22]. It was also stated that there should be an optimal balance between n-6 PUFAs and n-3 PUFAs and recommended 5–8% and 1–2% of daily energy intake per day, respectively. In 2010, the European Food Safety Authority (EFSA) based their recommendation for adults on cardiovascular considerations and recommended an adequate intake of 250 mg/day for eicosapentaenoic acid (EPA) plus DHA [23]. For pregnant and lactating women, they proposed an additional 100–200 mg DHA (EFSA, 2010). 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 Food and Agricultural Organization of the United Nations (FAO) provided specific recommendations on n-3 fatty acids 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 [24]. In relation to infants and young children, it is recommended that for 0–6 months, the daily requirement is 0.1–0.18% E of DHA (equivalent to a mean of 102 mg/day); 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.

There are few explicit dietary recommendations for ARA, in part, because it was widely assumed that linoleic acid (18:2 n6) is converted in adequate amounts to ARA. However, there is growing evidence indicating that this assumption is unsound [17–19, 25]. Food surveys report intakes of ARA between 50 and 300 mg/day for adult populations consuming a western style diet [26, 27]. Recommendations for infants and children are also few with a recommendation for infants during the first months of life being 140 mg ARA/day [11], and for young children, the Belgian Health Council recommended that the ARA content of the diet should be 0.10–0.25% energy (approximately 102–258 mg/day) and DHA 0.10–0.40% energy (approximately 102–413 mg/day) [28]. Interestingly, a subsequent study in Belgium noted that in children of 2.5–3 years, the DHA intake was 45 mg/day and for ARA 17 mg/day [29] indicating that intake was significantly below recommended levels.

The WHO has provided a global public health recommendation that infants should be exclusively breastfed for the first 6 months of life to achieve optimal growth, development and health. Thereafter, to meet their evolving dietary requirements, infants should receive nutritionally adequate and safe complementary foods while breastfeeding continues for up to 2 years of age or beyond [30]. In an evaluation of 33 developing countries, exclusive breastfeeding for 6 months occurred in 46% of infants, the median duration of any breastfeeding was 18.6 months and over 30% of infants received complementary foods before 6 months of age [31]. It is common practice in lower income developing countries for infants to be weaned on to foods that are prepared for the whole family [13], and therefore, the diet that infants receive during this important period of growth and development will reflect the nutritional content of the local adult diet. Prentice and Paul [13] report that in Gambia, which has access to a short coastline and inland fresh water, the fatty acid dietary profiles changed considerably following the cessation of breastfeeding with dietary ARA intakes falling from 17 mg/kg body weight during the first 6 months of life to 1 mg/kg body weight at 24 months and the reduction in dietary DHA intake during the same period fell from 21 mg/kg body weight to 1 mg/kg body weight.

The aim of this study was to provide estimates of the intake of DHA and ARA in infants and children who are aged 6–36 months and live in the developing world. This study builds on an analysis that reported daily per capita intakes of DHA and ARA in adults from developed and developing countries Forsyth et al. [32]. In the previous assessment, Food Balance Sheets (FBS) from the Food and Agriculture Organization Statistics Division (FAOSTAT) [33] and fatty acid composition data from Australian food composition tables in NUTrient TABles for use in Australia (NUTTAB 2010) under the Australian Food Composition Program [34] were utilized to generate mean per capita intake estimates for DHA and ARA for countries included in the WHO databases.

Methods

International data on food disappearance, breastfeeding rates and food composition were collected and analyzed in order to create estimates of DHA and ARA intake in infants and children who were aged 6–36 months. Coherent datasets were available for 76 developing countries, and due to a historical focus on identification of nutritional needs in developing countries, data sets for those countries are more complete than developed countries. To assess the effects of income, countries were further stratified by gross national income (GNI).

Sources of Data and Rationale for Inclusion as Source

As previously described, data from the most recent FBS FAOSTAT of the FAO and fatty acid composition data from Australian food composition tables in NUTTAB 2010 were utilized to generate mean per capita intake estimates for DHA and ARA for developing countries included in the WHO databases [33, 34]. Consumption data focused on foods known to be natural sources of DHA and ARA in the diet (i.e., fish, meat, eggs and milk).

To create estimates of ARA and DHA intakes of children aged 6–36 months consuming both BM and complementary foods, data on breastfeeding practices among children in the age group of interest were obtained from the United States Agency for International Development's (USAID's) Demographic and Health Surveys (DHS) for these countries and/or regions [35], and they were combined with information on BM fatty acid composition developed using rigorous analytical methods [36].

Table 1. Mean BM intake among exclusively breastfed infants in developed countries (WHO, 2002)

Age, months	BM intake, corrected for IWL, g/day
6	897
7	910
8	856
9	935
10	945
11	956
Average	917

The mean coefficient of variation across all ages was 16% in exclusively breastfed infants compared to 34% in partially breastfed infants.

The DHS is a retrospective, nationally representative household survey that provides data for monitoring and impacts evaluation purposes for population, health and nutrition issues in the developing world. DHS surveys have large sample sizes with a range of 5,000–30,000 households conducted approximately every 5 years to allow for comparisons over time. Within the nutrition module of the DHS surveys, data on the breastfeeding status of infants along with complementary feeding practices of young children are collected. In particular, the median duration of any breastfeeding among children <3 years of age is reported for the 76 countries. The strength of the DHS data include the comparability of indicators measured over a large number of countries in all regions of the developing world and a focus on children under the age of 3 years [35].

DHA and ARA intakes of children aged 6–36 months were therefore estimated by combining DHA and ARA food intakes from the FAOSTAT FBS analysis with the breastfeeding data from the USAID DHS surveys with current fatty acid compositional information for BM and foods used in complementary feeding.

Analysis of BM Consumption Data

The key components included in the calculation of DHA and ARA intake from BM are (1) volume of BM intake, (2) the DHA and ARA composition of BM, (3) energy requirements for children aged 6–36 months and (4) the duration of BM intake.

The volume of BM intake among children aged 6–36 months was based on data from a WHO expert consultation on the nutrient adequacy of exclusive breastfeeding for term infants with a focus on human milk nutrients [37]. The intake reported in the WHO review was slightly lower among developing countries compared to developed countries. However, the data from the developed countries were a complete data set adjusted for water loss and available for all infants aged 6–11 months whereas the developing country data set was incomplete. Table 1 summarizes these data as reported in the WHO review. The 6–11 months average intake rate of 917 g/day was used in the assessment to represent milk intake assuming BM is 100% of the infant diet.

DHA and ARA levels in BM were derived from the mean concentration of fatty acids in BM reported in a comprehensive analysis of 106 studies of BM composition [36]. In this analysis, the mean level of DHA and ARA from 84 studies included in the primary analysis was 0.32 and 0.47% of total fatty acids, respectively. Countries included in the analysis were from developed (e.g., US, Canada, Australia, Europe) and developing countries (e.g., Nigeria, Pakistan, Mexico, Philippines, Chile, Dominican Republic). In order to estimate the level of DHA and ARA in BM, these percentages were applied to BM total fat (g/100 g) content reported in human milk nutrient composition data from the USDA NDB SR 28 [38]. Based on these data, it was estimated that 4.2% of BM is composed of fatty acids. Therefore, the DHA and ARA levels in BM used in the current assessment were calculated to be 0.013% (i.e., 0.32 of 4.2%) and 0.020% (i.e., 0.47 of 4.2%), respectively.

The energy content of DHA and ARA calculations were based on the value of 9 kcal/g of fat, and DHA and ARA intake from BM as a percentage of daily energy was calculated using human energy requirements for children aged 6–36 months [39] (table 2). The average daily requirements among infants and children aged 6–36 months, used in the current assessment, to estimate DHA and ARA intakes from BM as a percentage of energy (%en) was 930 kcal/day. This value was used for all countries as country-specific data on energy intake for this age group were not available for the majority of the countries.

The median duration of breastfeeding among children aged <3 years was obtained from the USAID DHS surveys and used to provide a weighted average for DHA and ARA intake from BM and complementary foods.

Analysis of Complementary Food Consumption Data

Estimates of food consumption, excluding BM, known to naturally contain DHA and ARA were based on data collected by FAO and reported in the FBS. In order to account for variations from year to year in consumption and food availability, 3-year average consumption estimates using per capita consumption data in FAOSTAT from 2009 through 2011 were calculated [33]. Data were available for 4 regions (Africa, Asia, Latin America and Caribbean) and food categories of eggs, seafood, bovine meat, pork meat, mutton and goat meat, poultry, offal and milk were selected for analysis based on known natural sources of DHA and ARA in the diet and the reporting of data in the FAO FBS.

Fatty acid intake from consumption of foods known to contain DHA and ARA was estimated using an average level measured for the Australian food composition tables in NUTTAB 2010 under the Australian Food Composition Program [40] (table 3). 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. There are no data on the cooking practices and these will vary between countries. Similarly, local farming practices may influence fatty acid composition of the food. Since the FAO FBS data are based on availability of foods at the commodity level, fatty acid concentrations in the raw unprocessed food are most applicable. Similarly, fatty acid concentrations in eggs were based on whole eggs and not limited to the yolk.

DHA and ARA intakes as %en from complementary foods were initially calculated using the estimated daily intake (g/day), converting to energy per day, and this value was divided by the reported average population energy intake (kcal/day) from the FAOSTAT FBS data. Within this database, energy intakes per capita for an entire population were generally 2,000 kcal/day or higher; for children aged 6–36 months, energy requirement is considerably less, and for the purpose of this analysis of infant and young children, the calculation of the total energy intake was adjusted to 930 kcal/day, which is the average daily requirement among infants and children aged 6–36 months as determined by FAO and is consistent with the approach to the estimation of DHA and ARA in BM. As the adjustment in energy intake resulted in a proportionate reduction in DHA and ARA intake, the %en for DHA and ARA was not altered from the overall population levels.

Table 2. Daily energy requirements for boys and girls 6–36 months (FAO, 2001)

Age	Daily energy requirements, kcal/day	
	boys	girls
6–7 months	636	584
7–8 months	664	612
8–9 months	688	637
9–10 months	710	658
10–11 months	731	679
11–12 months	753	698
1–2 years	948	855
2–3 years	1,129	1,047
Weighted average (6–36 months)	970	890
Average for boys and girls	930	

Table 3. Average levels of DHA and ARA in select food categories from the Australia NUTTAB database (FSANZ, 2011)

Food category	Australia (2010)	
	ARA, g/100 g food	DHA, g/100 g food
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

The Analytical Model

The daily intakes of DHA and ARA (g/day) were calculated for infants and children aged 6–36 months in each country based on a combined average of fatty acid intake from BM and complementary food weighted according to the median duration of any breastfeeding as reported in DHS surveys. During the period of median duration of breastfeeding, it was assumed that 50% of the intake would be BM and the remaining 50% would be from complementary foods. For the remaining months, when the child is no longer breastfed, it was assumed 100% of their food intake was from complementary foods. The first 6 months of life are not included in the calculation since this is outside the time period of interest. For example, if the median duration of breastfeeding in a country was reported to be 18 months, the child would be receiving BM and complementary foods for 12 months (from 6 to 18 months of age) followed by only complementary foods for the remaining 18 months (from 19 to 36 months of age). The intakes from these 2 time periods are then averaged and weighted according to the proportion of months that they receive each type of food source out of the total 30 months (i.e., 6–36 months) to estimate the total average DHA and ARA intake during the 6–36 months period.

For the scenario described above, the calculations are:

$$ARA_{bm} = \frac{\text{\# months any BF (19 m)} - 6\text{ m}}{30\text{ m}} \times \text{ARA level in BM} \times \frac{\text{intake of BM}}{\text{day}} \times 50\%$$

$$ARA_{food} = \frac{\text{\# months any BF (19 m)} - 6\text{ m}}{30\text{ m}} \times \text{ARA food intake} \times 50\% + \frac{36 - \text{\# months any BF (18 m)}}{30\text{ m}} \times \text{ARA food intake}$$

$$ARA_{total} = ARA_{bm} + ARA_{food}$$

where, ARA_{bm} = ARA intake from BM, ARA_{food} = ARA intake from complimentary food based on food supply data in FAOSTAT, ARA_{total} = ARA intake from BM and food weighted according to the median duration of any breastfeeding, # months any BF = median duration of any breastfeeding.

GNI Data

The relationship between the developmental and the economic status of the country to dietary intake was assessed using the World Bank Atlas method, which classifies countries according to their per capita GNI (UN/DESA/DPAD 2014). Accordingly, the countries were grouped as high income per capita greater than US$12,276 (GNI 1), upper-middle income US$3,976–12,276 (GNI 2), lower-middle income US$1,006–3,975 (GNI 3) and low income less than US$1005 per capita (GNI 4) [41].

Geographical Factors

As access to coastal areas influence seafood consumption and therefore fatty acid status, the DHA and ARA dietary intakes of the countries were also related to geographical location and whether they are bordered by coastline or are landlocked [42].

Demographic Factors

Relevant demographic factors including population and birth rate data were considered in the analysis [43].

The data are predominantly presented as a descriptive analysis and were analyzed using IBM SPSS statistics version 22. As the key data, especially the data relating to DHA intake, did not have a normal distribution, the relevant data are presented as the median and the range, and differences in median intakes across categories are measured using non-parametric tests. The Kruskal–Wallis H test is used to determine if there are statistically significant differences in distribution of key outcome variables between 3 or more variable groups. Mann–Whitney U test is used to compare the distribution between 2 variable groups.

Results

Dietary intakes of DHA and ARA have been estimated for infants and young children aged 6–36 months from 76 developing countries (17 upper middle income, 34 lower middle income and 25 low income). A summary of the results is presented in table 4. Median duration of breastfeeding is significantly longer in the lower income countries, and this is associated with higher intakes of DHA and ARA from BM in these countries. In contrast, the intakes of DHA and ARA from food are higher in the upper middle income countries. These opposing patterns of dietary intakes result in mean total daily dietary intakes of DHA and ARA being similar across the 3 income categories. The median total daily dietary intake for ARA and DHA are 63.7 and 48.8 mg/day, respectively (table 4). These intakes are based on an energy intake of 930 kcal/day, and the median total daily dietary intakes for ARA and DHA as a percentage of energy are 0.062 and 0.047%, respectively. The median ratio of total dietary intake of ARA to DHA is 1.3 (range 0.37–3.36).

With reference to previous recommendations of 100 mg/day for DHA, provided by EFSA [23], FAO [24] and the Belgian Superior Health Council [28] and a recommendation by Koletzko et al. [11] of 140 mg/day for ARA during the first 6 months of life, in the 76 developing countries studied, the recommendation for DHA is not met in 91% of the countries, and for ARA, the figure is 100%.

The ARA and DHA intake from complementary foods was directly related to the GNI of the country (ARA: $r = -0.694$, $p < 0.001$; DHA: $r = -0.335$, $p = 0.003$) with the median intake of ARA and DHA from complementary foods following the discontinuation of breastfeeding for the 76 countries being 17.9 and 14.6 mg/day for ARA and DHA, respectively, and in the lowest income countries, this falls to 8.9 and 9.6 mg/day, respectively (table 4; fig. 1). The birth rate is highest in the lowest income group (table 4).

There were 23 landlocked developing countries included in this analysis, and the calculated median daily DHA intake between the ages of 6–36 months was 35.7 mg/day, with lowest levels in countries from the Caucuses and Central Africa, and this contrasts with a

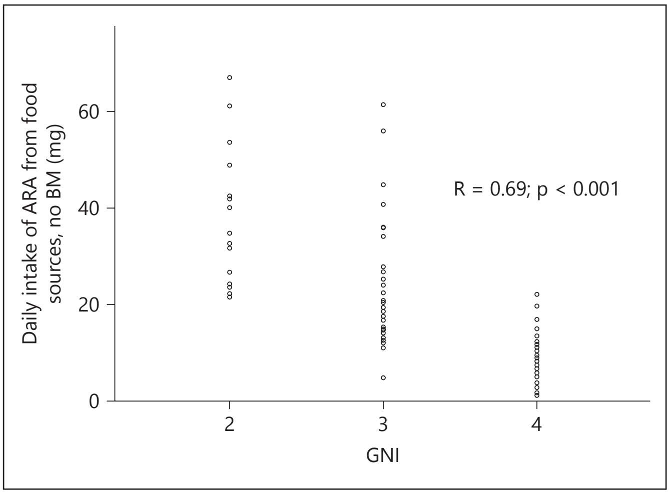

Fig. 1. Estimated daily dietary intake of ARA (mg/day) from complementary foods, no BM, in 76 developing countries by GNI.

median DHA intake of 54.9 mg/day in 10 developing island states, with an exceptionally high level in the Maldives. The median daily ARA intake was similar across the 2 groups with 63.8 and 63.7 mg/day, respectively (table 5).

The median daily dietary intake of ARA and DHA at the regional level is shown in table 6 with the island states in South East Asia reporting significantly higher levels of DHA intake. The estimated daily intake of ARA and DHA as milligrams per day and %en, from both BM and complementary foods, and for complementary foods alone, for individual countries, is shown in table 7. For some countries such as Nepal, Bangladesh, Ethiopia and Rwanda, the provision of ARA and DHA in complementary foods is miniscule.

Discussion

The key finding of this analysis of 76 developing countries is that the estimated daily intake of DHA and ARA in infants and young children between the ages of 6–36 months is significantly lower than current recommendations, and almost all of the countries in the developing world are failing to meet conservative recommendations of 100 mg/day for DHA and 140 mg/day for ARA.

The contributions of DHA and ARA by BM and complementary foods during the age of 6–36 months differed according to the economic status of the country. In the low income countries, breastfeeding duration was longer

Table 4. Relationship of GNI to birth rate, median duration of breastfeeding, and median daily intakes of ARA and DHA (mg/day) from BM and complementary foods (food) from 6 to 36 months of age

GNI	Birth rate (n/1,000 population)**+++	Median duration of BM, weeks**++	Median daily intake of ARA from BM/food	Median daily intake of DHA from BM/food	Median daily intake of ARA from BM**++	Median daily intake of DHA from BM**++	Median daily intake of ARA from food during BF	Median daily intake of DHA from food during BF	Median daily intake of ARA from food (no BM)**+++	Median daily intake of DHA from food (no BM)*+
Upper middle (n = 17)	18.5 (11–35)	14.7 (7–25)	68.3 (38–137)	42.9 (14–371)	26.6 (3–59)	17.3 (2–38)	7.0 (0.8–37)	3.6 (0.3–158)	34.6 (21–67)	23.7 (10–175)
Lower middle (n = 34)	23.5 (14–42)	18.1 (7–24)	63.1 (49–95)	51.5 (24–120)	37.0 (3–56)	24.0 (2–37)	6.3 (1.1–15)	6.1 (0.2–28)	19.1 (5–61)	16.5 (3–80)
Low (n = 25)	35.1 (21–46)	20.8 (17–37)	61.5 (50–92)	50.1 (28–121)	45.2 (34–84)	29.4 (22–55)	4.7 (3–9)	5.9 (0.7–28)	8.9 (1–22)	9.6 (0.7–65)
Total (n = 76)	24.2 (11–46)	18.9 (7–37)	63.7 (38–137)	48.8 (14–371)	39.4 (3–84)	25.6 (2–55)	5.9 (0.8–37)	5.2 (0.2–158)	17.9 (1–67)	14.6 (0.7–175)

Kruskal-Wallis H test: ** $p < 0.001$; * $p < 0.05$. Mann-Whitney U test: +++ groups 1 vs. 2, 1 vs. 3, 2 vs. 3, $p < 0.001$; ++ groups 1 vs. 2, $p = 0.01$; groups 1 vs. 3, 2 vs. 3, $p < 0.001$; + groups 1 vs. 2 NS, 2 vs. 3, $p < 0.001$; groups 3 vs. 4, $p < 0.05$.

Table 6. Median (range) daily dietary intake of ARA and DHA in low income regions (GNI 2–4) during period 6–36 months of age

Region	ARA intake, mg/day	DHA intake, mg/day
North Africa	54.3 (53–62)	47.3 (47–65)
Sub-Saharan Africa	62.5 (49–76)	52.9 (26–120)
South East Asia	68.4 (62–84)	101.6 (36–119)
Southern Asia	76.1 (57–137)	73.0 (33–371)
Western Asia	53.6 (45–55)	30.8 (29–35)
Central Asia	63.8 (38–77)	28.2 (14–35)
Caribbean and Central America	52.5 (49–65)	51.9 (38–64)
South America	76.3 (60–95)	38.6 (24–98)

and the dietary intake of DHA and ARA from this source was higher compared to the upper middle income countries. A reverse pattern was noted for dietary intake of DHA and ARA from complementary foods with the highest intakes estimated in the upper middle income countries. These opposing trends resulted in similar, but low values, for total daily DHA and ARA intakes across the income categories.

There is clear evidence of a direct relationship between ARA and DHA intake from complementary foods and GNI for the country. The intake of ARA and DHA from complementary foods in the low income countries was almost negligible in several countries including Nepal, Bangladesh, Ethiopia and Rwanda. It is notable that birth rate is higher in low birth rate countries, and this will undoubtedly impact on the overall prevalence of LCPUFA deficiency in these countries. The low income group includes 25 countries, a total population of 644 million, and with an average birth rate of 34 births per 1,000 population, it is estimated that each year in this group of countries, approximately 22 million infants will be at risk of LCPUFA deficiency.

The geographical factors are most explicit when the data from small developing islands and landlocked countries are compared with marked differences in the DHA and ARA content of the complementary foods. In the 23 landlocked countries, the intake of DHA is extremely low and this compares with the small island states, many of whom have the highest DHA intakes worldwide. Interestingly, the small island countries not only have high DHA intakes but also their ARA intakes reflect a relatively high meat intake.

The validity of the data is determined by the robustness of the methodology. In relation to the consumption

Table 5. Comparison of developing small islands and landlocked countries for median duration of breastfeeding (months) and dietary DHA and ARA intakes (mg/day) during the period of 6–36 months of age

	Median duration of breast feeding	Median daily intake of ARA from BM and foods	Median daily intake of DHA from BM and foods*	Median daily intake of ARA from BM	Median daily intake of DHA from BM	Median daily intake of ARA from foods during BF	Median daily intake of DHA from foods during BF	Median daily intake of ARA from foods (no BM)	Median daily intake of DHA from foods (no BM)*
Small developing island (n = 10)	18.3 (7–25)	63.7 (50–137)	54.9 (36–371)	37.6 (3–59)	24.4 (2–38)	5.5 (0.8–37)	7.6 (0.1–158)	21.2 (6–61)	32.7 (9–175)
Landlocked country (n = 23)	18.9 (8–34)	63.83 (38–92)	35.7 (14–65)	39.4 (6–84)	25.6 (4–55)	4.8 (1–10)	2.8 (0.3–11)	12.9 (1–56)	8.1 (0.7–27)

Mann–Whitney U test: * $p = 0.001$.

Table 7. Estimated daily intake of ARA and DHA from BM and food (mg/day), %en, ARA/DHA ratios and ARA and DHA from food (no BM) for infants and young children 6–36 months in 76 developing countries

Country	Daily intake of ARA from BM/food	Daily intake of DHA from BM/food	ARA %en	DHA %en	Ratio ARA/DHA intake	Daily intake of ARA from food (no BM)	Daily intake of DHA from food (no BM)
Maldives	137.2	371.4	0.133	0.359	0.37	40.7	174.7
Bolivia	95.1	38.4	0.092	0.037	2.48	40.4	9.5
Nepal	91.6	59.3	0.089	0.057	1.54	1.1	0.7
Bangladesh	87.3	87.2	0.084	0.084	1.00	2.8	10.3
Vietnam	84.5	110.8	0.082	0.107	0.76	35.6	64.8
Guatemala	81.8	37.2	0.079	0.036	2.20	24.9	5.6
Paraguay	80.9	24.2	0.078	0.023	3.35	55.6	11.1
Ecuador	79.8	46.7	0.077	0.045	1.71	41.5	22.9
Kazakhstan	77.8	35.2	0.075	0.034	2.21	42.1	14.7
Peru	77.7	85.3	0.075	0.083	0.91	23.3	39.1
Guyana	77.1	98.1	0.075	0.095	0.79	26.4	51.5
Turkmenistan	76.7	34.2	0.074	0.033	2.24	33.8	9.9
Rwanda	76.4	51.6	0.074	0.050	1.48	1.7	1.8
Mexico	76.1	43.2	0.074	0.042	1.76	66.7	37.3
El Salvador	75.9	48.2	0.073	0.047	1.58	20.6	12.6
Colombia	75.8	38.3	0.073	0.037	1.98	39.7	16.8
Gabon	75.6	102.4	0.073	0.099	0.74	53.3	82.6
South Africa	74.0	38.3	0.072	0.037	1.93	34.4	14.6
Central African Republic	73.6	59.1	0.071	0.057	1.25	19.4	20.2
Mali	71.4	54.1	0.069	0.052	1.32	11.3	11.9
Indonesia	70.6	93.0	0.068	0.090	0.76	15.1	40.6
Mauritania	69.6	53.3	0.067	0.052	1.31	16.7	16.2
Burkina Faso	69.0	49.3	0.067	0.048	1.40	8.5	8.1
Cambodia	68.8	119.6	0.067	0.116	0.57	18.3	64.2
Thailand	68.6	81.0	0.066	0.078	0.85	34.6	52.5
Philippines	68.3	112.4	0.066	0.109	0.61	35.6	80.1
Honduras	68.1	36.0	0.066	0.035	1.89	20.2	7.4
Senegal	68.1	94.1	0.066	0.091	0.72	14.8	42.9
Kyrgyzstan	67.5	33.0	0.065	0.032	2.04	21.9	6.4
Namibia	67.4	63.3	0.065	0.061	1.06	26.5	32.5
Togo	67.0	53.2	0.065	0.051	1.26	6.0	9.3
Sierra Leone	66.2	120.6	0.064	0.117	0.55	16.6	64.9
Ethiopia	65.9	40.3	0.064	0.039	1.64	3.8	1.1
Brazil	65.3	31.4	0.063	0.030	2.08	61.0	62.3
India	65.0	50.2	0.063	0.049	1.30	4.9	7.6
Botswana	64.6	37.6	0.063	0.036	1.72	60.8	28.7
Armenia	64.2	24.5	0.062	0.024	2.62	21.3	10.7
Sudan (former)	63.8	35.3	0.062	0.034	1.81	44.5	13.2
Madagascar	63.3	50.1	0.061	0.048	1.26	17.4	7.0
Zambia	63.0	53.0	0.061	0.051	1.19	9.4	11.8
Congo	62.9	93.8	0.061	0.091	0.67	5.1	7.7
Malawi	62.8	48.5	0.061	0.047	1.30	12.9	16.7
Sri Lanka	62.7	906	0.061	0.088	0.69	27.5	60.8
Sao Tome and Principe	62.7	92.2	0.061	0.089	0.68	12.8	42.4
Egypt	62.6	65.0	0.061	0.063	0.96	22.2	54.1
Timor-Leste	61.9	35.8	0.06	0.035	1.73	19.1	30.7
Kenya	61.5	41.4	0.06	0.04	1.49	20.1	9.9
Gambia	61.5	101.9	0.06	0.099	0.60	11.7	8.7
Trinidad and Tobago	61.4	62.7	0.059	0.061	0.98	14.6	53.6
Benin	61.0	62.2	0.059	0.06	0.98	10.6	21.8
Ghana	60.9	80.3	0.059	0.078	0.76	11.8	35.8
Guinea	60.6	56.8	0.059	0.055	1.07	7.4	15.7
Nicaragua	60.2	39.0	0.058	0.038	1.54	20.3	13.1

Table 7. (continued)

Country	Daily intake of ARA from BM/food	Daily intake of DHA from BM/food	ARA %en	DHA %en	Ratio ARA/DHA intake	Daily intake of ARA from food (no BM)	Daily intake of DHA from food (no BM)
Côte d'Ivoire	60.0	77.8	0.058	0.075	0.77	8.3	9.6
Uzbekistan	59.8	27.6	0.058	0.027	2.17	14.6	37.6
Chad	59.7	45.2	0.058	0.044	1.32	19.1	3.9
Uganda	57.8	64.6	0.056	0.063	0.89	12.0	26.9
Niger	57.4	35.9	0.056	0.035	1.60	8.9	4.8
Pakistan	57.3	33.1	0.055	0.032	1.73	12.4	5.3
Tanzania	56.6	48.4	0.055	0.047	1.17	7.4	12.4
Yemen	55.6	35.1	0.054	0.034	1.58	6.7	14.2
Mozambique	55.3	50.8	0.053	0.049	1.09	14.4	8.8
Tunisia	54.6	46.9	0.053	0.045	1.17	22.0	23.7
Nigeria	54.1	62.2	0.052	0.060	0.87	12.3	28.1
Swaziland	54.0	29.0	0.052	0.028	1.86	16.4	6.1
Zimbabwe	54.0	32.6	0.052	0.032	1.66	13.2	6.9
Jordan	53.9	31.0	0.052	0.030	1.74	32.4	17.4
Morocco	53.6	47.5	0.052	0.046	1.13	23.8	26.1
Liberia	53.3	35.3	0.052	0.034	1.51	8.3	5.8
Dominican Republic	52.9	52.2	0.051	0.051	1.01	9.73	1.8
Tajikistan	52.8	28.2	0.051	0.027	1.88	48.6	49.1
Cameroon	50.1	67.9	0.048	0.066	0.74	13.9	36.8
Haiti	49.6	38.3	0.048	0.037	1.30	12.1	12.6
Lesotho	49.2	26.4	0.048	0.025	1.87	11.0	2.8
Turkey	45.7	29.6	0.044	0.029	1.54	24.0	15.5
Azerbaijan	38.3	13.6	0.037	0.013	2.80	31.4	9.8
All countries	63.7*	48.8	0.062	0.047	1.30	17.9	14.6

data of complementary foods, there are strengths and limitations that need to be considered. The key strengths of the FAO data are that it is contemporary and the collection process is consistent. Thus, the estimates of intake are comparable between and among 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 [33].

The methods applied to the collection and analysis of the consumption of ARA and DHA at the population level have previously been described [32]. Limitations include the fact that the data do not reflect actual consumption but instead reflect the food supply and its 'disappearance' in a country, and this may not accurately capture non-food uses and waste. It has therefore been suggested that disappearance data may overestimate consumption when it is compared with measurements from either household or individual surveys [44]. More recent data on wastage, especially at the retail and household levels have been reported [45] and these were applied to the current analysis to adjust for potential wastage [32]. However, there is still a likelihood of an element of overestimation, and this can be interpreted as indicating that the low LCPUFA intake from food sources in developing countries may be even more severe than reported.

Data on BM intake for each country are not available, and therefore, in this analysis, a volume intake of 917 g/day was applied to all countries. This volume of BM was calculated on data from exclusive breastfed infants and was endorsed by a WHO expert consultation on the nutrient adequacy of exclusive breastfeeding for term infants with a focus on human milk nutrients [37].

The measurement of intake of DHA and ARA from BM as a percentage of total energy intake was calculated using human energy requirements in children aged 6–36 months [39]. The average daily requirement for this age range is 930 kcal/day, and this value was used for all countries as country specific data on energy intake for this age group were not available for the majority of the countries.

For each country, the median duration of breastfeeding among children <3 years was obtained from the USAID DHS surveys [35], and this was used to provide a weighted average that provides an estimate of fatty acid intake that takes into account the breastfeeding duration, and DHA and ARA intake from both BM and DHA and ARA food sources. The fatty acid composition of BM is variable, especially for DHA, being influenced by the diet of the mother and the food available within a specific country, and therefore, using a single mean level of DHA and ARA intake in BM may have overestimated the fatty acid intake in some of the developing countries while underestimating intakes in others.

The data on energy, DHA and ARA intakes in developing countries were previously derived as per capita for each total population. In this analysis on dietary intakes in infants and young children aged 6–36 months, the energy intake was adjusted to a daily energy intake of 930 kcal/day, the accepted energy requirement of infants at this age and the value that was used in the BM analysis [39]. The intakes for DHA and ARA were therefore proportionately reduced. This ensured that the energy data was consistent across the BM and complementary food analyses, and it also allowed DHA and ARA intakes to be evaluated within a context of optimal energy intake. In reality, this would not be the situation, and this may also lead to an element of overestimation of intake of DHA and ARA.

The public health implications of this data are considerable, and global policies need to more clearly reflect the needs of these most vulnerable population groups. With the increasing evidence that conversion rates from linoleic acid and alpha-linolenic acid to ARA and DHA, respectively, are extremely low [7, 8, 17–19], in both adult and in early life, the importance of adequate dietary intakes of preformed ARA and DHA during the critical period of growth and development in infants and young children is becoming more evident. International recommendations tend to be based on referenced scientific literature from high income countries, and they do not reflect the reality of infants and young children living in vastly different geographical, economic, social and cultural conditions. The evidence from this current analysis supports previous evidence that plant-based complementary foods by themselves are insufficient to meet the needs for DHA and ARA; and meat, poultry, fish or eggs need to be more prevalent in complementary food diets [14].

With the considerable variability in complementary food diets in different parts of the world, it may not be feasible to provide global dietary ‘prescriptions’ that would guarantee adequate intake of all essential nutrients, including ARA and DHA, and a focus on population-specific dietary guidelines for complementary foods may be preferable. A primary public health objective should be to provide a nutritional ‘safety net’ for those children and families who are at greatest risk, and this should include supplemented formulas for infants who are no longer receiving BM [46] and fortified complementary foods in regions where the local diet does not meet the nutrient requirements at this critical time.

It is concluded that the primary objective of the current assessment was to estimate DHA and ARA intakes in developing countries worldwide and identify populations that may be at risk of insufficient intake during a critical period of growth and development. The evidence from this analysis indicates that, in the vast majority of developing countries, the DHA and ARA intakes among children aged 6–36 months are significantly lower than current recommendations. This has significant public health implications, and future policies and recommendations on dietary DHA and ARA need to reflect the specific needs of the world’s most vulnerable populations.

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