Original Article

Modelling linoleic acid and α -linolenic acid requirements for infants and young children in developing countries

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Abstract

Essential fatty acids (EFAs), linoleic acid (LA) and α -linolenic acid (ALA), play a critical role in the growth and development of infants and young children. However, national guidelines for recommended intakes of EFAs are lacking in most developing countries. The objective of this study was to convert international EFA recommendations based on % of daily energy intake to recommended daily amounts for children aged 6–23 months in developing countries. The Food and Agriculture Organization (FAO) reports adequate intakes (AIs) for ALA as 0.4–0.6% of energy intake for children 6–23 months of age and as 3.0–4.5% of energy intake for LA. In order to estimate energy intakes, FAO daily energy requirements based on body weight were used. The daily AI amounts for these EFAs were calculated using the median body weight of the World Health Organization (WHO) Growth Standard population and median body weights with varying levels of malnutrition. The AI for ALA is equivalent to 0.3–0.4, 0.3–0.5 and 0.4–0.6 g day⁻¹, and the AI for LA is equivalent to 2.1–3.1, 2.4–3.5 and 2.8–4.3 g day⁻¹ for children aged 6–8, 9–11 and 12–23 months, respectively. While the lower median body weights of children in developing countries and associated reduced energy intake recommendations give lower estimated EFA requirements, recommendations based on median body weights in the WHO Reference Growth Standard is suggested. The upper levels of these calculated AIs are lower than or equal to those in North America (ALA: 0.5 and 0.7 g day⁻¹; LA: 4.6 and 7 g day⁻¹ for children aged 6–12 months and 1–3 years, respectively). The FAO AIs (g day⁻¹) calculated here for ALA and LA can serve as a guideline for developing countries for setting national standards.

Keywords: Linoleic acid, α -linolenic acid, requirement, infants and young children, developing countries.

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Background

The human body can synthesise saturated and monounsaturated fatty acids, but not the *n*-3 and the *n*-6 families of polyunsaturated fatty acids (PUFAs). The parent fatty acids of these families [linoleic acid (LA) and α -linolenic acid (ALA)] are essential fatty acids (EFAs) and must be provided in the diet (Innis 1991). They can then be converted to long-chain polyunsaturated fatty acids (LCPUFAs).

Lipids are structural components of all tissues and are indispensable for the assembly of cell membranes and cell organelles (German 2011). The brain grey matter, retina and other neural tissues are particularly rich in LCPUFAs, such as docosahexaenoic acid (DHA) (Innis 2009). Lipid supply, particularly EFAs and LCPUFAs, has also been shown to affect neural development and function (Innis 2009).

However, national guidelines for recommended intakes of EFAs are lacking in most developing

countries. The recent FAO (2010) recommendations on EFAs for infants and young children are based on their energy requirements. FAO reports adequate intakes (AIs) for ALA as 0.4–0.6% of energy for infants and young children 6–23 months of age and as 3.0–4.5% of energy intake for LA. Converting these requirements into daily amounts is needed for programme guidance and for setting appropriate levels in complementary foods.

Estimated daily energy intake can be derived from children's body weight, which increases dramatically during the first 2 years of life and their energy requirements per kg body weight decline from birth. As the prevalence of underweight is high in developing countries, the daily energy requirements are less than for developed country children. Because stores of essential fats may also be reduced for underweight children, it might not be appropriate to recommend lower EFA requirements based on their lower energy requirements. The purpose of this study is to calculate EFA recommendations for children aged 6–23 months in developing countries using varied assumptions of energy requirements based on levels of malnutrition and to compare whether these estimations differed from those estimations for normal children based on normal body weight.

Subjects and methods

Median *z*-score for children 6–8, 9–11 and 12–23 months of age was calculated under each prevalence of underweight ranging from 5% to 50% by shifting normal distribution (mean = 0, standard deviation = 1) to the left. The unit was calculated using the NORM.INV function with normal distribution (0,1) in the Microsoft Excel version 2010 (Table 1). Underweight was defined as weight-for-age *z*-score < −2 (de Onis 2006). The median body weight was calculated

Table 1. Median *z*-score of children in populations with different prevalences of underweight

Prevalence of underweight (%)	<i>z</i> -Score associated with the prevalence in N (0,1) distribution	Median <i>z</i> -score of population associated with the prevalence
5	−1.64	−0.36
10	−1.28	−0.72
15	−1.04	−0.96
20	−0.84	−1.16
25	−0.67	−1.33
30	−0.52	−1.48
35	−0.39	−1.61
40	−0.25	−1.75
45	−0.13	−1.87
50	0	−2

based on the Box-Cox power exponential method with the formula $\text{weight} = (z\text{-value} \times S \times L + 1)^{1/L} \times M$ (de Onis 2006). The World Health Organization (WHO) Child Growth Standards parameters (*L*, *M* and *S*) were used for the calculation (de Onis 2006), where '*L*' is the power transformation parameter for normal distribution, '*M*' is the median of weight distribution and '*S*' is the sample standard deviation.

The energy requirements for children 6–8, 9–11, and 12–23 months of age were calculated based on the median body weight (boys and girls combined) and the FAO estimations for energy requirement (WHO *et al.* 2004). The FAO energy requirement estimations for each age group were pooled together. The pooled energy requirements are 79, 80 and 81.3 kcal kg^{−1} body weight for 6–8, 9–11 and 12–23-month-old children. Daily energy requirements were calculated by multiplying the energy requirements per kg body weight with median body weight of the population. Then, the AI of EFAs was calculated based on the FAO (2010) recommendations.

Key messages

- The AI for ALA is equivalent to 0.3–0.4, 0.3–0.5 and 0.4–0.6 g/day, and the AI for LA is equivalent to 2.1–3.1, 2.4–3.5 and 2.8–4.3 g/day for children aged 6–8, 9–11 and 12–23 months, respectively.
- The FAO AIs (g/day) calculated here for ALA and LA can serve as a guideline for developing countries for setting national standards.

Table 2. World Health Organization reference median body weight and associated energy requirement for 6–23-month-old children calculated based on median body weight

Age (months)	Median body weight (kg)	Energy requirement calculated (kcal day ⁻¹)
6–8	7.93	627
9–11	8.82	705
12–23	10.46	851

Results

The median body weights of WHO Growth Standard were 7.93, 8.82 and 10.46 kg for 6–8, 9–11 and 12–23-month-old children, respectively (de Onis 2006). The associated energy requirements for a reference child are 627, 705 and 851 kcal day⁻¹ for 6–8, 9–11 and 12–23-month-old children (breastfed and formula fed combined), respectively (Table 2). These results are similar to those recommended by WHO, which are 600, 700 and 900 kcal day⁻¹ for non-breastfed children (WHO 2005), although the WHO document was published earlier than WHO has released its new growth standard in 2006.

The AI for ALA for reference children is equivalent to 0.3–0.4, 0.3–0.5 and 0.4–0.6 g day⁻¹, and the AI for LA is equivalent to 2.1–3.1, 2.4–3.5 and 2.8–4.3 g day⁻¹ for reference children aged 6–8, 9–11 and 12–23 months, respectively, based on the calculations using median infant and young child weights from the WHO standard (Tables 3–5) and the FAO (2010) recommended 0.4–0.6% of energy for ALA and 3.0–4.5% of energy for LA for infants and young children 6–23 months of age. This amount is based on the provision of breast milk to meet half of the daily energy needs and the remainder of energy is expected to come from complementary foods (FAO 2010). The AI for DHA ranges from 80 to 125 mg day⁻¹ for these children (Tables 3–5), using the FAO (2010) requirements for DHA of 10–12 mg kg⁻¹ body weight.

The 50th percentile body weight decreased from 7.63 to 6.31 kg, from 8.46 to 7.01 kg and from 10.04 to 8.31 kg for 6–8, 9–11 and 12–23-month-old children, respectively, as the prevalence of underweight increased from 5% to 50%. Based on the AI recommended by FAO (2010), the AI for LA was reduced

Table 3. Linoleic acid, α -linolenic acid and DHA requirements for 6–8-month-old infants under different scenarios of underweight prevalence

Prevalence of underweight	Linoleic acid (g day ⁻¹)	α -Linolenic acid (g day ⁻¹)	DHA (mg day ⁻¹)
Reference	2.1–3.1	0.3–0.4	79.3–95.2
5%	2.0–3.0	0.3–0.4	76.3–91.6
10%	1.9–2.9	0.3–0.4	73.2–87.9
15%	1.9–2.8	0.3–0.4	71.2–85.5
20%	1.8–2.7	0.2–0.4	69.6–83.5
25%	1.8–2.7	0.2–0.4	68.3–81.9
30%	1.8–2.6	0.2–0.4	67.1–80.5
35%	1.7–2.6	0.2–0.3	66.1–79.3
40%	1.7–2.6	0.2–0.3	65.0–78.0
45%	1.7–2.5	0.2–0.3	64.1–77.0
50%	1.7–2.5	0.2–0.3	63.2–75.8

DHA, docosahexaenoic acid.

Table 4. Linoleic acid, α -linolenic acid and DHA requirements for 9–11-month-old infants under different scenarios of underweight prevalence (median of body weight)

Prevalence of underweight	Linoleic acid (g day ⁻¹)	α -Linolenic acid (g day ⁻¹)	DHA (mg day ⁻¹)
Reference	2.4–3.5	0.3–0.5	88.2–105.8
5%	2.3–3.4	0.3–0.5	84.6–101.5
10%	2.2–3.2	0.3–0.4	81.2–97.4
15%	2.1–3.2	0.3–0.4	79.0–94.7
20%	2.1–3.1	0.3–0.4	77.2–92.6
25%	2.0–3.0	0.3–0.4	75.7–90.8
30%	2.0–3.0	0.3–0.4	74.4–89.3
35%	2.0–2.9	0.3–0.4	73.3–88.0
40%	1.9–2.9	0.3–0.4	72.1–86.6
45%	1.9–2.8	0.3–0.4	71.2–85.4
50%	1.9–2.8	0.2–0.4	70.1–84.1

DHA, docosahexaenoic acid.

from 2.0–3.0 to 1.7–2.5 g day⁻¹ for LA for 6–8-month-old infants, from 2.3–3.4 to 1.9–2.8 g day⁻¹ for 9–11-month-old infants and from 2.7–4.1 to 2.3–3.4 g day⁻¹ for children 12–23 months of age, or about 300–700 mg difference depending on the age and level of malnutrition.

The AI for ALA was reduced from 0.3–0.4 to 0.2–0.3 g day⁻¹ for 6–8-month-old infants, from 0.3–0.5 to 0.2–0.4 g day⁻¹ for 9–11-month-old infants and from 0.4–0.5 to 0.3–0.5 g day⁻¹ for children 12–23 months of age, or about 100 mg day⁻¹ depending on the age and level of malnutrition.

Table 5. Linoleic acid, α -linolenic acid and DHA requirements for 12–23-month-old children under different scenarios of underweight prevalence (median body weight)

Prevalence of underweight	Linoleic acid (g day ⁻¹)	α -Linolenic acid (g day ⁻¹)	DHA (mg day ⁻¹)
Reference	2.8–4.3	0.4–0.6	104.6–125.5
5%	2.7–4.1	0.4–0.5	100.4–120.5
10%	2.6–3.9	0.3–0.5	96.3–115.6
15%	2.5–3.8	0.3–0.5	93.7–112.4
20%	2.5–3.7	0.3–0.5	91.5–109.8
25%	2.4–3.6	0.3–0.5	89.8–107.7
30%	2.4–3.6	0.3–0.5	88.2–105.9
35%	2.4–3.5	0.3–0.5	86.9–104.3
40%	2.3–3.5	0.3–0.5	85.5–102.6
45%	2.3–3.4	0.3–0.5	84.4–101.3
50%	2.3–3.4	0.3–0.5	83.1–99.8

DHA, docosahexaenoic acid.

Recommended levels for DHA were reduced from 76.3–91.6 to 63.2–75.8 mg day⁻¹ for infants 6–8 months of age, from 84.6–101.5 to 79.1–84.1 mg day⁻¹ for 9–11-month-old infants and from 100.4–120.5 to 83.1–99.8 mg day⁻¹ for 12–23-month-old infants, or about 6–20 mg day⁻¹.

Discussion

Malnourished children may have lower stores of EFAs, especially ALA and DHA. The conversion of EFAs to their long-chain derivatives may also be defective for malnourished children (Franco *et al.* 1999; Decsi & Koletzko 2000; Marin *et al.* 2000). For moderately malnourished children under 5 years of age, Golden has proposed that at least 4.5% of energy supply should be from *n*-6 fatty acids, which is the upper level of FAO recommended AI. At least 0.5% of energy should be from *n*-3 fatty acids, which is the mid-point of FAO recommended AI (Golden 2009).

Compared with the AI calculated for a reference child, as the prevalence of underweight increases to 50%, the calculated requirements for EFAs and DHA based on the corresponding median child weights are reduced gradually. For countries with a low prevalence of malnutrition, the difference is quite small, but for countries with higher prevalence of malnutrition, the recommended levels would be much lower than

those for a reference population, by up to 20%. Thus, determining daily requirements for EFAs and DHA in developing countries based on their own body weight distribution could underestimate the needs and might increase the risk of inadequate intake. Thus, it may not be appropriate to estimate the needs based on body weights lower than the median of the WHO growth Reference Standard (boys and girls combined), even though the average body weights are lower in developing countries.

In addition, the upper level of these AIs for ALA estimated based on median body weight of WHO Reference Growth Standard are lower than or equal to those in North America Dietary Reference Intakes (DRIs) of 0.5 and 0.7 g day⁻¹ for children aged 7–12 months and 1–3 years, respectively (Table 5). The AIs for LA are also lower than those in North America DRIs (4.6 g day⁻¹ for children aged 7–12 months and 7.0 g day⁻¹ for those 1–3 years, respectively) (Table 6) (Food and Nutrition Board 2005). These DRIs were based on the average intakes of EFAs from complementary foods and from human milk in the United States for infants 7–12 months of age.

Dietary LA intake has increased significantly in developed countries during the past 20 years. By contrast, dietary intake of *n*-3 LCPUFA has been gradually reduced (Ailhaud *et al.* 2006). Gibson *et al.* (2011) reviewed the conversion of LA and ALA during the first 2 years of life and concluded that the balance of LA to ALA is a key determinant of LCPUFA status and increasing ALA amounts alone is not an effective strategy to improve DHA status. Thus, to achieve adequate intake of EFAs, the balance of dietary intake of LA and ALA should be addressed.

The energy requirements (breastfed and non-breastfed) calculated with the current WHO Growth Standards were slightly greater than those common estimates for 6–11-month-old children (627 kcal day⁻¹ vs. 615 kcal day⁻¹ for 6–8 months; 705 kcal day⁻¹ vs. 686 kcal day⁻¹) and were slightly less than those common estimates for 12–23-month-old children (851 kcal day⁻¹ vs. 894 kcal day⁻¹) (Dewey & Brown 2003) and those suggested in the WHO (2005) recommendations for non-breastfed children of 600, 700 and 900, respectively (WHO 2005), which was published before the new WHO Growth Standard was released

Table 6. Comparison of recommended levels of EFAs and DHA based on FAO (2010) and US guidelines

Type of fatty acid	Age (months)	FAO (2010) (using WHO Reference Growth Standard) (g day ⁻¹)	Age	US Institute of Medicine (2005) Dietary Reference Intakes (g day ⁻¹)
LA	6–8	2.1–3.2		
	9–11	2.4–3.5	7–12 months	4.6
	12–23	2.8–4.2	1–3 years	7.0
ALA	6–8	0.3–0.4		
	9–11	0.3–0.5	7–12 months	0.5
	12–23	0.4–0.6	1–3 years	0.7
DHA	6–8	79.8–95.7		
	9–11	88.2–105.8	7–12 months	Not given
	12–23	104.5–125.4	1–3 years	Not given

ALA, α -linolenic acid; DHA, docosahexaenoic acid; LA, linoleic acid.

in 2006. The first year difference could be related to both breastfed and non-breastfed infants included, as non-breastfed infants have higher energy requirements than breastfed infants. However, the smaller estimates for 12–23-month-old children could be due to lighter body weights of the reference children in the new WHO Growth Reference than the US children used for estimating energy requirements (Butte *et al.* 2000).

The limitation of this study is that FAO AI was based on habitual dietary intakes of healthy population, not on any biochemical or health endpoints (FAO 2010), which could over- or underestimate the requirements (e.g. LA and ALA) in developing countries. Limited evidence on dietary intakes of LA intake in developing countries suggests that breast milk and complementary foods may meet the AI, but not for ALA or DHA (Huffman *et al.* 2011).

Conclusion

For countries to develop recommendations for daily intake of essential fats based on FAO (2010) recommendations, an average child's weight needs to be used to estimate energy intake per kg and per cent of that energy intake that should come from essential fats. We suggest that using the WHO Growth Standard Reference population is also applicable for popula-

tions with various prevalences of underweight. While FAO gives a suggested range of per cent of energy from essential fats, for programmatic purposes, using the upper level of the range may be more easily interpreted. These upper levels give intakes of ALA and LA that are less than or equal to the US AIs.

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Conflicts of interest

The authors declare no conflicts of interest.

Contributions

Both ZY and SLH were involved with the design and preparation of the manuscript. ZY conducted the mathematical modeling.

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