Nutritional Status of Infants and Young Children and Characteristics of Their Diets[1]

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ABSTRACT Adoption of the recommended breast-feeding and complementary feeding behaviors and access to the appropriate quality and quantity of foods are essential components of optimal nutrition for infants and young children between ages 6 and 24 mo. Iron, zinc and vitamin B-6 are deficient in complementary food diets in Bangladesh, Ghana, Guatemala, Mexico and Peru. Low intakes of iron are consistent with a high prevalence of anemia seen in this age group. The adequacy of observed intakes for calcium, vitamin A, thiamin, folate and vitamin C depends on the age range in question and the set of requirements used in the assessment. The lipid content of many complementary food diets is low. In addition to providing essential fatty acids, lipids are needed for the absorption of fat-soluble vitamins and also enhance the texture, flavor and aroma of foods, which may lead to increased intake. The relative roles of palatability, micronutrient deficiency and morbidity-induced anorexia in the appetite of infants and young children are not known. However, even among children who were growth retarded and had a total energy deficit compared with requirements, up to 25% of food offered was not consumed. This indicates that dietary quality rather than quantity is the key aspect of complementary food diets that needs to be improved. Targeted fortification or the production of complementary foods fortified with micronutrients and of an adequate macro- and micronutrient composition is one approach to help meet nutritional requirements during the vulnerable period of 6–24 mo. J. Nutr. 133: 2941S-2949S, 2003.

KEY WORDS: • *fortified complementary foods* • *complementary feeding* • *micronutrients* • *child growth*

Adoption of recommended breast-feeding and complementary feeding behaviors and access to the appropriate quality and quantity of foods are essential components of optimal nutrition for infants and young children between ages 6 and 24 mo. Nutritional vulnerability during this period results from the poor nutritional quality of the foods offered relative to nutritional requirements (1), high prevalences of diarrhea and respiratory infections and their interaction (2–4). It is also the result of the quantity of foods offered, frequency with which they are fed and responsiveness of the mother or caregiver to the needs of the child during feeding (5). Iron, zinc and vitamin B-6 have been identified as the nutrients most likely to be lacking in complementary feeding diets in developing countries (6). Riboflavin and niacin are also likely to be lacking in some populations. The adequacy of complementary feeding diets to meet calcium, vitamin A, thiamin, folate and vitamin C needs depends on the set of requirements used for this assessment. The lipid content of complementary foods is often low and may pose a problem, particularly for weaned children (6,7); the adequacy of the protein composition in complementary food diets has been inadequately studied.

Fortification of staple foods will not address the micronutrient deficiencies of infants and young children because of the small amounts they consume relative to their high requirements. Targeted fortification or the production of complementary foods fortified with micronutrients and of an adequate macro- and micronutrient composition is one approach to help meet infant and young child nutritional requirements during this vulnerable period (8–10). In this paper, micronutrient deficiencies and nutritional characteristics of infant and young child diets in the developing world are described to provide background information relevant to the development of an appropriate macro- and micronutrient composition for fortified complementary foods. A brief review of the acceptability and intake of fortified complementary foods is also provided.

Definitions and international recommendations

The recommended duration of exclusive breast-feeding, defined as human milk being the only source of infant food and liquid, is 6 mo (11). After this age complementary foods should be introduced and breast-feeding continued up to the child's second birthday or beyond. The period of complementary feeding is defined as the period when foods other than human milk are provided to infants and young children who are still breast-feeding (1). Complementary foods are defined as those nonhuman-milk food-based sources of nutrients that

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TABLE 1

Prevalence of low (≤2 SD) height-for-age, weight-for-age and weight-for-height in nationally representative demographic and health surveys

Country and year	Sample size	Height-for-age	Weight-for-age	Weight-for-height
			%	
Sub-Saharan Africa				
Benin, 1996	2,273	25.0	29.2	14.3
Burkina Faso, 1998–99	2,530	30.9	36.4	17.7
Cameroon, 1998	1,923	29.3	22.2	6.0
Central African Republic, 1994–95	2,310	33.7	27.3	7.2
Chad, 1996–97	3,541	53.1	39.1	17.9
Comoros, 1996	921	33.8	25.8	8.3
Cote D'Ivoire, 1994	3,341	24.5	23.8	8.3
Eritrea, 1995	2,269	38.4	43.8	16.4
Ghana, 1998	1,638	20.0	24.9	12.9
Guinea, 1999	2,067	23.2	25.5	11.7
Kenya, 1998	2,821	30.9	21.5	7.0
Madagascar, 1997	3,080	48.3	40.0	7.4
Mali, 1995–96	4,678	30.1	40.0	23.3
Mozambique, 1997	2,737	35.9	26.2	7.9
Niger, 1998	4,022	14.1	49.6	20.7
Tanzania, 1996	3,498	40.3	31.7	8.6
Togo, 1998	3,260	21.8	25.1	12.2
Uganda, 1995	3,816	35.5	26.7	5.9
Zambia, 1996	3,588	38.9	25.3	5.4
Zimbabwe, 1994	2,014	21.4	15.5	5.4
North Africa/Near East				
Egypt, 1995	5,780	30.0	15.0	5.6
Jordan, 1997	3,266	7.3	4.9	2.0
Turkey, 1999	1,610	12.0	7.6	2.5
Yemen, 1997	4,966	45.7	43.7	15.0
Asia				
Bangladesh, 1996–97	2,864	47.6	52.5	20.5
Nepal, 1996	3,705	48.4	46.9	11.3
Newly Independent States				
Kazakhstan, 1995	717	15.7	8.3	3.2
Kygyz Rep., 1997	1,015	24.8	11.1	3.5
Uzbekistan, 1996	989	31.3	18.8	11.6
Latin America/Caribbean				
Bolivia, 1998	3,451	24.2	9.0	2.0
Brazil, 1996	2,306	10.3	5.4	2.8
Colombia, 2000	4,060	13.5	6.7	0.8
Dominican Rep., 1996	2,131	11.0	6.3	1.6
Guatemala, 1999	2,149	41.9	23.9	3.1
Haiti, 1994–95	1,721	27.0	25.4	9.6
Nicaragua, 2000	6,242	20.2	12.2	0.3
Peru, 1996	7,957	22.7	8.6	1.5

Source: Summary data from demographic and health surveys (Mukuria, A. G., Johnston, R., Cushing, J., unpublished, ORC Macro Inc., 2003).

are offered during this period (1). Fortified complementary foods are defined as centrally produced and specially formulated complementary foods to which one or more micronutrients have been added to enrich their nutrient content.

Historically, both the WHO and the United Nations Children's Fund (UNICEF)[3] have emphasized the use of local foods formulated in the home rather than centrally produced fortified foods for complementary feeding (12,13). However, in recognition of recent scientific information showing the potential limitations of purely home-based and local approaches to satisfy the requirements for some nutrients (1), the WHO/UNICEF *Global Strategy for Infant and Young Child Feeding* (14) states, "*Industrially processed complementary food* also provide an option for some mothers who have the means to buy them and the knowledge and facilities to prepare and feed them safely" and "*Food fortification* and universal or targeted *nutrient supplementation* may also be required to ensure that older infants and young children receive adequate amounts of micronutrients."

Nutritional status and timing of growth faltering

Growth faltering is widely prevalent in the developing world with wide variations among regions and within regions among countries (**Table 1**). Overall, the prevalence of stunting (low height-for-age) and low weight-for-age is highest in Asia, affecting one in every two children. The prevalence of acute malnutrition (low weight-for-height) is also extremely high, reaching >20% in Bangladesh and 11% in Nepal. Sub-Saharan Africa also has a high prevalence of stunting, low weight-for-age and acute malnutrition, although the absolute levels are less than those in Asia. A less consistent picture emerges from the North Africa and Near East regions. Preva-

[3] Abbreviations used: DRI, Dietary Reference Intake; EAR, estimated average requirement; RDA, Recommended Dietary Allowance; UNICEF, United Nations Children's Fund.

lences in Yemen are similar to those in Asia whereas those of Jordan and Turkey are considerably lower. The prevalence of stunting and low weight-for-age in the Newly Independent States, Latin America and the Caribbean is generally lower than in Africa although wide variation among countries is observed. In Guatemala nearly 42% of children are stunted compared with only around 10% in Brazil and the Dominican Republic (Table 1). With the exception of Uzbekistan, acute malnutrition is far less prevalent in the Newly Independent States, Latin America and the Caribbean compared with other regions of the world.

A recent analysis of nationally representative data from 39 developing countries showed that although the actual prevalence of underweight and stunting varies markedly among countries and regions of the world, the timing of faltering in both weight and length follows a remarkably similar pattern (15). Faltering in weight begins at about age 3 mo and continues rapidly until about 12 mo. Thereafter, it continues to decline at a slower pace until about 18–19 mo with a subsequent catch-up pattern. The pattern for faltering in length is different, suggesting that different physiologic mechanisms, dietary deficiencies or other environmental insults underlie these two manifestations of growth faltering. Generally, mean birth length is close to the National Center for Health Statistics reference (16) at birth but starts to falter immediately thereafter and continues well into the 3rd y. In contrast, mean birth weight differs among the different regions studied, suggesting that prenatal factors are more likely to affect birth weight than birth length. Stunting in length after 24–36 mo is permanent and, therefore, unlike the pattern with weight, no catch-up is observed. The results clearly confirm earlier less comprehensive and representative studies showing that growth faltering occurs during the prenatal period and the first 2–3 y of life. The results are also consistent with studies showing that the response to improved feeding is greatest during this time (17,18) and point to the period of breast-feeding and complementary feeding as a critical window of opportunity to improve postnatal growth.

Nutrients required from complementary foods

The amount of nutrients required from complementary foods depends on the quantity provided by human milk and varies markedly by nutrient, ranging from nearly 100% for iron to 0% for vitamin C (**Fig. 1**). The calculation of the nutrients required from complementary foods is based on the recommended intake for each nutrient minus the amount of the nutrient consumed daily from human milk (1,6). Although conceptually straightforward, this calculation is complicated by the fact that no single set of nutritional requirements for infants and young children has been agreed upon. Three are currently in use: The Recommended Nutrient Intakes in the WHO 1998 report (1), largely derived from the Dietary Reference Values from the United Kingdom (19); the Dietary Reference Intakes (DRI) published by the U.S. Institute of Medicine (20–23); and the WHO/FAO preliminary report on recommended nutrient intakes (24). It is also complicated by the fact that some micronutrients are highly variable in human milk, depending on the woman's nutritional status, and that human milk intake itself is highly variable. WHO identified two groups of micronutrients: those that do not vary with maternal nutritional status and those that do (1). The B vitamins (except folate) and vitamin A, iodine and selenium are in this latter category.

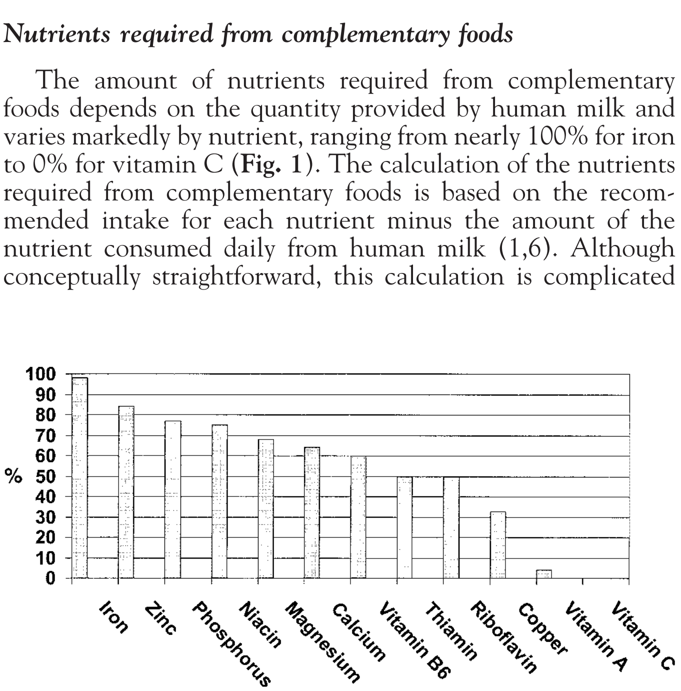

FIGURE 1 Proportion (%) of nutrients that complementary foods must provide for a 6–8 mo breast-fed child.

Identification of problem nutrients

In the 1998 WHO report, the concept of problem nutrients was introduced and defined as those nutrients for which the discrepancy between the content in complementary foods and the amount estimated to be required by children aged 6–24 mo was the greatest (1). The nutrient density per 100 kcal needed to satisfy nutrient requirements was calculated (as described above) and compared with the actual densities of nutrients consumed by breast-fed children in Bangladesh and Peru. Iron, zinc and calcium were identified as problem nutrients based on this assessment.

More recently, weighed nutrient intake data from Bangladesh, Ghana, Guatemala, Mexico and Peru were used to compare actual nutrient density with the estimated average desired densities for breast-fed children using the three sets of requirements noted above (6). The results for children aged 6–8, 9–11 and 12–23 mo show that the median protein density in each of the populations exceeded the estimated desired density (**Table 2**). For iron, median densities were less than the estimated desired density in each of the populations for infants of both age groups. In all populations from developing countries, median iron intakes were also less than the estimated desired density for children aged 12–23 mo. Moreover, calculations of the quantity of foods from animal source that would need to be consumed to satisfy iron requirements show that it would be difficult for infants and young children to consume such quantities (1,6).

In all populations, median zinc intake was less than the calculated desired density for infants aged 6–8 mo (Table 2). For infants aged 9–11 mo, median intakes were less than the calculated desired density in all countries except Ghana, where a fortified food containing zinc had been provided. For children aged 12–23 mo, median zinc intakes were similar to or slightly greater than the estimated desired densities based on the 1998 WHO values and the new DRI but lower than those based on the new WHO/FAO requirement.

For the remaining nutrients, the adequacy of observed densities was a function of the set of requirements used for the calculation, illustrating the urgent need to harmonize nutrient requirements for infants and young children. For example, in all populations median calcium intakes were less than the estimated desired density for infants at both 6–8 and 9–11 mo when the WHO 1998 or recent WHO/FAO requirements were used (Table 2). When the DRI were used, median intakes were inadequate at 6–8 mo in all developing country populations but adequate at 9–11 mo in Ghana, Guatemala and Mexico. For children aged 12–23 mo, median intakes were mostly adequate with respect to WHO 1998 estimated desired

TABLE 2

Nutrient densities per 100 kcal of complementary food diets for children aged 6–8, 9–11 and 12–23 mo in Bangladesh, Ghana, Guatemala, and Peru compared with estimated desired nutrient densities[1]

	WHO	IOM DRI	WHO/FAO	Bangladesh	Ghana	Guatemala	Peru	Mexico
6–8 months								
Number of children				50	207	194	107	—
Protein, *g*	0.7	1.0	1.0	1.9	3.3	2.2	2.6	—
Vitamin A, *μg RE*	5	81	31	0*	7*	87	35	—
Calcium, *mg*	125	40	105	16*	35*	27*	19*	—
Iron, *mg*	4.0[2]	5.3[2]	4.5	0.4*	1.2*	0.5*	0.4*	—
Zinc, *mg*	0.8	1.1	1.6	0.2*	0.6*	0.4*	0.4*	—
Riboflavin, *mg*	0.07	0.08	0.08	0.04*	0.03*	0.06*	0.07*	—
Thiamin, *mg*	0.04	0.08	0.08	0.04*	0.07*	0.04*	0.04*	—
Niacin,[1] *mg*	1.1	1.5	1.5	0.9*	0.8*	0.4*	0.5*	—
Niacin equivalent, *mg*	—	—	—	1.3*	1.3*	0.8*	1.0*	—
Folate, *μg*	0	11	11	5*	—	7*	—	—
Vitamin B-6, *mg*	0.09[4]	0.12	0.12	0.02*	—	0.05*	—	—
Vitamin C, *mg*	0	11	1.5	0*	0.02*	2.3	2.3	—
9–11 months								
Number of children				66	171	148	99	—
Protein, *g*	0.7	1	1	2.5	3.1	2.7	2.6	—
Vitamin A, *μg RE*	9	63	30	1*	9*	62	29*	—
Calcium, *mg*	78	32	74	20*	40*	37*	27*	—
Iron, *mg*	2.4	3.5	3	0.4*	1.3*	0.6*	0.4*	—
Zinc, *mg*	0.5	0.7	1.1	0.3*	0.6*	0.4*	0.4*	—
Riboflavin, *mg*	0.04	0.06	0.06	0.05*	0.02*	0.06	0.07	—
Thiamin, *mg*	0.04	0.06	0.06	0.05*	0.06	0.05*	0.04*	—
Niacin[3], *mg*	0.9	1	1	1.0	0.7*	0.5*	0.5*	—
Niacin equivalent, *mg*	—	—	—	1.4	1.2	0.7*	1.0	—
Folate, *μg*	0	9	9	8*	—	13	—	—
Vitamin B-6, *mg*	0.08	0.08	0.08	0.03*	—	0.07*	—	—
Vitamin C, *mg*	0	8	1.7	0.3*	0.9*	2.4	1.1*	—
12–23 months								
Number of children				—	—	116	—	18
Protein, *g*	0.7	0.9	0.9	—	—	2.5	—	3.0
Vitamin A, *μg RE*	17	5	23	—	—	58	—	8*
Calcium, *mg*	26	63	63	—	—	24*	—	60*
Iron, *mg*	0.8	1.2	1.1	—	—	0.6*	—	0.6*
Zinc, *mg*	0.3	0.4	0.6	—	—	0.4	—	0.5
Riboflavin, *mg*	0.05	0.06	0.06	—	—	0.05*	—	0.04*
Thiamin, *mg*	0.05	0.07	0.07	—	—	0.05*	—	0.04*
Niacin, *mg*	0.9	0.9	0.9	—	—	0.5*	—	0.6*
Niacin equivalent, *mg*	—	—		—	—	0.6*	—	1.1
Folate, *μg*	0	19	21	—	—	13*	—	14*
Vitamin B-6, *mg*	0.09	0.08	0.08	—	—	0.07*	—	0.06*
Vitamin C, *mg*	1.1	0	1.5	—	—	2.6	—	0.8*

[1] Summarized from Tables 10–11 in Dewey and Brown (6). DRI, Dietary Reference Intake; IOM, Institute of Medicine; WHO, World Health Organization.
* Indicates that the observed density is below at least 2 of the 3 reference values for average desired density.
[2] Medium iron bioavailability.
[3] Excluding the contribution of dietary tryptophan.
[4] Corrected value.

densities but lower than the estimated desired densities using the DRI or recent WHO/FAO requirements. Likewise, determination of the adequacy of observed intakes for vitamin A, thiamin, folate and vitamin C depended on which set of requirements were used. The adequacy of vitamin B-6 was an exception and was determined to be low or marginal in all populations.

The use of recommended daily allowances (RDA) or intakes rather than estimated average requirements (EAR) in the calculation of estimated desired density will overestimate actual density required to meet population needs (25). Therefore, the EAR should be used when available. However, because the EAR are not available for several nutrients, the RDA are used. For several nutrients such as iron, zinc and vitamin B-6, intakes are so low that they will be considered inadequate in complementary feeding diets regardless of the choice of recommendation or use of the RDA rather than the EAR. The identification of iron and zinc as problem nutrients is consistent with an analysis of 23 different food mixtures used in developing countries that showed that although most met protein and energy requirements, none met the estimated desired iron density and only a few met the estimated desired zinc or calcium density (26). It is also consistent with analyses showing the difficulty of satisfying infant iron requirements in the absence of fortified foods (1,6). However, for other nutrients such as calcium, vitamin A, thiamin, folate and vitamin C, determination of inadequacy depends on the intake of the specific population in question and the choice of requirement. Use of an EAR rather than an RDA may influence the assessment of adequacy.

Macronutrients and lipid composition

Compared with micronutrients, there is a paucity of data on the macronutrient composition of the complementary food diets against which to assess adequacy. In particular, the composition of lipid in the diets of infants and young children in developing countries has received little attention. Numerous studies have shown the key role of EFA and especially the (n-6) and (n-3) long-chain PUFA in neurological development (27–29). These PUFA are likely to be low in the milk of women consuming little food from animal sources as well as in cereal-based complementary food diets.

Because of its high lipid content (45–55%), the total lipid needs of 30–45% of total dietary energy are provided in early infancy by human milk (6). However, as an increasing proportion of energy is provided by complementary foods during the weaning period, total lipid intake declines because complementary foods tend to have a much lower lipid content than human milk. In The Gambia, the percentage of energy from lipid decreased from over 50% during exclusive breastfeeding to 15% by the time of weaning (7). Unpublished 24-h recall data collected by the Pan American Health Organization from Bolivia (in 2001), Ecuador (in 2002) and Peru (in 1999) show that lipids provide only 9–13% of energy from complementary foods for breast-fed children aged 6–24 mo. In contrast, the recent nationally representative nutrition survey in Mexico showed that 32% of the energy in the diets of young children aged 12–23 mo was derived from lipid (30). To the extent that the composition of foods offered to young children does not change with weaning, intake of lipids is likely to be significantly less than the recommended amount in some populations.

In addition to providing EFA, lipids are essential for increasing the energy density of the diet and for the absorption of fat-soluble vitamins (31,32). Per unit weight the metabolic energy from lipid is more than twice that of protein and carbohydrate and, thus, makes an important contribution to the energy density of complementary foods. Lipids also enhance the texture, flavor, and aroma of foods, thus promoting increased intake (33). The relative roles of palatability, micronutrient deficiency and morbidity-induced anorexia in the appetite of infants and young children are not known. However, several studies showed that even among children who were growth retarded and had a total energy deficit compared with requirements, up to 25% of food offered was not consumed (34). Among Bolivian children aged 6–24 mo, where stunting was prevalent (18.5%) and low weight-for-age was less than expected in a normally distributed population, between 10 and 30% of the food offered was not consumed depending on the meal (35). This indicates that dietary quality rather than quantity is the key aspect of complementary food diets that needs to be improved. It also suggests that attempting to increase energy intake by merely providing more of the same foods in the absence of improving their quality will not have the desired effect.

Published data on the energy adequacy of complementary food diets is based on outdated energy requirements. The new FAO/WHO energy requirements for infants and young children are between 5 and 18% lower when expressed per day and about 5 to 13% lower when expressed as a function of body weight (6). Comparing energy intake data for infants aged 6–11 mo from Guatemala and Bangladesh in Brown et al. (34) with the new FAO/WHO requirements shows that energy requirements are met when expressed as a function of body weight although not when expressed as a daily requirement. However, as mentioned above, children in these same studies did not consume all the food they were provided, suggesting that lack of food was not a limiting factor to meeting total energy requirements. Unpublished 24-h recall data from infants and young children in Bolivia, Ecuador and Peru (Pan American Health Organization, 2001, 2002, 1999, respectively) show that the energy from complementary foods exceeded the estimates of Dewey and Brown (6), which were based on average human milk intake. The recent national nutrition survey in Mexico showed median energy intake from complementary foods to be 767 kcal/d, which is about 100 kcal/d less than the new recommendations for children aged 12–23 mo (based on no human milk intake) (30). This reported low intake may be partially due to underestimation by the 24-h recall method. However, there was practically no wasting in this population (2%, which is below the percentage expected in the reference population) and 12% of children in this age group had weight-for-age Z scores $<$ 2 standard deviations, indicating that energy may not be limiting when expressed as a function of body weight or when human milk intake is also considered.

Although total nitrogen when expressed as protein intake appears to be adequate in complementary food diets (1,6,34), very little attention has been paid to the quality of the protein and the effect, if any, that different protein sources have on growth. Several recent studies showed a positive effect of meat consumption, milk consumption or both on nutritional status [(36,37) Neumann, C. G., Whaley, S., Sigman, M., Weiss, R., Guthrie, D., Murphy, S.,N. Bwibo, N. and Grillenberger, M. unpublished results]. The specific macro- and micronutrient nutrients responsible for improved status cannot be determined because products from animal sources are a good source of multiple micronutrients, PUFA and potentially limiting amino acids. As such, the relative role of improved protein quality provided through animal rather than cereal sources cannot be determined.

Micronutrient deficiencies

Dietary data showing iron to be a problem nutrient are consistent with biochemical data on iron deficiency anemia, the most widespread micronutrient deficiency among infants and young children (**Table 3**). Recent randomized trials showing the effect of iron supplementation on motor and language development suggest that improving iron status in iron-deficient populations is likely to yield significant benefits (39–41). Using the HemoCue method, nationally representative Demographic and Health Surveys show a prevalence of hemoglobin $<$ 100 g/L among infants and children ranging from 37% in Kazakhstan to 73% in India and Madagascar (Table 3). With only two exceptions (Egypt and Kazakhstan), the prevalence of hemoglobin $<$ 100 g/L affects one-half to three-fourths of the infant and child population. Although the current diagnostic criteria for assessing iron deficiency in infants have been questioned (42), refinements of these criteria are unlikely to change the conclusion that at the population level iron deficiency anemia is a serious worldwide problem. The data in Table 3 show that the proportion of children with hemoglobin levels of 70–99 g/L comprise a relatively large proportion of the total. The degree to which other causes of iron deficiency anemia such as parasites, malaria and dysentery also contribute to these high prevalences cannot be determined from the data available. As a result, the proportion of children who would respond to increased iron intake cannot be calculated. However, even if the contribution of these other causes of iron deficiency anemia are on the order of 50% of the

TABLE 3

Iron deficiency anemia in children in nationally representative demographic and health surveys[1]

Country and year of survey	Sample size	Anemia			
		Mild, 100–109 *g/L*	Moderate, 70–90 *g/L*	Severe, <70 *g/L*	Total
			%		
Sub-Saharan Africa					
Madagascar, 1997	2,308	21.2	44.7	7.7	73.6[2]
Uganda, 2000	5,624	18.4	34.5	6.2	59.1[3]
North Africa					
Egypt, 2000	4,630	18.8	11.4	0.2	30.4[3]
Newly Independent States					
Kazakhstan, 1999	570	17.8	17.9	1.5	37.2[3]
Kgrgyz Republic, 1997	843	23.3	21.8	1.4	46.5[2]
Uzbekistan, 1996	988	33.3	25.8	1.4	60.5[2]
South/Southeast Asia					
Cambodia, 2000	1,414	30.2	31.3	2.0	63.5[3]
India, 1998–99	19,943	22.9	45.6	5.2	73.7[2]
Latin America/Caribbean					
Bolivia, 1998	1,721	19.8	32.4	3.4	55.6[3]
Haiti, 2000	2,428	28.3	33.0	1.7	63.0[3]
Peru, 2000	2,150	23.4	24.9	1.3	49.6[3]

Source: Data abstracted from Table 5 in Micronutrient Update (38).
[1] Direct measures of hemoglobin levels were made using a drop of blood from the heel.
[2] Children 6–35 mo.
[3] Children 6–59 mo.

total, the lack of dietary iron would still constitute a public health problem of generalized and significant importance.

The Mexican National Nutrition Survey also shows iron deficiency anemia to be highly prevalent and widespread (30). Using the HemoCue method and cutoff values of <95 g/L for infants aged 6–11 mo and <110 g/L for children aged 1—5 y, a prevalence of anemia of 49 and 27% was detected in children aged 12–23 mo and <5 y, respectively. Of these, 64% were iron deficient as determined by transferrin saturation. A recent nationally representative survey of infants and young children in the province of Buenos Aires, which comprises about one-third of the Argentine population, showed the prevalence of anemia (cutoff criteria not defined) among children less than age 24 mo to be 48% (43). Of these, 63% were iron deficient as assessed by serum ferritin. Meat consumption was common; 49% of infants less than age 12 mo and 85% of children aged 12–24 mo had received meat in the previous day. The prevalence of low height-for-age was 3.6% and wasting and acute malnutrition was below that expected in a normal distribution, illustrating that anemia is highly prevalent even when meat consumption is relatively common and growth is adequate.

Zinc deficiency is also highly prevalent (44,45) and associated with depressed immunity and impaired taste and smell among other adverse effects (46). Nationally representative data from Mexico show 25% of children to have serum concentrations < 9.9 μmol/L (65 μg/dL) with a prevalence of 40% in rural areas compared with 18% in urban areas (30). Small-scale studies from different regions of the world also show zinc to be deficient among infants and young children, which is consistent with dietary data showing inadequate intake of this mineral.

Biochemical data on vitamin B-6, calcium and other potential problem nutrients with the exception of vitamin A are lacking. Milk levels of vitamin A depend on maternal status, and milk from women with a good vitamin A status is an excellent source of this nutrient for their breast-fed children (1). In contrast, milk concentrations of vitamin A among women with poor status will be low and their breast-fed children will need to derive a far greater proportion of their requirement from complementary foods. For breast-fed infants of women with adequate vitamin A status, the vitamin A content of complementary food diets should be adequate to satisfy requirements (1).

The high prevalence of micronutrient deficiencies among infants and young children in the developing world is a function of both high requirements relative to body size and the composition of typical complementary feeding diets, which are almost entirely cereal based and contain very little meat. A calculation of the estimated average iron requirement set by the Institute of Medicine (23) and reference body weight according to the National Research Council (47) for different age groups illustrates the difficulty for infants and young children to meet iron requirements (**Fig. 2**). The EARs for iron for infants (0–11 mo) and young children (1–3 y) are 0.76 and 0.54 mg/kg body weight, respectively. In contrast, the EAR for adult women is 0.13 mg/kg and for men is 0.08 mg/kg. Likewise for zinc, the EAR for infants is nearly three times higher than that for adult women (**Fig. 3**) and the adequate intake for

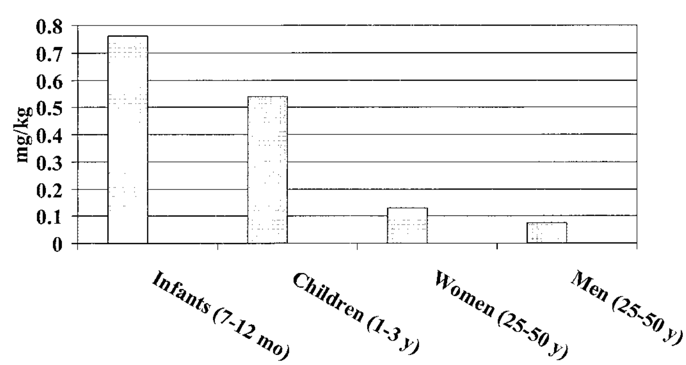

FIGURE 2 Estimated average iron requirement by reference weight.

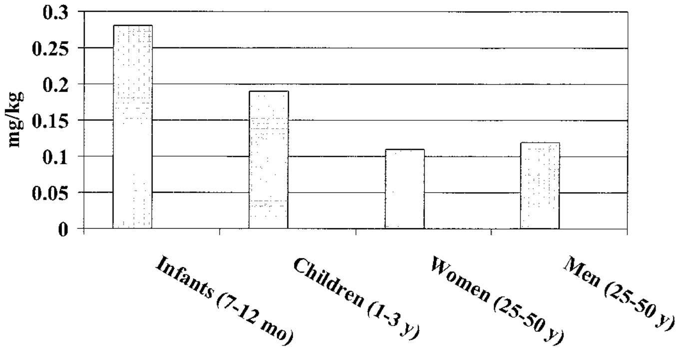

FIGURE 3 Estimated average zinc requirement by reference weight.

calcium for young children is more than three times that for adult men (**Fig. 4**).

The limited gastric capacity of infants and young children further exacerbates the difficulty in meeting their requirement for iron and other micronutrients. Through the use of data from the rehabilitation of severely malnourished nonbreast-fed children, gastric capacity was estimated to be about 30 mL/kg body weight (48), which suggests that an intake of 250–50 g/meal represents the upper limits of the functional capacity of infants and young children aged 7–8 mo (36). In addition, energy requirements for infants and young children have been steadily declining as a result of improved measurement methods (6), further increasing the micronutrient density per unit of energy needed to satisfy micronutrient requirements. For diets with an average energy density of 1.07 kcal/g, infants and young children would only need to consume 187–515 g/d to satisfy their energy requirement if they had an average intake of human milk (49).

The current emphasis on fortification of staple foods, although useful for improving the micronutrient intake of population groups consuming large amounts of these products, will do little to improve the micronutrient adequacy of complementary food diets. The level of micronutrients needed to contribute significantly toward infant and young child nutrition requirements given the small quantities they consume would vastly exceed that needed for the rest of the population and could not be justified either for cost or safety, even if technologically feasibility. Nearly 200 g of fortified bread would need to be consumed by breast-fed infants to meet half of their iron EAR. [This calculation is based on 65% of bread being composed of flour fortified at 30 mg/kg, which is typical in Latin America (50)]. This amount of bread equals the estimated quantity of food needed to satisfy energy requirements of this age group with an average human milk intake (6,49). Unpublished nationally representative data from Mexico for 2001 show average bread intake among children aged 1–4 y to be 90 g. Data collected by the Pan American Health Organization from a poor periurban community in Bolivia in 2001 show that the average intake of foods containing wheat flour was 25.5, 39.0 and 70.0 g for children aged 6–8, 9–11 and 12–24 mo, respectively. In Ecuador average intakes were 17.3, 25.7 and 15.5 g for these same age groups in 2002, illustrating that the fortification of stable foods will have a negligible effect on the iron status of this vulnerable population.

Are fortified complementary foods acceptable to the target population?

A high-quality fortified complementary food is of value in improving the nutritional status of a child at-risk for malnutrition only if it can be safely prepared and fed, is accepted by the child and has the intended biological effect. Experiences in Guatemala, Mexico and Peru suggest that such foods are easily adopted by mothers, can be safely prepared and are consumed by the infants and young children. The effect on linear growth is mixed, in part because of the fact that many factors affect linear growth and in part because of differences in study design. These effects were recently reviewed by Dewey (51) and are not discussed further in this paper.

In Guatemala a recent study on the uses of *Incaparina*, a fortified cereal-based food available on the commercial market, in one indigenous community ($n = 50$) and one mestizo community ($n = 50$) showed that food was prepared between 12 and 15 d/mo (52). Eighty percent of the respondents reported having given the food to a child between ages 6 and 23 mo, but mothers tended to add 50% more water than specified on the package thus reducing the nutrient density. In Guatemala, *Incaparina* is purchased rather than provided free of charge through a public health program, which indicates that a high-quality low cost fortified food can be promoted to the public, purchased by low income families and consumed by infants and young children.

In Mexico a social program targeted to the nearly four million families below the poverty line provides a multiple-micronutrient fortified complementary food to all children aged 4–23 mo and to mild-to-moderate underweight children (<-1 weight for age *z*-score) aged 24–59 mo. An evaluation carried out in a random sample of 2500 families with children younger than 5 y showed that in 1999, 1 y after joining the program, 43% of children aged 4–23 mo and 65% of underweight children aged 24–59 mo were consuming the fortified food regularly (≥4 d/wk for at least 6 mo). Consumption was higher in children from lower-income families.

A second cross-sectional sample was studied 1 y after the implementation of the program. The prevalence of anemia in children younger than age 5 y who were exposed to the program was 6.5% less ($P < 0.05$) than that for children in comparable villages who had similar socioeconomic and demographic characteristics and were therefore eligible for but had not benefited from the program (control group). Results were adjusted for age, height-for-age and socioeconomic status. After the second cross-sectional survey (1 y after the intervention), the villages used as a control group joined the program. A third cross-sectional survey was conducted 2 y after the implementation of the program, when all children had been exposed to the program for 1 or 2 y. Therefore, one of the analyses was the comparison of growth by category of consumption. Children aged 6–23 mo who reported regular consumption of the supplements (as defined previously) grew

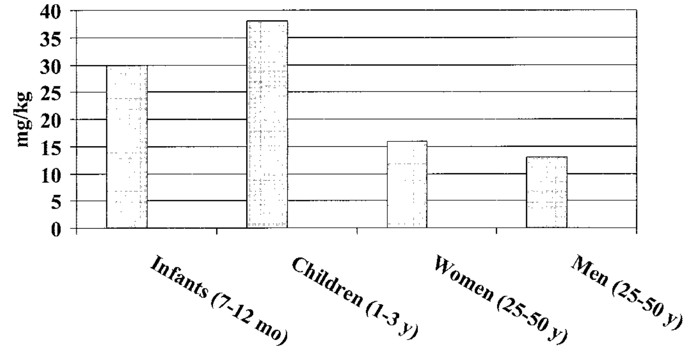

FIGURE 4 Estimated adequate calcium intake by reference weight.

1.2 cm more than did children who reported not consuming the supplement regularly after adjustment for sex, weight for age and socioeconomic status ($P < 0.05$).

In Peru, in a largely indigenous population, a fortified complementary food called "Ali Alimentu" was consumed by 66% of the target population in the 24 h before the data collection survey. It contributed ~50, 75, 73 and 55% of protein, iron, vitamin A and calcium intakes, respectively (53). Although the food contributed 36% of total energy intake (the ration of 90 g/d was designed to cover 33% of requirements for energy), the total increase in energy was only 13%. However, because Ali Alimentu replaced foods of lower nutritional quality, an increase in the intake of all nutrients was observed. The fortified complementary food resulted in significant improvements in serum retinal and hemoglobin levels among children who received the food compared with control children. Although increments in length-for-age during the 11-mo evaluation were greater in children receiving the food, these increases were not statistically significant.

Summary

Most infants are physically able to consume home-prepared or family foods by about age 12 mo (1,6); however, their high nutritional requirements relative to body size and small amounts of foods consumed indicate that nutrient-dense foods will still be required into the second and third years of life. Although deficits in energy intake in this age group cannot be ruled out as a cause of growth faltering, dietary quality rather than quantity appears to be the key problem with complementary food diets. To the extent that energy intake is sometimes limiting, it may not be because of lack of food offered but the result of illness, depressed appetite secondary to micro- or macronutrient deficiencies, inappropriate consistency or poor palatability of the foods offered.

Complementary food diets are inadequate in iron, zinc and vitamin B-6. Riboflavin, niacin, calcium, thiamin, folate, vitamin C and vitamin A are also likely to be inadequate in some populations. Given the high level of nutrient requirements and small amounts consumed, fortification of staple foods with iron will not address these deficiencies. The total proportion and composition of lipid are likely to be deficient in complementary food diets. Although total nitrogen content appears to be adequate, little attention has been paid to potentially limiting amounts of amino acids, which may occur when virtually all the protein is provided by cereals. Beyond their contribution of a good and highly bioavailable source of iron and zinc, foods from animal sources also increase the proportion of fat in the diet and provide EFA and high quality protein. An association of milk consumption with growth has also been documented (54). Lipids, the content of which is relatively high in foods form animal sources, also enhances the absorption of fat-soluble nutrients.

The health impacts of iron and vitamin A deficiencies in this age group have led to large-scale supplementation programs (55). However, only vitamin A supplementation, which can be administered though immunization campaigns every 6 mo, and does not depend on continual delivery through primary health care services, has come close to achieving broad and sustained coverage. Successful public health programs to deliver daily and/or weekly iron have not been demonstrated. Also, such single-nutrient interventions do not address the multiple micronutrient and possible macronutrient deficiencies in complementary food diets.

The elimination of iron deficiency anemia as a public health problem in the United States has been attributed to the fortification of infant foods (56); iron fortification of milk used in supplemental feeding programs significantly reduced anemia among Chilean infants (57). Although costly, the provision of fortified complementary foods, milk, or both is a part of social welfare programs of a number of countries in Latin America (8). In Guatemala, Mexico and Peru, such fortified complementary foods have been widely accepted and consumed by indigenous and urban poor populations. Data show that these foods have been effective in improving micronutrient status in Peru and linear growth and hemoglobin levels in Mexico. Data from Guatemala show that a fortified commercial product perceived to be of high quality and of an accessible cost is widely purchased by low income families and given to infants and young children, demonstrating a role for the commercial as well as the public sector in the promotion of such foods.

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