The immediate consequences of early poor nutrition on children’s health include an increased risk of morbidity and mortality from illness, and delayed mental and motor development.

**Key insights**
Complementary feeding in developing countries is often restricted to cereals and legumes; however, it is important to add fruits, vegetables, and animal source foods to the diet to meet children’s micronutrient needs. The inclusion of milk and dairy products or fish and meat in children’s diets in developing countries is associated with faster growth, weight gain, and better cognitive performance.

**Current knowledge**
Since the 1970s, in order to prevent undernutrition and stunting, child feeding recommendations have been focusing on exclusive breastfeeding from birth to 6 months and introduction of high-quality complementary foods in addition to continued breastfeeding up to 2 years. Only in the late 1980s and early 1990s was growth stunting recognized as being caused by a lack of micronutrients in children’s diets.

**Practical implications**
If families cannot afford including animal source foods in the diet, fortification with micronutrient powders or lipid-based supplements may be able to prevent micronutrient deficiencies.

**Recommended reading**
Global Dietary Patterns and Diets in Childhood: Implications for Health Outcomes

Lindsay H. Allen

USDA, ARS Western Human Nutrition Research Center, University of California, Davis, Calif., USA

Abstract

This article provides an overview of child feeding recommendations and how these relate to actual practice and dietary adequacy, primarily in developing countries. From birth to 6 months, recommendations focus on optimal breastfeeding practices, although these are still suboptimal in about one third of infants in developing countries. From 6 months of age, breast milk can no longer meet all the nutrient requirements of the child, so from 6 months through at least 24 months, the recommendation is to continue breastfeeding but gradually introduce complementary foods. In poorer populations, the available foods for complementary feeding are primarily cereals and legumes, to which small amounts of fruits and vegetables are added, and even less animal source foods. Based on intake data from infants and preschoolers, it is evident that usual diets typically fall far short of supplying micronutrient needs. By adding more fruits, vegetables, and animal source foods to the diets of children in developing countries has been demonstrated to improve their growth and development. Milk or dairy product intake is associated with child growth in both wealthier and poorer populations.

Key Messages

- To grow and develop normally, exclusive breastfeeding is recommended for the first 6 months of life. After 6 months, breastfeeding should be continued for 2–3 years, but high-quality complementary foods should be added through age 2 years.

- It is difficult to meet children’s micronutrient requirements after age 6 months unless their diet contains some animal source foods such as milk, eggs, fish or meat, and/or is fortified commercially or in the home. Typically, consumption of animal source foods or fortified foods is low, leading to a predictable and relatively universal set of nutrient deficiencies including vitamin A, iron, zinc, and vitamin B12.

- Adding animal source foods to the diets of children in developing countries has been demonstrated to improve their growth and development. Milk or dairy product intake is associated with child growth in both wealthier and poorer populations.

Key Words

Breastfeeding · Children · Developing countries · Diets · Health · Infants · Micronutrients
micronutrient powders or lipid-based nutrient supplements hold great potential to prevent micronutrient deficiencies at reasonable cost, thus preventing the adverse consequences of these deficiencies for child development.

Introduction

Child malnutrition remains a major global public health problem in spite of the advances that have been made in child feeding practices and medical care. This is due primarily to the fact that infants and children in many environments consume diets that are nutritionally inadequate, in that they do not provide adequate amounts of essential nutrients. Other factors are definitely involved, including poor maternal nutritional status in pregnancy and lactation, and frequent and chronic infections in the child; however, poor dietary patterns remain the central causal factor in child malnutrition.

Depending on the definition used, malnutrition affects about 50–150 million children under the age of 5 years, most of which live in Africa and Asia. UNICEF reports that poor nutrition causes one third of the under-5 year mortality [1]. The definition of ‘undernourished’ commonly refers to underweight and/or growth stunting which usually reflect chronic undernutrition and poor dietary quality. It also includes the less common condition of wasting, or low weight-for-length or weight-for-height, which is often caused by a more severe lack of food, and/or diarrhea or other diseases. Most growth stunting occurs during the first 2 years of life, the recognition of which has caused increased attention to the ‘first thousand days’ (i.e. nutrition during pregnancy and the first 2 years postpartum) as a critical period for improving child nutrition.

Consequences for Health

The immediate consequences of early poor nutrition on children’s health include an increased risk of morbidity and mortality from illness, and delayed mental and motor development. In the longer term, early nutrient deficiencies and stunting are associated with many more subtle functional decrements including impaired intellectual performance in school children, increased risk of women delivering a low-birth-weight infant, and reduced adult work and earning capacity [3, 4]. While most attention is now being paid to improving nutrition in the first thousand days, the adequacy of dietary intake by preschoolers, schoolers, and adolescents remains important for their meeting their maximum growth potential, muscle mass, cognitive function and school performance, activity level and immune function [5].

Most growth stunting occurs during the first 2 years of life, the recognition of which has caused increased attention to the ‘first thousand days’ (i.e. nutrition during pregnancy and the first 2 years postpartum) as a critical period for improving child nutrition.
Feeding during the First 6 Months of Life

The World Health Organization and other public health agencies recommend that infants be exclusively breastfed for the first 6 months of life [6], with breastfeeding initiated within the first hour of birth. While global awareness of the importance of breastfeeding has improved, unfortunately breastfed infants are often given other liquids and foods during the first 6 months of lactation. Exclusive breastfeeding is relatively uncommon; only 36% of infants from 46 developing countries are breastfed exclusively (table 1) [7]. The problem with feeding other liquids and foods during this period of life is that they usually have a lower density of energy and other nutrients than breast milk, and can be contaminated with bacteria. Breastfeeding is especially important during periods of illness because the infant will usually continue to consume breast milk when it rejects other foods.

To ensure optimal nutrient concentrations in breast milk, the mother needs to be well-nourished during lactation, and probably during pregnancy as well, since this will enable her to begin lactation with good nutrient stores. The nutrients in breast milk most affected by low maternal intakes or status include all of the B vitamins, iodine, selenium, vitamin A, and vitamin D [8, 9]. Concentrations in milk have been reported to be as low as 6% (for iodine in regions of endemic iodine deficiency) and for many micronutrients, levels are usually about half of those in well-nourished women [9]. Where women’s diets are lacking in these micronutrients, supplements need to be provided to the mother. To date, there has been no systematic analysis of the optimal amount of supplemental micronutrients needed to raise the concentration in milk of women consuming poor-quality diets to that of well-nourished women, but supplying at least the recommended daily intake would be a reasonable strategy.

Table 1. Problems encountered with child feeding in developing countries [7]

<table>
<thead>
<tr>
<th>Problem</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 50% are put to the breast within 1 h of birth</td>
<td></td>
</tr>
<tr>
<td>Only 36% are exclusively breastfed through age 6 months</td>
<td></td>
</tr>
<tr>
<td>Less than one third have met the minimum dietary diversity</td>
<td></td>
</tr>
<tr>
<td>Only 50% are fed the minimum number of meals</td>
<td></td>
</tr>
<tr>
<td>Coverage of interventions is generally low</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Nutrients that should be supplied by complementary foods [12]

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>35</td>
</tr>
<tr>
<td>Folate</td>
<td>5</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>10–30</td>
</tr>
<tr>
<td>Zinc</td>
<td>40</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>55</td>
</tr>
<tr>
<td>Calcium</td>
<td>60</td>
</tr>
<tr>
<td>Thiamin</td>
<td>70</td>
</tr>
<tr>
<td>Niacin (vitamin B3)</td>
<td>85</td>
</tr>
<tr>
<td>Vitamin B6</td>
<td>85</td>
</tr>
<tr>
<td>Iron</td>
<td>95</td>
</tr>
</tbody>
</table>

Complementary Feeding

Breastfeeding should continue until at least 24 months of age, but complementary foods should be introduced around age 6 months. These foods should be nutrient-dense due to the high nutrient requirements but small gastric capacity of young infants and children. They should be provided with sufficient frequency and correct consistency. It is important that the caretaker practices responsive feeding, i.e. is sensitive to cues indicating satiety and hunger, and uses appropriate techniques to encourage eating [10]. The degree of engagement in responsive feeding varies greatly across cultural settings, so caretaker education can improve infant feeding practices in many situations [11]. Introducing complementary foods before the age of 6 months does not improve growth and carries increased risk of microbiological infections and inadequate nutrient intakes.

Introducing complementary foods before the age of 6 months does not improve growth, and carries increased risk of microbiological infections and inadequate nutrient intakes.

After age 6 months, breast milk cannot provide the rapidly growing infant with sufficient amounts of some micronutrients, especially iron and zinc [6]. This is especially true for infants born with low birth weight or preterm, as their nutrient stores (including iron) will be lower from the time of birth. From around 9 months to 2 years of age, complementary foods must supply approxi-
mately the following percentages of the nutrients required by infants: protein 35, folate 5, vitamin A 10–30, zinc 40, riboflavin 55, calcium 60, thiamin 70, niacin and vitamin B6 85, and iron 95 [12] (table 2). For children with an average breast milk intake, complementary foods should provide daily an additional 200 kcal at 6–8 months of age, 300 kcal at 9–11 months, and 550 kcal at 12–23 months [12]. This requires feeding complementary food 2–3 times daily at age 6–8 months and 3–4 times after age 9 months, in addition to 1 or 2 snacks.

Examples of the type of foods provided between ages 9 and 11 months in Nepal and Tanzania are shown in fig. 1. Typically, as in these examples, the main complementary food in most developing countries is a porridge based on maize, rice, sorghum, millet or wheat. During cooking, such porridges become very gelatinous, so it is necessary to add a substantial amount of water to make the gruel edible for the child. This means that the nutrient density is often too low; energy content is often <0.5 kcal/g and the intakes of all other nutrients will be inadequate. The addition of fat can increase energy density and provide essential fatty acids if it is the right kind of oil (e.g. soy or canola), but adding too much fat results in lower food intake and a low density of other nutrients. Micronutrient-rich fruits and vegetables need to be added but often are not. However, without the addition of ASF it is not possible to meet the micronutrient needs of the child.

In a review of how well complementary foods meet the nutrient requirements of young children in developing countries, Brown et al. [13] calculated the nutrient intakes of children aged 6–11 months in Guatemala, Bangladesh, and Malawi. Families were generally able to prepare complementary foods with sufficient energy density and feeding frequency such that infants’ energy requirements were met, but in one third of families this was not achieved – often due to use of watery gruels and soups. Nevertheless, intakes of fat and protein were mostly adequate. In contrast, the intake of many micronutrients was inadequate to meet recommended intakes, notably B vitamins, calcium if the diet did not contain milk, iron, zinc, and in Bangladesh, vitamin A.

Such diets explain the high prevalence of micronutrient deficiencies in preschoolers in developing countries; around 50% have anemia, half of which is attributed to iron deficiency; one third are deficient in vitamin A, and 5–79% may be deficient in zinc based on estimates of absorbable dietary zinc and growth stunting. Vitamin B12 deficiency is also very common in infants and young children consuming diets low in ASF [14].

In countries such as the United States, infants and young children obtain most of their nutrients from breast milk and/or infant formulas, followed by cow’s milk and fruit juices and fruit-flavored drinks [15]. Nutrient intakes are adequate for most except for a ‘small but important’ proportion of infants with low iron and zinc intakes. Fortified cereals and other fortified foods provide a substantial proportion of micronutrient requirements, especially vitamin A, folate, and iron. In fact, some concern has been voiced that there is an overreliance on fortified foods and some risk of excessive intakes of preformed iron, zinc, sodium, and folic acid, such that caretakers should be advised instead to provide a wide range of fruits, vegetables, and whole grains, good food sources of iron and fiber, and healthier sources of fat [15]. Overweight and obesity among children are becoming a major concern, and the diets of many exceed dietary guidelines for fat, cholesterol, added sugar, saturated fatty acids, and sodium, and are low in fiber [16]. The Nutrition Transition – the change from undernutrition to overnutrition – is happening in most countries in the world and the trend to children’s higher intakes of sugar, salt, and saturated fat is occurring even in poor populations [17].

**Animal Source Foods**

Where resources are limited, a higher proportion of dietary energy is consumed as low-cost cereals (e.g. rice, maize, wheat, sorghum) or root crops such as cassava. To these staples caretakers typically next add vegetables and legumes to the household meals, when affordable or
available in season, to increase dietary diversity. Then, when resources permit, smaller amounts of ASF are added. ASF are often unavailable due to factors such as cost which prohibits purchase by the household, and lack of refrigeration. In some populations, ASF are avoided for religious and/or cultural reasons. Unfortunately, the main factor determining dietary quality in most low-income populations is the proportion of daily energy intake that is consumed as ASF. This proportion varies from <5% in sub-Saharan Africa to 5–10% in other African countries and south Asia, 10–15% in eastern and north Asia, >20% in wealthier regions, and >30% in the United States. Specific examples show the percent of ASF energy consumed by toddlers as 1% for Bangladesh [Yakes, unpubl. data], 8% for Kenya [18], and 11% for Cambodia [19].

Compared to plant-based diets, ASF contain more preformed vitamin A (retinol), vitamins D and E, riboflavin, calcium, and iron and zinc in forms that are better absorbed from the diet [18, 21]. They are the only natural food source of vitamin B12, so in recent years it has become apparent that this vitamin deficiency is highly prevalent in population groups that consume low amounts of ASF, at all ages including infants and children [14]. Meat and dairy products differ in their content of micronutrients, with meat supplying more well-absorbed heme iron and zinc, and milk supplying more calcium, B12, riboflavin, and folate but little iron [18, 21].

A diverse diet, with foods from all food groups, is necessary for population groups to meet their requirements for essential nutrients. Increasing dietary diversity is a specific recommendation for children 6 months to 2 years of age [10]. Dietary diversity (Table 3) is a significant predictor of growth, as illustrated by an analysis of Demographic and Health Survey data from children aged 6–24 months in 11 countries in Africa and Latin America [22]. This relationship remained significant controlling for differences in children’s age, maternal height, and body mass index, the number of children <5 years in the household, and household health and welfare. Diversity was measured as the frequency of consumption of each food group. Illustrating the range of dietary diversity, a high proportion of children in Mali, Ethiopia, and Malawi consumed only 0–2 food groups on 3 or more days in the previous week, whereas over half of those in Peru and Colombia had consumed between 5 and 7 food groups on at least 3 days in the previous week. Among the food groups studied, milk intake was the strongest predictor of children’s height. This is likely due to the growth-promoting effects of milk (see below), although it is also true that milk was more likely to be consumed by children than other ASF. One caveat about measuring dietary quality as a diversity score is that the amount of food consumed in each category is also important – a very small amount of a high-quality food will have little impact on nutritional status.

The importance of ASF in children’s diets was also revealed by the Nutrition Collaborative Research Support Program (CRSP) conducted in Egypt, Kenya, and Mexico in the 1980s. The objective of the Nutrition CRSP was to determine the dietary causes of growth stunting and other malnutrition-related deficits in child development, pregnancy outcome, and work capacity, which at the time were generally assumed to be food shortage and specifically a lack of dietary energy [23]. However, in the Nutrition CRSP, which was a longitudinal observational study on infants, preschoolers, schoolers, and their mothers and fathers in each country, the investigators reported that energy intakes were usually adequate except in Kenya which suffered a drought and famine during the study. What was also clear was that within and across the countries, children who consumed a higher proportion of energy as ASF were taller, heavier, and had better cognitive and school performance than those with lower intakes. In addition, their birth weight was higher and correlated with the ASF intake of their mothers during pregnancy. Children had consistently better growth and other outcomes in Egypt, followed by Mexico, then Kenya, which corresponded with the Egyptians having the

Table 3. Indicators of dietary diversity in children aged 6–24 months [22]

<table>
<thead>
<tr>
<th>Food group</th>
<th>Percentage consuming 3 or more days in the previous week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starchy staples – grain, roots or tubers</td>
<td>20%</td>
</tr>
<tr>
<td>Legumes and nuts</td>
<td>15%</td>
</tr>
<tr>
<td>Dairy</td>
<td>10%</td>
</tr>
<tr>
<td>Meat, poultry, fish, eggs</td>
<td>5%</td>
</tr>
<tr>
<td>Vitamin A-rich fruits and vegetables</td>
<td>10%</td>
</tr>
<tr>
<td>Other fruits and vegetables</td>
<td>5%</td>
</tr>
<tr>
<td>Foods made with oil, butter or other fat</td>
<td>10%</td>
</tr>
</tbody>
</table>

**Compared to plant-based diets, ASF contain more preformed vitamin A (retinol), vitamins D and E, riboflavin, calcium, and iron and zinc in forms that are better absorbed from the diet.**
The importance of milk for childhood nutrition.

In Kenya, a follow-on randomized controlled trial subsequently confirmed the importance of ASF [5]. Based on the observations in the earlier Nutrition CRSP, the trial provided 554 school children with supplements of beef (60–80 g/day), milk (200–250 ml/day), or an equal amount of energy (250 kcal) as oil, added to one meal a day of the local maize, bean, and greens-based meal *githeri*. These meals were fed during the school term (about 6 months a year) for 2 years. A control group received no additional food, but their families were given a goat at the end of the study. Compared to the controls, the supplemental milk increased height gain by 15% in the more stunted children, mid arm muscle area by 50%, and mid upper arm circumference by 40%. Supplemental beef prevented loss in weight-for-height by 50%, and increased mid arm muscle area by 50% and mid upper arm circumference by 80%. The beef supplement significantly increased lean body mass, scores on cognitive tests, and end of term test scores, possibly due to its effects on activity and status of iron or other micronutrients.

The micronutrient status of the Kenyan children at baseline was very poor, reflecting the low consumption of ASF in the population [24]. Around two thirds of children had low serum zinc, 40% had low serum retinol, 30% were riboflavin deficient, and vitamin B12 deficiency was severe in 30% and marginal in 40%. The odds ratio for low serum vitamin B12 (<148 pmol/l) was 6.28 in children consuming the lowest versus highest tertile of ASF at baseline, even though intake of such foods was very low [25]. Only serum folate was normal in almost every child, a situation often found in developing countries. Iron status was uncertain due to the high prevalence of malaria.

Vitamin B12 status showed the greatest improvement, with the prevalence of severe deficiency falling from 20 to 40% in the control and energy-supplemented groups, and to 8 and 5% in the milk- and meat-supplemented children, respectively.

A recent review of the importance of milk in the diets of children concluded that dairy product intake is associated with better linear growth and bone development during childhood, even in wealthier countries with a high usual intake of milk.
amount of protein, which could have potential metabolic advantages. It also allows for a reduced content of soy and cereal and thereby a reduction of potential antinutrients such as phytic acid. It is likely that adding milk could improve weight gain, linear growth, and recovery from malnutrition [28] and this is being tested in ongoing trials. Bioactive factors in whey might have beneficial effects on the immune system and muscle synthesis, but evidence from vulnerable groups is lacking. Milk proteins will improve flavor, which is important for acceptability in vulnerable groups. The most important disadvantage is a considerable increase in price. Adding 10–15% milk powder would double the price, which means that such a product should be used only in well-defined vulnerable groups with special needs.

**Strategies for Improving the Diets of Infants and Young Children**

In addition to receiving one (e.g. high-dose vitamin A supplements which are provided routinely 2 or 3 times a year through 5 years of age in many developing countries, or iron) or more (e.g. multiple micronutrient supplements formulated for children) micronutrients as supplements, the following strategies are used to improve micronutrient intake through foods.

**Increasing Dietary Diversity and the Intake of ASF**

A generally recognized and encouraged approach to filling the nutrient gap for infants and young children is to increase their intake of ASF, fruits, and vegetables. This is, of course, not always feasible due to cost, availability, and cultural constraints. Using a linear programming technique and estimating the micronutrient gaps in the intakes of breastfed infants 6–8 and 9–11 months of age in Bangladesh, Ethiopia, and Vietnam, investigators concluded that unfortified foods could meet nutrient re-

<table>
<thead>
<tr>
<th>Table 4. Indicators for assessing infant and young child feeding practices [37]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early initiation of breastfeeding (within 1 h of birth)</td>
</tr>
<tr>
<td>Exclusive breastfeeding under 6 months</td>
</tr>
<tr>
<td>Continued breastfeeding between 12 and 15 months</td>
</tr>
<tr>
<td>Solid, semi-solid or soft foods received on the previous day, between 6 and 8 months</td>
</tr>
<tr>
<td>Received ≥4 food groups on the previous day, between 6 and 23 months</td>
</tr>
<tr>
<td>Received the minimum number of servings of solid, semi-solid or soft foods on the previous day, between 6 and 23 months; minimum number changes by age across the period</td>
</tr>
<tr>
<td>Consumed iron-rich or iron-fortified foods (commercial or in the home) on the previous day</td>
</tr>
</tbody>
</table>
quirements [31]. However, this would require an unrealistically high intake of liver and a level of intake of other ASF which greatly increased the cost of the diet. Nevertheless, many women do not understand the importance of these foods in the diet of their child and can be educated to include eggs, dairy products or fruits and vegetables in their usual diet. There is currently considerable ongoing research into how to increase the intake of nutrient-dense fruits and vegetables and ASF through improved agricultural practices, and especially those of small-holders.

Infants and young children are too often given sugary snacks or foods, which provide energy but lack other essential nutrients. In Cambodia, Demographic and Health Survey data reveal that around half of the children had consumed a sugary food on the previous day. Snacks supplied 42% of the total energy intake of Cambodian children aged 12–24 months [19], and rice an additional 20%. In KwaZulu-Natal, sugar was consumed by infants aged 6–12 months at least 4 times a week by 50%, savory snacks by 42%, biscuits by 27%, carbonated drinks by 12%, and sweets by 8% [32].

Increasing Micronutrient Intake through Fortified, Processed Complementary Foods

There are many types of fortified commercial complementary foods on the market, worldwide. However, consumption of such fortified ‘baby foods’ is quite low in many poorer populations. From the Demographic and Health Survey for infants aged 9–11 months it is estimated that these are consumed by 3–4% in Cambodia and Malawi, 5–6% in Tanzania and Burkina Faso, and 12–15% in Nepal and Senegal [Huffman, in preparation]. The nutrient content and quality of these foods can vary widely depending on the manufacturer and the price of the food, and there is concern that marketing strategies may encourage their use at too early an age and/or that they may displace breast milk. Not surprisingly, they are perceived as convenient by caretakers [33].

Increasing Micronutrient Intake through Micronutrient Supplements

Home-prepared foods for infants and children can be fortified by the caretaker using specially formulated micronutrient powders [34] or supplements delivered by programs or purchased by the household. Lipid-based nutrient supplements (LNS) are a relatively new approach for delivering multiple micronutrients. These supplements usually have a peanut base (although other nuts can be used), with added sugar and dry milk, and are high in lipid (energy) and essential fatty acids. They can be consumed as such but are often mixed into complementary foods. The composition and dose can be varied so the products are suitable for young infants as well as pregnant and lactating women. LNS were developed initially as a source of energy and other nutrients for treating severely malnourished children [35]. Now, interest has increased in their use to prevent micronutrient deficiencies, growth stunting, and associated developmental delays in young children [36]. Several trials are underway to compare the efficacy of LNS versus micronutrients alone delivered in tablet or powdered form.

Summary Measures to Assess Infant and Young Child Feeding Status

Knowledge of the most important dietary influences on the nutritional status of the infant and young child, described above, has enabled the development of indicators of the success of infant and young child feeding (table 4) [37]. While these are intended for evaluation of success in population groups, they can also be useful for clinicians assessing individual mother-child dyads.

Disclosure Statement

The author currently receives funding from the Bill and Melinda Gates Foundation as an investigator in studies of the efficacy of LNS. In the past, she has been funded by the Small Livestock CRSP (USAID) to evaluate the effects of ASF on nutritional status.

References


24 Siekmann JH, Allen LH, Bwibo NO, Demment MW, Murphy SP, Neumann CG: Kenyan school children have multiple micronutrient deficiencies, but increased plasma vitamin B-12 is the only detectable micronutrient response to meat or milk supplementation. J Nutr 2003;133:3972S–3980S.


