Nutritional Solutions to Major Public Health Problems of Preschool Children: How to Optimise Growth and Development

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Significant opportunities to improve child health globally were provided in the second half of the 20th century. However, malnutrition remains a major problem and in many countries the situation seems to have worsened (1). In a recent report about survival rate in childhood (2), UNICEF remained that the United Nation’s first Millennium Goal, was to eradicate extreme poverty and to reduce the proportion of people who suffer from hunger by half between 1990 and 2015, as measured by the percentage of children under five years of age who are underweight. The first Millennium Goal of the United Nations is to eradicate extreme poverty and to reduce the proportion of people who suffer from hunger by half between 1990 and 2015, as measured by the percentage of children under 5 y old who are underweight.

It is estimated that 146 million children under age 5 y are underweight. It was reported that undernutrition accounts for almost half of the deaths of children under 5 (3). Worldwide more than half of the underweight children reside in south Asia, primarily in India, Bangladesh and Pakistan. Similarly, the prevalence of childhood undernutrition in sub-Saharan Africa has not changed appreciably since 1990 but, with population growth, the number of underweight children has increased. Moreover, the situation has worsened during the last 20 y, especially in sub-Saharan Africa and South Asia concomitantly with the onset of HIV/AIDS (4,5). Indeed, through worsening malnutrition, this burden of disease contributes to reversal of gains made by child survival programs. Based on the same developments, it seems unlikely that the nutrition component of the UN’s first Millennium Goal will be achieved by 2015.

The main problem is not necessarily a shortage of food. Micronutrient deficiencies, poor sanitation, infectious diseases, lack of exclusive breast-feeding and marginalization of females within society are also emerging as key issues. Many types of nutritional deficiencies have been shown to be detrimental to child development. Most of the existing information pertains to the possible effects of low birth weight, inadequate breast-feeding, stunting and wasting, short-term food deprivation, and micronutrient deficiencies. It is well established that deficiencies of micronutrients, such as vitamin A, increase the risk of childhood infections and subsequent mortality (6). Nutritional interventions have a major impact, as emphasized by both Allen and Bhutta in their articles in this supplement to the *Journal of Pediatric Gastroenterology and Nutrition*. Child nutrition programs involving vitamin A supplementation are recognized as important public health interventions among young children in areas of endemic vitamin A deficiency. Other deficiencies of micronutrients such as zinc and iron are also being recognized as widespread in developing countries and associated with increased risk of morbidity and mortality. The impact of infections on micronutrient status and their subsequent impact on health outcomes have also been established. Increased losses of micronutrients such as vitamin A and zinc during infectious illnesses, especially diarrhoea, are important contributors to micronutrient deficiencies. The role of zinc supplementation in accelerating recovery from diarrhoeal diseases in developing countries supports its use in endemic areas from the viewpoint of public health strategies (7). Furthermore, vitamin C and zinc reduce the incidence and improve the outcome of pneumonia and malaria, especially in children in developing countries (8).

It is clear that nutritional solutions for preschool children remain a challenge for the third millennium. It is well established that inappropriate feeding and infections are the main causes of protein-energy malnutrition, which contributes to morbidity and mortality in preschool children. As mentioned previously, nutritional

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interventions may improve infant and young child nutrition and health. This is central to human well-being and as such contributes to both economic development and poverty reduction. However, current circumstances reveal a nutritional paradox. As reported by Uauy and coworkers in Latin America and emphasized by Zlotkin in this issue, overweight and obesity are increasing rapidly in more developed areas of the world. The current system of sharing world resources has resulted in a paradigm in which the number of obese and overweight children actually surpasses the number of undernourished children globally. Improving weight gain is thus insufficient to promote child health (9). Thus, underweight, obesity and iron deficiency may coexist in the same country and even in the same household at the same time.

Nutritional rehabilitation and prevention may be achieved by carefully assessing the situation associated with an integrated combination of improved dietary intake, supplementation, commercial and home-based fortification of complementary foods. As emphasized by Mannar, several developing as well as developed countries have implemented with sustained impact successful approaches to eliminate protein-energy malnutrition and micronutrient deficiencies for nutrients including iron, iodine, selenium, zinc and vitamin A. These include provision of oral supplements in capsule, tablet or syrup form as well as fortified complementary foods provided through public feeding programs and commercially marketed foods. Mannar stresses that government commitment, clear policy and program direction, advocacy and communication combined with a strong public–private partnership are essential for successful programs to improve the health and well-being of millions of children around the world.

Importantly, during the last 3 decades the links between infant nutrition and health in adulthood have been established. Clinical and experimental data have provided evidence that the concentrations of hormones, metabolites and neurotransmitters during critical phases of early human development may have detrimental effects on brain development and metabolic processes and may cause diseases in subsequent adulthood. This phenomenon is recognized today as programming or metabolic imprinting. Interactions between the genetic background of the individuals and environmental influences during infancy and early childhood are supported by numerous experimental data (10). There is now evidence in humans that programming is 1 of the most important risk factors for obesity and cardiovascular disease (11). Barker and coworkers provided strong epidemiological evidence for a link between the quality of foetal growth as assessed by anthropometric measures at birth and morbidity and mortality during adulthood, especially in terms of high blood pressure and cardiovascular disease (12,13). In addition, Barker et al. provided evidence for a strong link between the rate of postnatal catch-up growth and the onset of metabolic and cardiovascular diseases in adulthood (14).

Establishing the links between nutrition and brain development is challenging. However, there is increasing evidence that protein-energy malnutrition has deleterious effects on learning and cognition (15). Many studies have suggested or even demonstrated that these effects are dependent not only upon the type of nutrients involved (eg, iron, iodine, selenium, zinc, vitamin A, essential fatty acids) but also upon the specific periods of development including prenatal life, infancy, school age and aging. The postinfancy or preschool age is a period in which a number of nutritional deficiencies have been shown to interfere with normal development and cognition (16). The most commonly studied deficiencies in children with protein-energy malnutrition are iodine, iron and essential fatty acids deficiencies. Yehuda and coworkers provide in this issue a short review that aims to examine the limited studies that have been performed on children of this age and offer a broader view on this topic. Finally, previous experience as well as more recent knowledge establishes the link between early nutrition and health, not only in childhood but also in adulthood. Nutrition during pregnancy as well as feeding during infancy and young childhood remain crucial issues for humanity, whether in developing or developed countries.

Assessing the nutritional status of populations, improving research and knowledge in the field of nutrition and increasing food resources by developing agriculture and economies exist as the challenges of this century and beyond. Globally malnutrition, whether intrauterine growth retardation, vitamin or micronutrient deficiency, inappropriate protein and/or energy supply, persist as significant causes of disability, with young children the worst affected.

As emphasized by Darnton-Hill in this supplement, improved health and nutrition will lead to enhanced economic development, but having a poverty focus appears to be essential if poor people are not to be marginalized further. The HIV/AIDS pandemic illustrates this challenge clearly. The role of education, especially girls’ education, in improved health and nutrition status of children and in birth spacing, is now clear, as is improving women’s status. Increases in female status and education have been estimated to account for half of the reduction in child malnutrition rates during the past 25 y.

Thus, it was logical to devote a symposium to how to adequately feed preschool-age children and to overcome the double burden of malnutrition: undernutrition and obesity. This supplement of the Journal of Pediatric Gastroenterology and Nutrition reports the proceedings of the 2005 symposium on nutritional solutions to major public health problems of preschool children, organized by Danone Institute International in Durban, South Africa, on the occasion of the 18th International Congress
of Nutrition. This collection of presented papers offers a unique opportunity to report the outstanding work of well-known international experts in the field. It is critical to promote the right of all of the world’s children to achieve their full genetic growth potential and to guard against the side effects of an inadequate nutritional supply, whether caused by under- or overnutrition.

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Nutritional Solutions to Major Health Problems of Preschool Children: How to Optimise Growth and Development

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ABSTRACT

Despite major economic development in the last few decades, childhood nutrition remains a great challenge for the human species. A combination of undernutrition, overnutrition, and poor dietary quality affect to a variable extent all of the world’s populations, and are often combined in the same areas and even in the same families. Malnutrition is part of the life of many individuals since conception and is transmitted by 1 generation to the next. Countries with lower income per capita and poor socioeconomic strata are mainly affected and, in turn, malnutrition hampers their development. The eradication of child malnutrition is crucial in the fight against poverty. This article examines whether this goal will be achieved within the time frame the United Nations has set. JPGN 43:S4–S7, 2006.

Key Words: Childhood malnutrition—Childhood obesity—Iron deficiency—Essential fatty acid deficiency—Vitamin A.

INTRODUCTION

The first United Nations Millennium Development Goal (MDG), set in 2000, is to “eradicate extreme hunger and poverty” (1). To achieve this goal, the target is to halve both the number of people suffering from hunger and those whose income is less than $1/d by 2015. This article focuses on why the eradication of child malnutrition is so crucial in the fight against poverty and discusses whether this goal will be achieved within the time frame the United Nations has set.

In some regions of the world, such as Asia, great strides have been made to alleviate hunger, but the difficulties in other regions make the MDGs for nutrition look unachievable (2). Poor nutrition in childhood fuels the poverty cycle, in which underachievement, reduced opportunities, and greater morbidity and mortality ensue for that and subsequent generations.

In recent years overnutrition has resulted in a huge increase in the numbers of children who are overweight or obese. This will become a considerable health burden to many countries because the problem is of epidemic proportions and runs alongside the age-old issue of undernutrition. In some low-to-middle income countries both ends of the nutritional spectrum are found (3,4).

A major challenge that still is unrecognised is the one referred to as hidden hunger, generated by poor dietary quality and involving inadequate micronutrient intake. Implementing appropriate intervention strategies for specific populations is the only way in which the MDGs have any chance of being achieved.

UNDERNUTRITION

Undernutrition remains a huge cause of mortality for children throughout the world, with approximately 10 million children dying before the age of 5 years. Although global childhood mortality declined from 147 deaths per 1000 live births in 1970 to 80 deaths in 2002, improvements are not universal. In some regions, especially in sub-Saharan Africa, childhood mortality has not decreased, and 14 African countries have child mortality rates that are higher now than in 1990 (5). HIV/AIDS has also had a significant impact in this region.

Low Birth Weight

An estimated 1 in 6 infants is born with a low birth weight; that is, less than 2500 g (6). Worldwide, >20 million babies are born with low birth weight, around 95% of them in developing countries. Even this is an underestimate because many babies born at home or with traditional birth attendants are not weighed at all. The problem arises because they either have been born too

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early, have experienced growth restriction, or both. The health and nutrition of the mother significantly influence these factors. A low birth weight predisposes an infant to a wide range of other risk factors including developing and dying from diarrhoea or infectious diseases. Continued malnutrition and underweight can also lead to decreased cognitive development (7) with a significant impact on productivity in adulthood, and an increased risk of wasting or stunted growth (8).

In affluent societies, low birth weight is known to be a significant risk factor for other health outcomes in later life. These outcomes include coronary heart disease, stroke, type 2 diabetes mellitus, and the metabolic syndrome. Their impact cannot be discounted in developing countries, where early deprivation may predispose a child so that subsequent "overnutrition" may have a significant effect on morbidity and mortality rates (9). Actions, including better maternal nutrition, breast-feeding and improved complementary feeding, to ensure optimal fetal development to reduce the immediate health impact and the future increased chronic disease risk are therefore warranted.

**Stunting**

The first MDG target, halving the number of people suffering from hunger, uses the prevalence of underweight in children under 5 years old as a key indicator. Underweight measures chronic malnutrition (low height for age or stunting) as well as acute malnutrition (low weight for age or wasting), but the contribution of stunting to underweight is greater than that of wasting.

Stunting is generally declining worldwide. The World Health Organization (10) reported that between 1990 and 2000, the global prevalence of stunting in children fell from 34% to 29%. However, in eastern Africa, the number of children with stunting increased in this period from 40 million to 45 million. Stunting is defined by the World Health Organization as 2 standard deviations below the z scores for height and for age. Children who are underweight or stunted in growth may not show catch-up growth in later childhood and thus carry the risk of continuing poor health into adult life (11). In some countries, for example, South Africa, children who are growth stunted coexist with those who are overweight or obese (12). This of course has complex implications for policymakers.

**Wasting**

Children who have low weight for age (wasted) are at increased risk of dying from pneumonia, measles, malaria or diarrhoea (13). Throughout the world the numbers of underweight children are decreasing and it is thought this global decline will continue until 2015, the date by which the MDGs should have been achieved. However, it is unlikely that the goals will universally be met. The great improvements are mainly due to the formidable economic and social changes in Southeast Asia, whereas in other parts of the world, such as sub-Saharan Africa, the prevalence of underweight in children under age 5 years is forecast to increase from 24% to 26.8%. In this region, HIV/AIDS has had a huge impact on the population, and continues to affect the health and development of infants and children (2).

**OVERNUTRITION**

For an increasing number of children, overweight and obesity have become the health issue of their generation. Even in countries that have traditionally been associated with good dietary health, such as the Mediterranean countries of southern Europe, obesity is commonplace in children (14). Italy, for example, has an estimated 35% of primary-school children (7–11 y) with a body mass index >25. Overnutrition is also found in populations that may also have malnutrition, and it is often the poor and disadvantaged sectors of the population who suffer (15).

Global estimates of overweight suggest that some 20 million children and 1 billion adults are overweight. Chronic noncommunicable diseases such as heart disease, cancer, stroke and diabetes account for 60% of global deaths and 47% of the burden of disease. The incidence of noncommunicable diseases is expected to grow as many low to middle income countries start to exhibit the diseases formerly associated with more affluent countries.

The International Obesity Task Force has shown an increasing incidence of childhood obesity in the last decade, and it is expected to continue to rise dramatically over the next several decades unless serious action is undertaken to reduce the environmental pressure to avoid energy overconsumption and sedentary lifestyles (16).

As with malnutrition, the obesity epidemic is multi-dimensional. The high availability of low-cost, high-energy content foods and drinks, with ever-expanding portion sizes available in fast food outlets promoted by heavy marketing is 1 of the main determinants (17). The increased amount of leisure time spent in sedentary activities such as television viewing and playing electronic games (18), with a corresponding reduction of physical activity in schools and transportation policies encouraging sedentary behaviour is another determinant (19). A link between the decline in breast-feeding and a concomitant rise in childhood overweight has also been demonstrated (20).

**HIDDEN HUNGER**

Malnutrition is not just about insufficient energy intake. In many parts of the world, inadequate dietary iron, zinc, iodine and vitamin A cause significant ill
health that affects generation after generation. Malnutrition of the child feeds into an insidious vicious cycle of poor health and poor outcomes throughout life. Poor childhood nutrition does not equip women for pregnancy and birth; a malnourished mother with low stores of micronutrients gives birth to children who continue in the same cycle. Elderly people are more susceptible to infections and less able to take care of young children. The cycle of malnutrition therefore continues from 1 generation to the next. Interventions are needed not only for children but also for the mothers. There is no doubt that improving maternal nutrition can improve the birth outcomes and the subsequent growth of the offspring.

Iron

Iron deficiency is a less obvious form of malnutrition than protein energy malnutrition but it permeates all aspects of child health in developing countries. Iron-deficiency anaemia affects the growth, cognition, motor development and social development of children, resulting in reduced school performance and lowered productivity. In conjunction with serious infection, it also can bring about irreversible and lifelong consequences, diminishing the potential of the child. Iron-deficiency anaemia is an extremely common condition, especially in Africa where the incidence is as high as 80% of children under 5 years (21), closely followed by India and other countries in southern and Southeast Asia.

Iodine

Iodine deficiency remains a significant problem in those parts of the globe with low water levels of iodine. The consequences of this deficiency particularly affect pregnant women and their offspring with increased risk of perinatal mortality and the mental retardation of the child (22). In areas where iodine deficiency is endemic it is estimated that up to 15% of the population can suffer from cretinism (23). South central Asia has a high prevalence of iodine deficiency, with 104 million schoolchildren having insufficient iodine. Iodine deficiency is often combined with iron deficiency, thus creating a long-term threat to neurodevelopment, as in the case of Tajikistan (24).

Vitamin A

Vitamin A deficiency is one of the most common deficiency syndromes in children in developing countries (25). Deficiency leads to reduced immunity, with the resultant increased severity and complications of infections. There can be growth faltering and poor development, and the breakdown of epithelial cells in the respiratory and digestive tract. Because vitamin A is also essential for good vision, deficiency leads to poor night vision, xerophthalmia and ultimately to blindness.

Cost of Micronutrient Malnutrition

Interventions to reduce micronutrient deficiency can have a significant effect on subsequent generations and improve the economic performance of segments of the population. Studies in China have clearly shown the economic impact of interventions to reduce iron and iodine deficiency and decrease stunting (27). It has been estimated that the increase in productivity due to a 30% reduction in iron-deficiency anaemia over 10 years would be worth 107 billion yen. If childhood anemia was also reduced by 30% during the same time period, the economic gain would be as much as 348 billion yen, considerably less than the cost of any intervention.

CONCLUSIONS

Despite major economic development in recent decades, childhood nutrition remains a great challenge for the human species. A combination of undernutrition, overnutrition and poor dietary quality affect to a variable extent all of the world’s populations, often combined in the same areas and even in the same families. Malnutrition often accompanies the life of individuals from conception and is transmitted by 1 generation to the next. Countries with lower income per capita and poor socioeconomic strata are mainly affected and, in turn, malnutrition hampers their development.

As shown by some success stories, general interventions to reduce poverty and improve livelihoods are necessary, but often not sufficient to improve nutritional status. Specific nutrition actions are therefore also needed. These must start from conception and early infancy.

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Causes of Nutrition-related Public Health Problems of Preschool Children: Available Diet
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ABSTRACT
The primary goal of this review is to examine the timing and nature of dietary inadequacy during the first 5 years of life. An important issue is that many children in developing countries are already nutritionally depleted by the end of the first year of life, because maternal undernutrition can cause low fetal accumulation of nutrient stores and secretion of inadequate amounts of some micronutrients in breast milk. Improvement of maternal diet and micronutrient status is required to remedy this situation. During the period of complementary feeding, most households may be able to provide their young children with sufficient energy and protein from home-produced complementary foods, but many do not feed foods with an adequate energy density or a sufficient number of meals per day. Inadequate micronutrient intakes and resulting deficiencies are common in preschoolers because of a lack of sufficient animal source foods, and have been associated with delayed child development. Dietary diversity is an especially important determinant of micronutrient intakes when animal source food intake is low. Interventions with animal source foods have produced improvements in growth, micronutrient status, cognitive performance and activity of children. Although much is now known about the role of inadequate diets in preschooler malnutrition, on a global scale the ability of households to apply this knowledge to improve the diets of their children is still limited. JPN 43:S8–S12, 2006. Key Words: Preschoolers—Malnutrition—Diet—Micronutrients. © 2006 Lippincott Williams & Wilkins

INTRODUCTION
Among the several causes of preschooler malnutrition discussed in this symposium, consumption of an inadequate diet obviously is a primary causal factor. In this review we summarize current knowledge about lack of an adequate diet during specific stages of early childhood development, and the relative importance of macronutrient intake versus dietary quality (dietary diversity and the consumption of animal source foods [ASF]). Although this review addresses the diet of preschoolers (2–5 y), data were often lacking from this age group so that some information was used from younger and older children.

An “adequate diet” for children is one that contains an appropriate density of nutrients, is sufficiently diverse that it supplies adequate but not excessive amounts of nutrients, is palatable and culturally acceptable, affordable and available year-round and overall supports normal growth and development.

IMPORTANCE OF NUTRITIONAL DEPLETION ON ENTRY TO THE PRESCHOOL PERIOD
When discussing the needs of preschoolers, it is important to recognize that a high proportion of children in developing countries are already nutritionally depleted when they enter this phase of life. Many are born low birth weight or preterm, which results in their nutrient (eg, iron) stores at birth being relatively depleted (1). Poor maternal micronutrient status during pregnancy almost certainly contributes to lower infant nutrient deposition in utero, for example, for iron (2) and vitamin B12 (3,4). These mothers are likely to continue to be at high risk for micronutrient deficiencies during lactation, a time when nutrient requirements of the mother are even higher due to the secretion of nutrients in breast milk. This means that the concentrations of some nutrients in the breast milk will be lower than normal, especially B vitamins (except for folate), vitamin A, iodine and selenium, which puts the breast-feeding infant and child at risk for these micronutrient deficiencies (5). Thus, infants may often be subjected to in utero depletion and/or low breast milk concentrations of nutrients, leading to nutritional deficiency during the first 6 to 12 months of life (5). For example, we have reported that 49% of...
lactating mothers in Guatemala City and 68% of their breast-feeding infants have low or deficient plasma vitamin B\textsubscript{12} concentrations at 12 months of age (6). The fact that infant nutritional depletion can occur in breast-fed infants in no way contraindicates the recommendation for exclusive breast-feeding during the first 6 months of life, but rather indicates the need to improve maternal micronutrient status during pregnancy and lactation. Even the breast milk of well-nourished women does not contain sufficient iron and zinc to meet an infant’s requirements after the first 6 months of life; so that after this age additional intake from micronutrient-rich or -fortified complementary foods or supplements is required (5). However, commonly breast-feeding ends too early and breast milk is substituted by complementary foods of inadequate quality.

**PERIOD OF COMPLEMENTARY FEEDING**

During the transition from breast-feeding to complementary feeding, breast-feeding should be continued while gradually adding complementary foods. Because the intake of breast milk falls with age, it is evident that the amount and percent of nutrients required from complementary foods increase with age. By 9 to 11 months old, the average breast-fed baby in low-income countries needs to obtain about 50% to 90% of its vitamin and mineral requirements from complementary foods (7). The energy intake of the child depends on the number and energy density of meals. It has been estimated that at 1 to 2 years old, assuming the average amount of breast milk that is consumed at this age in low-income countries, if two complementary feeds are given daily, then the energy density of the meals needs to be at least 1.5 kcal/g; for 3 meals per day it needs to be 1.0 kcal/g and for 4 meals, 0.74 kcal/g (8). Children more than 8 months old probably need about 3 meals per day.

To evaluate how well nutrient requirements are met by complementary feeding in developing countries, food intake data were analyzed from Guatemala City, Bangladesh and Malawi (8). The analysis revealed that families can prepare complementary foods that have an adequate energy density, and can feed them often enough to meet their childrens’ energy needs, but about one third of the children in the different countries were given meals with insufficient energy density for the number of meals provided. Moreover, the amounts of food consumed by the children were much less than their gastric capacity.

Intakes of energy (when expressed per kilogram of body weight), protein and fat were adequate. However, the intake of many micronutrients was inadequate, especially the B vitamins, iron, zinc, calcium (if dairy product intake is low), and vitamin A (in Bangladesh). In fact, the authors concluded that it would be difficult for these children to meet their recommended micronutrient intakes from food, and iron and zinc needs would be met only if large amounts of liver were to be included in the diet. If the amount recommended by the World Health Organization (1 rounded tablespoon per day) were to be consumed routinely, however, vitamin A intakes would be 20 times greater than recommended. An additional problem is that the per-capita amounts of meat, liver and egg available in Guatemala, Bangladesh and Malawi were estimated to be less than the amounts required to meet the iron requirements of infants ages 6 to 11 months, pointing to the need for young children to receive iron-fortified foods or iron supplements.

**ADEQUACY OF ENERGY INTAKE**

In places with food shortages, there is clearly a risk of inadequate energy intake and low weight-for-height (wasting). Usually the adequacy of energy intake per se is difficult to determine because a low intake of many other nutrients will occur if food intake is inadequate. Interpretation of energy intervention trials is also often difficult because supplemental energy can displace the usual diet. Using a more sophisticated experimental design, Krahenbuhl et al. compared the effects of a high-fat versus a high-carbohydrate energy supplement against a nonintervention placebo group in rural Gambian children with stunting (9). The supplemented children, ages 68 ± 21 months, were provided with a high-fat or a high-carbohydrate biscuit for 12 months. They were moderately stunted and wasted at the start of the intervention. Their usual diet was low in fat (17% of energy) but adequate in protein (11%). Energy intake was only 80% of that recommended, but adequate on a per kilogram body weight basis. The high-fat biscuit increased energy intake by 1551 kJ (378 kcal), and the high-carbohydrate biscuit increased energy intake by 1659 kJ (404 kcal). In spite of these substantial increases in energy intake, the supplements had no effect on growth in length or weight or on resting metabolic rate. The high-fat biscuit produced a small increase in fatness. Interestingly, weight gain during the 3-month harvest season was about 3 to 10 times as much as it was during the other seasons, perhaps indicating the importance of the other nutrients in food.

**DIETARY DIVERSITY**

Dietary diversity can be defined as the number of foods or food groups consumed in a defined period, such as 1 day or 1 week. Using Demographic and Health Survey data from 11 countries, Arimond and Ruel compared the prevalence of stunting to diet diversity in children ages 6 to 23 months (10). Dietary diversity was a 7-point score based on the number of groups of nutritionally important foods/food groups that the child had consumed on ≥3 days in the previous week; starchy staples, legumes, dairy products, other ASF, vitamin A–rich fruits and
vegetables, other fruits and vegetables, and foods made with oil, fat or butter. After adjusting for the age of the child, maternal height and body mass index, the number of children in the household <5 years old and 2 health and welfare factor scores, there remained a significant correlation between dietary diversity and the prevalence of stunting in all but 1 of the countries.

IMPORTANCE OF ASF

In most developing countries, the intake of ASF is too low to provide the population with sufficient amounts of nutrients such as vitamin B₁₂, bioavailable iron and zinc, riboflavin and calcium. For example, ASF provide <5% of total dietary energy in many sub-Saharan countries, 5% to 10% in most other African countries and southern Asia, 10% to 15% in most of eastern and northern Asia, and >20% in wealthier regions such as the United States and Europe.

The ASF intake of preschoolers tends to parallel the general availability of milk, eggs and meat for the population. About 10 years ago, a multicountry study of preschoolers 18 to 30 months old in Egypt, Mexico and Kenya showed that children in all 3 countries consumed about 66 kcal/d in dairy products, but that meat plus egg intake provided 85 kcal/d in Egypt, 60 kcal/d in Mexico and only 6 kcal/d in Kenya (11). These low intakes of ASF were accompanied by low intakes of vitamins (12) and minerals (13) but not protein (14) and a high prevalence of micronutrient deficiencies.

More recently the investigators in the Kenya project returned to the same location to assess the effects of increasing ASF intake of schoolchildren ages 7 to 12 years in the same communities. The children’s diets had not improved, and they consumed only an average of 12 kcal/d from meat and 52 kcal/d from milk; most of the energy was from maize and beans. Using food intake data from this study, we asked the question whether the intake of specific food groups or the overall diversity of the diets was the strongest predictor of the micronutrient adequacy of the children’s diets (15). The outcome variable was the mean probability that a child would consume his or her estimated adequate requirement for 15 micronutrients. The analyses revealed that the average number of food groups consumed daily was associated with a gradual increase in micronutrient adequacy across the range examined, from 2 to 7 groups per day. However, increasing the number of servings of ASF from 0 to 3/d had only a small impact on micronutrient intake at baseline because the usual intake of ASF was so low, only 17 g/d. When ASF intake was increased to 52 g/d on average by supplements of meat or milk, the incremental benefits of increasing intake from 0 to 3 servings per day was much greater. Thus, it was concluded that ASF certainly improve children’s abilities to meet their micronutrient requirements, but that their impact on micronutrient adequacy of the diet is limited until intake is greater than a minimal amount. Also, it was apparent that increasing dietary diversity is especially important in cases in which the usual intake of ASF is low. It should be noted, however, that even the small amounts of ASF usually consumed by children in developing countries have been reported to make a positive difference to mental and motor function (16,17). The usual intake of ASF by Kenyan preschoolers 18 to 30 months old was the main predictor of their subsequent cognitive scores at age 5 years (18).

INTERVENTIONS WITH ASF

A review of the efficacy of various interventions for improving child growth elicited the following conclusions (19). Energy supplements tend to increase body weight but not length. Protein supplements provide little benefit to improve growth. In contrast, supplements containing dried skim milk as at least 1 component improved the growth of children in 12 of 15 trials. When families of Dutch macrobiotic preschoolers increased their children’s intake of milk or fish, their linear growth improved more than those of the other macrobiotic children (20). In contrast, adding dry fish to complementary foods did not affect the growth of infants ages 6 to 12 months in Ghana (21).

The benefits of adding supplemental meat to Kenyan children’s diets have been tested in a recent study and compared with those of adding milk (22). On a per kilocalorie basis, meat tends to be higher in available iron and zinc and vitamin B₁₂ than does milk, whereas the latter contains more riboflavin, folate and calcium. Details of the study design and results have been provided elsewhere (22,23). Basically, the children, ages 7 to 12 years, were given 1 of 3 types of snacks daily in school while school was in session for 2 years. The 3 isocaloric groups were: an “energy” supplement in the form of 250 kcal as the traditional food githeri, primarily maize and beans, plus oil; a meat supplement (ie, githeri plus 60–80 g of ground beef); or a milk supplement (ie, githeri plus 1 cup of milk). Households in a nonintervention control group received a goat at the end of the study. In general the meat supplement produced greater improvements in cognitive function assessed using Raven’s progressive matrices and arithmetic scores, resulted in the highest levels of physical activity, caused the biggest increase in initiative and leadership behavior, and provided the largest increment in muscle mass (22,24–26). The latter may have been the cause or the result of the greater physical activity. Milk supplementation significantly increased the growth of the shorter children.

Vitamin B₁₂ is found only in ASF and the high global prevalence of this vitamin deficiency is becoming recognized (27,28). At baseline, 69% of the children had a
deficient or marginal plasma cobalamin concentration, and the latter was significantly correlated with the usual total intake of ASF ($r = 0.308$), or of meat, eggs or milk. Children in the lowest tertile of ASF consumption had a 6.3 times greater risk of having a deficient or marginal plasma cobalamin concentration, even though usual intakes of ASF were very low (E. McLean, MD, and colleagues, unpublished data). Both the meat and milk supplements significantly reduced the prevalence of vitamin B$_{12}$ deficiency, with the meat increasing the plasma cobalamin concentration by $\approx 200$ pg/mL and the meat increasing it by $\approx 125$ pg/mL at the end of the study.

In many resource-limited households, it still may be possible to provide young children with larger amounts of ASF than they are receiving. Caregivers often need to be taught about the importance of these foods for the nutrition of children and their mothers. Dairy products or fish may be more affordable than meat in some locations, and cheaper types of meat including concentrated nutrient sources such as liver could be targeted in small amounts. However, energy density of the diet is low and not compensated for by an adequate number of meals. However, energy supplements generally tend to slightly increase weight but not height, even where there is seasonal food shortages. The amount of ASF consumption is a critical determinant of children’s nutritional status (especially vitamin B$_{12}$ status) and development. The development community needs to appreciate the importance of ASF for nutritional status (29) and normal development in low-income countries, especially in the common situation that fortified foods and micronutrient supplements are not sufficiently available. Newer concepts concerning the feasibility and merits of livestock production in developing countries (30) and novel approaches to increasing the availability of ASF for children (31) should receive greater attention if the prevalence of undernutrition in this age group is to be reduced.

CONCLUSIONS

When addressing the role of inadequate diet as a cause of malnutrition in preschool children, it is important to recognize that many children in developing countries will already be nutritionally depleted by the end of the first year of life because of the poor nutritional status of their mothers. During the period of transition to complementary feeding, energy deficiency may occur if food is short or if the energy density of the diet is low and not compensated for by an adequate number of meals. However, energy supplements generally tend to slightly increase weight but not height, even where there is seasonal food shortages. The amount of ASF consumption is a critical determinant of children’s nutritional status (especially vitamin B$_{12}$ status) and development. The development community needs to appreciate the importance of ASF for nutritional status (29) and normal development in low-income countries, especially in the common situation that fortified foods and micronutrient supplements are not sufficiently available. Newer concepts concerning the feasibility and merits of livestock production in developing countries (30) and novel approaches to increasing the availability of ASF for children (31) should receive greater attention if the prevalence of undernutrition in this age group is to be reduced.

REFERENCES


Effect of Infections and Environmental Factors on Growth and Nutritional Status in Developing Countries

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ABSTRACT

Despite numerous advances and improvements in child health globally, malnutrition remains a major problem and underlies a significant proportion of child deaths. A large proportion of the hidden burden of malnutrition is represented by widespread single and multiple micronutrient deficiencies. A number of factors may influence micronutrient deficiencies in developing countries, including poor body stores at birth, dietary deficiencies and high intake of inhibitors of absorption such as phytates and increased losses from the body. Although the effects of poor intake and increased micronutrient demands are well described, the potential effects of acute and chronic infections on the body’s micronutrient status are less well appreciated. Even more obscure is the potential effect of immunostimulation and intercurrent infections on the micronutrient distribution and homeostasis. The association therefore of relatively higher rates of micronutrient deficiencies with infectious diseases may be reflective of both increased predisposition to infections in deficient populations as well as a direct effect of the infection itself on micronutrient status indicators. Recently the association of increased micronutrient losses such as those of zinc and copper with acute diarrhea has been recognized and a net negative balance of zinc has been shown in zinc metabolic studies in children with persistent diarrhea. It is also recognized that children with shigellosis can lose a significant amount of vitamin A in the urine, thus further aggravating preexisting subclinical vitamin A deficiency. Given the epidemiological association between micronutrient deficiencies and diarrhea, supplementation strategies in endemic areas are logical. The growing body of evidence on the key role of zinc supplementation in accelerating recovery from diarrheal illnesses in developing countries supports its use in public health strategies. JPGN 43:S13–S21, 2006. Key Words: Infections—Micronutrient deficiencies—Zinc—Diarrhea—Protein diversion—Amino acids. © 2006 Lippincott Williams & Wilkins.

INTRODUCTION

Despite numerous advances and improvements in child health globally, malnutrition remains a major problem, and in many parts of the world the situation seems to have worsened (1,2). In a recent estimation of approximately 10 million global under the age of 5 child deaths, malnutrition was estimated to underlie almost half of such deaths (3). A large proportion of cases of malnutrition occur in the south Asia region (3), which also harbours almost three fourths of the global burden of low birth weight (LBW) infants (4). In other parts of the world, high rates of HIV threaten to reverse all of the gains made by child survival programs, with malnutrition worsening (5). Such overt forms of malnutrition, however, do not reflect the true burden of malnutrition because a large proportion of the hidden burden of malnutrition is represented by widespread single and multiple micronutrient deficiencies.

The relationship between micronutrient deficiencies such as vitamin A deficiency and increased risk of childhood infections and mortality is well established (6). Vitamin A supplementation is now recognized as an important public health intervention among young children in areas of endemic vitamin A deficiency. Other micronutrient deficiencies such as zinc and iron deficiency are also recognized as widespread in developing countries and associated with increased risk of morbidity (7) and mortality (8).

Although the effect of micronutrient deficiencies on immunity and burden of infections in developing countries is well documented, relatively little is known about the impact of infections on micronutrient status and their subsequent impact on health outcomes. This article focuses on the mechanisms and effect of infections on nutrition status and growth in children.
BIOLGICAL PLAUSIBILITY OF THE EFFECT OF INFECTIONS ON GROWTH

The association of recurrent infections on nutrition and growth during childhood is well described. The classic studies in rural Guatemala by Scrimshaw et al. (9–15) established the important relationship among infections, nutrition and growth. This relationship was also vividly described by Mata et al. (16,17) in follow-up studies that demonstrated the relationship of recurrent infections with growth failure. The recognition of the synergistic relationship between nutrition and infection influences most public health interventions to prevent malnutrition.

All infections, irrespective of the degree of severity, decrease nutrient intakes and increase nutrient losses. The nutrient losses include decreased intestinal absorption, direct loss of nutrients in the gut through increased secretion, internal diversion for metabolic responses to infection and increased basal metabolic rate when fever is present. In this way, infection influences not only protein and energy status but also that of most other nutrients. The clinical importance of these consequences of infection depends on the prior state of the individual, the nature and duration of the infection and the diet of the individual during the infection, particularly dietary intake during the convalescent period and whether full recovery takes place before another infection occurs. The principal mechanisms of effect of infections on growth include anorexia and poor intake, protein and energy losses (eg, in diarrhoea and fever), impact on micronutrient status, and effects of catabolism during infection and protein diversion on growth.

Anorexia and Poor Intake

Many infections are associated with increased production of inflammatory cytokines that may directly affect appetite (18,19). In a study of malnourished children in Goncalves Dias, Brazil, Schorling et al. (20) observed an ablation of catch-up growth with progressively increasing diarrhoeal burdens. In addition, many parents themselves reduce dietary intake during or after infections such as diarrhoea, thereby compounding the impact on nutrient intakes (21).

Protein and Energy Losses

Even subclinical gastrointestinal infections and increased secretion are associated with direct nutrient losses from the body. These losses may include both protein (22) and substantial losses of micronutrients such as zinc and vitamin A from the intestine or urinary tract (23). Faecal nitrogen losses may contribute significantly to the negative nitrogen balance in children with acute diarrhoea. Nitrogen malabsorption may be substantial during acute diarrhoea, ranging from 40% to 75% of intake (24). Rotavirus diarrhoea appears to be associated with more marked and prolonged nitrogen losses than shigella or Escherichia coli infections (24). The energy cost of nitrogen losses during acute illness has been estimated at 5 to 7 energy units/kg/d (25).

Chronic diarrhoea, intestinal parasitism, and protein-losing enteropathy are associated with sustained loss of protein through the gastrointestinal tract. It has been estimated that a moderate degree of intestinal hookworm parasitisation may cause an average loss of 100 energy units/d (26). In particular, protein losses and impaired absorption may be both marked and sustained in persistent diarrhoea (27), and the effect on protein metabolism can be compounded by coexisting malnutrition and micronutrient deficiency.

The effects of subclinical gastrointestinal infections may be manifest by an increase in intestinal permeability, which may reflect subclinical intestinal inflammation and alteration in barrier function. This increase in intestinal permeability has been shown to be associated with growth faltering in Gambian children (28,29). Although such growth failure may be a result of overt gastrointestinal infections, in recent years there has been much interest in subclinical infections, especially those occurring in early infancy. Helicobacter pylori infections are ubiquitous and have been shown to affect young infants and children in diverse settings in Africa (30) and Asia (31). Altered intestinal permeability and gut barrier function may lead to subclinical bacterial translocation and bacteremia, causing increased mortality in malnourished children (32), and these have also been associated with cytokine release from other intestinal bacterial infections (33–36). In other instances chronic viral infection such as with HIV may be associated with systemic immune activation and wasting (37), as well as increased losses from the gastrointestinal tract.

Impact on Micronutrient Status

A number of factors may influence micronutrient deficiencies in developing countries, including poor body stores at birth as a consequence of maternal intrauterine malnutrition, dietary deficiencies and high intake of inhibitors of absorption such as phytates and increased losses from the body. To illustrate, in the case of iron deficiency, in addition to poor dietary intake and inhibitors of absorption (38), increased intestinal losses following parasitic infestation may also be an important cause of iron deficiency anaemia (39). Overall, although the effects of poor intake and increased micronutrient demands are well described, the potential effects of acute and chronic infections on the body’s micronutrient status is less well appreciated. Even more obscure is the potential effect of immunostimulation and intercurrent infections on the micronutrient distribution and homeostasis. There is little information on the short-term compartment
changes of micronutrients such as iron, zinc and vitamin A. However, other mechanisms underlying net body losses and homeostasis are well described. It is possible to elucidate the mechanism of alteration in micronutrient status and consequent deficiency from other direct studies and observations.

The gut plays a special role in the pathogenesis and severity of micronutrient deficiencies. The association of helminthic infections, especially hookworms, with iron deficiency in young children is well established and largely relates to direct intestinal losses (40). Although the association between diarrhoeal disease control programs and malnutrition or growth rates has been questioned, in many parts of the world there is a close relationship between the two. In particular, prolonged and recurrent episodes of diarrhoea, frequently in association with HIV infection, are a frequent cause of morbidity and micronutrient deficiency. In recent years the association of increased micronutrient losses such as those of zinc and copper with acute diarrhoea has been well recognized (41). These findings may explain the high rates of subclinical zinc deficiency among children with frequent and recurrent bouts of diarrhoea, and may be particularly marked among children with persistent diarrhoea.

It is also recognized that children with shigellosis can lose a significant amount of vitamin A in the urine, thus further aggravating preexisting subclinical vitamin A deficiency (42). As already illustrated, the risk of micronutrient deficiency in infancy and early childhood can be compounded severalfold by the presence of low body stores from birth as in low birth weight infants, and further aggravated by poor breast feeding and complementary feeding practices (43).

**Effects of Catabolism during Infection and Protein Diversion on Growth**

This is one of the most important mechanisms that may underlie the growth failure seen in children with infections. Subclinical infection with possible immunostimulation has been hypothesized as a possible mechanism for growth failure and stunting in children from developing countries, where poor environmental hygiene and exposure to a high burden of infections are ubiquitous (44). It has long been recognized that accidental injury, surgical trauma and infection lead to a significant loss of body nitrogen (45). Although the anorexia that often accompanies these insults will in itself lead to negative nitrogen balance, the nitrogen exchange is also affected by several other factors such as muscle loss, increased urinary nitrogen losses, and changes in body composition (46). The rates of nitrogen loss from starvation and burns are often substantially greater than those from trauma or infection (47).

**TABLE 1. Gross amino acid composition of positive acute-phase reactant proteins and skeletal muscle protein with estimated amino acid needs to support a typical acute-phase response**

<table>
<thead>
<tr>
<th>Amino acid</th>
<th>C-reactive protein</th>
<th>Fibrinogen</th>
<th>α1-acid Glycoprotein</th>
<th>α1-Antitrypsin</th>
<th>Haptoglobin</th>
<th>Amyloid A</th>
<th>SMP</th>
<th>Acute-phase response</th>
<th>Muscle protein equivalent</th>
<th>Excess release, mg</th>
</tr>
</thead>
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<tr>
<td>Leucine</td>
<td>91</td>
<td>62</td>
<td>101</td>
<td>124</td>
<td>82</td>
<td>29</td>
<td>80</td>
<td>89</td>
<td>1090</td>
<td>72</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>54</td>
<td>32</td>
<td>48</td>
<td>49</td>
<td>47</td>
<td>29</td>
<td>48</td>
<td>54</td>
<td>1120</td>
<td>41</td>
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<tr>
<td>Valine</td>
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<td>48</td>
<td>46</td>
<td>59</td>
<td>84</td>
<td>8</td>
<td>54</td>
<td>67</td>
<td>1240</td>
<td>40</td>
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<td>92</td>
<td>33</td>
<td>98</td>
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<td>920</td>
<td>104</td>
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<td>Histidine</td>
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<td>45</td>
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<td>32</td>
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<td>12</td>
<td>28</td>
<td>16</td>
<td>22</td>
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<td>18</td>
<td>6</td>
<td>24</td>
<td>0</td>
<td>13</td>
<td>14</td>
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<td>12</td>
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<td>84</td>
<td>52</td>
<td>23</td>
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<td>116</td>
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<td>54</td>
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<tr>
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<td>48</td>
<td>34</td>
<td>41</td>
<td>44</td>
<td>34</td>
<td>48</td>
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<td>Glycine</td>
<td>46</td>
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<td>33</td>
<td>44</td>
<td>44</td>
<td>61</td>
<td>45</td>
<td>1110</td>
<td>39</td>
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<tr>
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<td>84</td>
<td>91</td>
<td>31</td>
<td>49</td>
<td>40</td>
<td>47</td>
<td>41</td>
<td>70</td>
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<td>11</td>
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<tr>
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<td>29</td>
<td>36</td>
<td>43</td>
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<td>106</td>
<td>59</td>
<td>51</td>
<td>860</td>
<td>66</td>
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<td>82</td>
<td>113</td>
<td>102</td>
<td>106</td>
<td>113</td>
<td>128</td>
<td>92</td>
<td>121</td>
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<td>61</td>
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<tr>
<td>GLX2</td>
<td>112</td>
<td>119</td>
<td>173</td>
<td>136</td>
<td>115</td>
<td>87</td>
<td>145</td>
<td>147</td>
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<td>140</td>
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<tr>
<td>Threonine</td>
<td>58</td>
<td>60</td>
<td>74</td>
<td>66</td>
<td>66</td>
<td>54</td>
<td>47</td>
<td>65</td>
<td>1380</td>
<td>28</td>
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</tbody>
</table>

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1. Gross amino acid composition of positive acute-phase reactant proteins and skeletal muscle protein with estimated amino acid needs to support a typical acute-phase response (assuming that the typical acute-phase response consists of an increase [mg/kg] of C-reactive protein [250], fibrinogen [200], α1-acid glycoprotein [50], α1-antitrypsin [200], haptoglobin [50], or amyloid A [100]) acute-phase protein response expressed in absolute terms (mg amino acid/kg body weight/d) or in terms of muscle protein equivalent (mg muscle protein/kg body weight), together with an estimate of the excess amino nitrogen release. Adapted from References (50,51).

2. ASX = aspartate + asparagines; GLX = glutamate + glutamine.

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loss (~220 mg/kg/d) (45,46) exceeds even that which is expected under fasting conditions. Given the dominating influence of muscle mass protein pool on whole-body protein, it is expected that much of the nitrogen mobilized during acute need derives from the skeletal muscle protein mass. However, following infection or injury, mechanisms are activated that lead to depletion of muscle protein. These changes are presumably induced by the combined actions of the cytokines (eg, interleukin-1, tumour necrosis factor-α) and stress hormones (eg, the glucocorticoids, glucagons, epinephrine).

Recent advances in stable isotope techniques have allowed measurements of protein synthesis and losses in a variety of physiological states (47–49). These studies indicate that subclinical and acute infections accelerate protein catabolism and diversion to the production of acute phase proteins. Reeds et al. (50,51) have estimated the approximate amino acid composition of various acute-phase proteins and the protein or amino acid “cost” of a typical acute-phase response (Table 1). In a study of children (ages 6–24 months) with persistent diarrhoea we estimated whole-body protein kinetics using 15N-glycine and indicated that despite adequate nutrient intake, most children with subclinical infections were in negative protein balance (Fig. 1). In a subsequent phase following nutritional rehabilitation and treatment of infection, these children were exposed to a vaccine challenge. Evaluation of protein kinetics indicated that the immunostimulation was associated with a phase of negative protein balance (Fig. 2). These studies indicate that in many children with subclinical infections and immunostimulation, a limiting factor may be amino acid and protein intakes during rehabilitation.

**Amino Acid Supply, Growth and Implications for Therapy**

The role of dietary protein as a determinant of growth is well recognized. Millward (52) proposed a protein-driven regulatory mechanism, centered on the control of bone elongation by protein kinetics. Other studies (53) showed that bone growth continued at reduced but substantial rates even when dietary energy intake was reduced by 50%, as long as protein intake remained constant. The ability of dietary protein to increase growth, particularly during periods of catch-up growth after illness is well recognized (54,55). The amino acid composition of dietary proteins has a direct effect on growth by determining the supply of essential amino acids at the cellular level. Protein synthesis requires the presence of each component amino acid at the time of chain elongation. Thus, a dietary protein intake deficient in essential amino acids will not be able to sustain protein synthesis. Many vegetable proteins have limiting amino acids (eg, with levels below those in high-quality reference proteins such as egg or milk).

Among the adaptive changes in plasma amino acid concentrations with malnutrition are a temporary increase in the levels of branched-chain amino acids, an increase in glycine levels, and a fall in alanine concentration (56). This specific and early effect on branched-chain amino acids is an indication that these are among the first to become limiting for protein synthesis in malnourished children. The presence of intermediary metabolites of histidine and tyrosine in the urine of malnourished children (57) suggests a widespread impairment of enzyme activity. It must be emphasized that the plasma amino acid profile in most malnourished children also reflects the superimposed effects of infection and anorexia. In the well-nourished host, infection episodes trigger a cascade of adaptive responses, aimed at enhancing immune competence and preserving vital cellular activities and preventing colonization of the infective agent. The role of cytokines as mediators of systemic responses to infection has become clearer during the past decade (58). Although the precise molecular mechanisms are unclear, the cellular biology of tumour necrosis factor suggests a role in promoting the transfer of amino acids from peripheral tissues to liver for use in acute-phase protein synthesis and gluconeogenesis.
Glycine
Alanine
Valine
Phenylalanine
Isoleucine

Alterations in serum amino acid profile in various pathological states (66,67)

<table>
<thead>
<tr>
<th>Amino Acid</th>
<th>Starvation</th>
<th>Protein-free</th>
<th>Infection</th>
<th>Malnutrition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leucine</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Isoleucine</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Phenylalanine</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alanine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glycine</td>
<td></td>
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</tbody>
</table>

It is important to emphasize that this cytokine-induced catabolic state cannot be overcome merely by enhancing substrate availability.

As indicated above, acute infection has a major negative impact on nitrogen balance. Studies by Biesel (60) showed that the infection process was responsible for higher nitrogen losses than could be accounted for by a decreased protein intake. This specific effect of infection varied depending on the etiological agent and on the initial nutritional status of the host. In the relatively well-nourished host, mild infection was associated with an increased protein turnover (61), although the modest rise in protein synthesis could be negated by the associated marked increase in the rate of protein breakdown (62,63).

The host response to infection requires the rapid synthesis of immune proteins. The catabolic response to infection leading to breakdown of skeletal muscle protein and release of free amino acids into the bloodstream provides most of the extra amino acids needed to mount that response. Although the impact of protein deficiency on altering the acute-phase response is well recognized (64), the precise amino acid requirements to mount this immune response have been the subject of speculation.

The issue is particularly important for developing countries, where childhood infections are common and the cumulative burden that these episodes can have on amino acids requirements of the small child is substantial (65).

Table 2 indicates the alterations in plasma amino acid profiles in response to short-term dietary alterations, malnutrition or infection (66,67). These complex changes do not provide much help in understanding the dynamics of protein metabolism in malnourished infected individuals. Preliminary animal data suggest that it is possible to modulate the endogenous production (68) as well as the metabolic response to tumour necrosis factor-α (69) by modifying the amino acid composition of the diet.

### Intervention Strategies to Reduce the Nutritional Impact of Infections

Given the above findings, it is important to ensure that a wide variety of intervention strategies are employed to ameliorate the nutritional penalty of infections. These can be broadly classified as follows.

#### Preventive Strategies

The major environmental penalty of poverty is increased burden of infections, and clearly this must be a long-term goal for most developing countries. The reality of global inequity and poverty, however, is totally different in many parts of the world, especially sub-Saharan Africa, which has slid down the poverty ladder. Thus, there is continued interest in intervention strategies to accelerate the reduction in childhood diarrhoea and acute respiratory infections.

It has been shown that targeted education strategies do have an impact on reducing diarrhoea burdens and improving breast-feeding practices (70,71). In addition, interventions focused on improving the supply of safe water through filters (72,73), chlorination (74) or other strategies (75) have been shown to have a significant impact on diarrhoea rates. Community education and hand washing strategies through promotion of the use of soap have been shown to reduce rates of diarrhoea and acute respiratory infections in community-cluster randomized trials (76–78), indicating the benefit of incremental strategies for community behaviour change.

Although these studies are important and systematic reviews (79) support the benefit of hand washing and soap, the reality is that this is an expensive intervention that is difficult to roll out and sustain. As a recent analysis (80) of the global costs for child survival interventions indicates, we are currently spending almost $2 billion on safe water and sanitation in developing countries, yet the intervention does not reach those in greatest need. There is thus the continued need for additional preventive strategies. Given the close relationship between malnutrition and infections, nutrition interventions are widely regarded as critical to public health programs.

#### Macronutrient Interventions

Although the role of balanced energy-protein supplementation for nutritional rehabilitation is well described, the critical role of adequate protein intake in malnutrition is also widely recognized (81,82). Although some regard the absolute intake of protein as a more important factor (83), others have evaluated specific amino acids in malnourished children with infections (84,85) and found them to be equally beneficial. Some of this uncertainty stems from observations that during acute stress if infections some amino acids become conditionally essential and that replenishing the need acute phase proteins would result in breakdown of muscle protein (51). Manary et al (86,87) specifically demonstrated the benefits of using an egg whites-based tryptophan source in infected severely malnourished children.
Micronutrient Interventions

In addition to the role of protein and amino acid intakes, a number of epidemiological studies support the close association of infections with micronutrient deficiencies. These include findings of lower serum concentrations of zinc with increasing burden and duration of diarrhoea (88), as well as lower serum concentrations in patients with HIV infection (89). Although children with hypovitaminosis A and low serum concentrations of vitamin A have higher rates of associated infections, the specific contribution of infection to vitamin A deficiency cannot be discounted. The relationship between low serum vitamin A and severity of disease has been observed with increasing severity of HIV infection (90). Several infections are, however, directly associated with an increased risk of micronutrient deficiency. These include diseases such as measles, which have been directly implicated in unmasking as well as triggering vitamin A deficiency (91). The association of relatively higher rates of micronutrient deficiencies with infectious diseases may be reflective of both increased predisposition to infections in deficient populations as well as a direct effect of the infection itself on the micronutrient status indicators (92). Low serum concentrations of micronutrients have been frequently described in subclinical infections. These levels also appear to be lowest at the highest levels of inflammatory proteins. High serum concentration of C-reactive protein and haptoglobin are known to relate to the density of malarial parasites, with correspondingly lower concentrations of plasma retinol, in Tanzanian children (93). The levels of plasma retinol among apparently healthy children in Ghana were also found to be lowest in those with raised markers of acute inflammation (94). The effects of infection on blood indicators of micronutrient status may be more marked in areas with widespread malnutrition. To illustrate, in an evaluation of the comparative effects of malnutrition and coexisting malaria on serum antioxidant levels in Nigeria, the reduction in plasma β-carotene concentrations was significant with malaria rather than with malnutrition (95).

CONCLUSIONS AND IMPLICATIONS

The present review illustrates the close interaction between infections, especially those prevalent in poor, deprived populations and malnutrition. Although this relationship is bidirectional, with malnutrition predisposing to infections, the role of recurrent infections in inducing and worsening malnutrition must be equally emphasized. A number of intervention strategies target reducing the burden of infections directly through nutrition education (eg, promotion of exclusive breast-feeding and appropriate complementary feeding and water/sanitation and hygiene interventions). It is anticipated that the reduction of the burden of infections would lead to substantial benefits in growth, and this has been demonstrated in several intervention studies (96,97).

The important contribution of some infections to aggravation of micronutrient deficiencies in at-risk populations cannot be ignored. Increased losses of micronutrients such as vitamin A and zinc during infectious illnesses such as diarrhoea are important contributors to micronutrient deficiencies. This may be particularly marked with prolonged diarrhoea and dysentery and may lead to clinically significant deficits and overt micronutrient deficiency.

Given that the epidemiological association between micronutrient deficiencies, such as zinc and diarrhoea, is well established, supplementation strategies are logical in endemic areas. The growing body of evidence on the key role of zinc supplementation in accelerating recovery from diarrhoeal illnesses in developing countries supports its use in public health strategies in endemic areas (98–100). The association of measles with overt and subclinical vitamin A deficiency also recognized that the administration of vitamin A to all such malnourished and at-risk children forms a cornerstone of such management strategies. Population-based micronutrient interventions and targeted replenishing of critical nutrients that may become deficient during infective stress may have significant public health benefits in developing countries.

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Nutritional Deficiencies in Learning and Cognition

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ABSTRACT

The postinfancy period is crucial for normal brain development, providing subsequent optimal conditions for learning and cognition. Both iron deficiency and essential fatty acids deficiency may impair normal neurological development. This review examines the limited number of studies that have been performed in preschool children and offers a broader view of the relationships among nutrition, nutrients and cognition.


INTRODUCTION

Many studies demonstrate the destructive effects of malnutrition and nutrient deficiencies on learning and cognition. Most studies examine specific periods of development (eg, prenatal, infancy and school age or aging) while neglecting the postinfancy period, in which a number of nutritional deficiencies including but not limited to choline, selenium, zinc, folate, vitamin B12 and iodine, have been shown to interfere with normal development and cognition (1).

The most commonly studied deficiencies in children are protein-energy malnutrition, including Kwashiorkor and marasmus, iron deficiency and essential fatty acids deficiency. The aim of this review is to examine the limited studies that have been performed on children of this age, and to offer a broader view of the relationships among nutrition, nutrients and cognition.

RELATIONSHIP OF NUTRITIONAL DEFICIENCY TO THE TIMING OF BRAIN DEVELOPMENT

Malnutrition, undernutrition, and nutrient imbalance may affect learning and memory by modifying or interfering with brain physiology or with brain structure. Two conditions of nutritional insults may prevail: temporary damage (which lasts only as long as the nutritional problem exists) includes short-term blockage in the bioavailability of nutrients essential for a specific action. However, if the nutritional insult occurs in a "critical period," the damage will no longer be temporary but rather have long-term consequences. Many studies tend to concentrate on nutritional deficiencies during the early infancy period when many accelerated developmental events occur. It was recently concluded that while the brain undergoes rapid development during infancy, the maturation of the brain is not yet completed. Maturation of areas of the brain is not uniform, and different areas mature at different ages. It seems that the areas of the brain that mediate cognitive function mature last. There are several indicators for brain maturation, such as synaptogenesis, myelin formation and dendrite formation (2,3). Several techniques, such as the PET scan or magnetic resonance imaging (4), demonstrate brain development well into the preschool period, and the glucose utilization test shows a higher rate of brain glucose metabolism in the postinfancy period than during adulthood (5). The 2 brain areas that mediate most of the cognitive functions, the frontal and prefrontal cortex and the hippocampus, mature during postinfancy or later. Several investigations have correlated the appearance of different types of cognition and memory with the rate of maturation of specific brain areas (6). Some researchers estimate that the frontal cortex finally matures at age 10. Insults to the process of the synaptogenesis or to the rate of myelination induce severe delay in development and maturation of brain areas, which results in delayed cognitive development.

The sensory system matures before the cognitive system; Delay in maturity (eg, disturbance in the myelin formation process) in the visual or auditory system,
severely impacts the cognitive system, where sensory-motor coordination is essential for normal cognitive development. Even a correction of the nutritional deficit may leave persistent long-term effects on the auditory system.

**Micronutrients Deficiency**

Protein energy malnutrition (PEM) is a state that mainly affects infants as a result of energy restriction and a protein- and amino acid–deficient diet. Although most children with PEM exhibit cognitive deficits, the magnitude of the disorder among postinfancy children is not known. This syndrome is a combination of the effects of undernutrition and a severe decrease in essential enzymes and neurotransmitters. Other known nutritional disorders may be confounded by a history of energy restriction.

**Iodine**

Iodine may be responsible for mental retardation and can appear at any age, although it is most devastating when it occurs during infancy. The mechanism is clear: iodine is required for the formation of thyroxin, which is an essential nutrient for the brain.

**Iron**

Iron deficiency (ID) is the most prevalent nutritional disorder at all ages. There are many animal and human studies describing the effects of ID and its effects on dopamine and dopamine D2 receptors (7). Behaviorally, children with ID showed lethargy, irritability, apathy, fatigue, inability to concentrate, pica, inattention and a decreased IQ. Some theories relate ID to attention-deficit/hyperactivity disorder (ADHD). In animal studies, ID induces a delay in maturation of the frontal cortex, which may explain the cognitive deficits found in animal and human studies, and hippocampus, which may explain the spatial cognitive decline (7,8).

Recently the authors found that most of the neurologi-cal reflexes (galabell, palmer grasp, planter grasp, passive movement arm, passive leg movement, and Babinsky) were severely delayed in ID/low ferritin premature infants (9). The long-term effects of infancy ID has been studied in a group of rehabilitated children. At ages 9 to 10 (with normal values of hemoglobin, iron and ferritin) their IQ score was the same as non-ID infant children; however, their scores on subset tests that required spatial cognition were significantly lower. In addition, in auditory tests they exhibited statistical but not clinical delay in processing auditory signals (10). One of the mechanisms that may explain these results is the interference of ID in the normal rate of myelination. In addition, ID may slow down the development and maturation of brain neurotransmitters. In contrast to infantile ID, which is hard to treat and has a long-term effect, ID that occurs later in life is much easier to treat. Despite discussions of ID-impaired learning or memory or motivation and concentration, the ultimate resulting condition is decreased cognitive function (11,12). In our study with rehabilitated ID children we did not find any decrease in motivation or concentration, but we did find a tendency toward lower IQ scores.

Nutritionally induced ID modifies other body systems in addition to the brain and its biochemistry. Modifications of the endocrine system (an increased insulin sensitivity and a decreased thyroxin level) were reported. Several aspects of the 2-way relationship between ID and cell-mediated immunity have been described. On the one hand, interleukin-1 (IL-1) induces ID; on the other hand, our results showed that among ID rats the level of IL-1 (proinflammatory) is increased and the level of IL-2 (anti-inflammatory) is decreased (7). An increased level of IL-1 and a decreased level of thyroxin leads to deficits in the learning process and cognition. In addition, the effects of ID on the immune system can explain the finding that the rate of children with ID who are sick with infectious diseases is much higher than that for non-ID children.

It is important to note another effect of ID, namely that the bioavailability of molecules in the brain is highly dependent on proper function of the blood-brain barrier (BBB). Although the neonate is born with an immature BBB, the BBB matures quickly to protect the developing brain. We found that the pattern of penetration of several compounds into the brain of ID rats is different from that of the control rats (13). It is interesting to note that the ID state does not damage the BBB but rather induces specific changes in the penetration rate. One of the compounds that is able to cross the BBB in ID rats is β-endorphin, which is unable to cross the BBB in normal rats. Here again, higher brain levels of β-endorphin are associated with poor learning and memory.

**ESSENTIAL FATTY ACIDS DEFICIENCY**

The activity of the brain is highly dependent on the integrity of the neuronal membrane (14,15). The neuronal membrane is composed mainly of proteins and lipids. The proteins in the membrane are relatively stable, whereas the lipids exhibit a fast turnover rate. Also, it should be remembered that the neuronal membrane, the myelin sheath, surrounds the membrane, and that the myelin is composed mainly of lipids.

The physical state of the neuronal membrane is critical for the neuronal functions. The ideal state is a gel state. There are known molecules that are able to change the physical state of the membrane, for example, alcohol fluidizes the membrane, whereas cholesterol hardens the membrane. The change in the physical state of the
neuronal membrane modifies some of the membrane functions, including neuronal information along the axon and neuronal information in the synapse.

Essential fatty acids (EFA) are essential for the developing brain. It is outside the scope of this review to deal with the most important issue of EFAs supplements to baby formulas. EFA are involved in most of the aspects of brain development and maintenance. They are major components of myelin and are able to induce myelination, determining the index of membrane fluidity. EFA are also involved in neurotransmitters and the production of peptides. In EFA deficiency (EFAD) states the membrane becomes much harder and cannot perform its functions.

Whereas the brain uses linoleic (n-6) and α-linolenic (n-3) acids for many functions, their derivatives (ie, the longer chains of polyunsaturated fatty acids [PUFA]) are also important. The same enzymes that are responsible for the elongation of the fatty acids act upon both families of PUFA and compete with each other. Numerous studies have confirmed that the level of PUFA in the neuronal membrane is important, and recent studies have shown that the types of PUFA and the ratio between n-3 and n-6 PUFA are just as important. For example, the ratio between the total PUFA and cholesterol level in the membrane determines the membrane fluidity index. Not all ratios of PUFA are equally effective in decreasing the level of cholesterol in the membrane. The ratio of 1:4 (n-3:n-6) was found to be the most effective in decreasing the cholesterol level in the membrane (14).

The role of n-3 in various brain functions is facilitated greatly by diet-induced deficiency. Studies have shown that n-3-deficient rats exhibit poor learning and memory in a variety of tasks, including but not limited to Morris Water Maze performance and olfactory-based learning in addition to sensory deficits such as selected visual functions (16). In n-3 deficiency there is a significant decrease in the neuron size in the hippocampus, hypothalamus and cortex, the areas of the brain that mediate spatial and serial learning. In addition, n-3 deficiency induces a significant reduction in cerebral catecholamines, in glucose transport capacity and glucose utilization in the brain and in the rate of myelination (17). Each of these variables can be responsible for learning deficits.

Clearly, the various fatty acids serve different roles in the nervous system and throughout the body’s machinery. It has been suggested that the nervous system has an absolute molecular species requirement for proper function. Studies in our laboratory confirm this finding and even suggest an added qualifying requirement (eg, the need for a proper ratio between the EFAs. Many studies examined the effects of various fatty acids on learning and memory, but few examined the ratio between various PUFA. We tested a wide range of PUFA ratios and found that a mixture of linoleic (n-6) and α-linolenic acids (n-3) with a ratio of 4:1 was the most effective in improving learning performance (as assessed by the Morris Water Maze and passive avoidance), elevating pain threshold, improving sleep and improving thermoregulation. This ratio was also able to correct learning deficits induced by the neurotoxins AF64A and 5,7-dihydroxytryptamine and by 6-OH-DA (ie, reduction in brain dopamine level).

Our studies in animal models were not limited to an examination of memory disorders. The PUFA compound was effective in decreasing elevated cortisol levels in an experimental model of stress (18). The PUFA mixture was also found to improve the status of an experimental rat model of multiple sclerosis and a decrease in the frequency of seizures in pentetrazol-treated rats. Ongoing clinical trials with patients with refractory seizure, using a commercial fatty acid preparation, appear to confirm the success of seizure control that was observed in the animal data (14).

A question of major concern in pediatric neurology relates to the establishment of the degree of nutritional deficiencies that is able to induce behavioral disturbances, even in the preschool period. In a recent survey the authors found that a large percentage of children with ADHD are iron deficient, EFAD, and some are both. We were unable to establish that the nutritional deficiency was the unequivocal cause of the behavioral disturbances, or that because the children tend to be anorectic and consume large amounts of junk food, the nutritional deficiencies are the results of the behavioral disturbance. However, recent studies showed that ID induces changes in the index of membrane fluidity. In addition, children with EFAD exhibited the same auditory changes as children with ID, and changes in the BBB functions were found among EFAD rats.

CONCLUSIONS

The succinct message of this review is that the post-infancy or preschool period is not a quiet period in brain development. Although it is true that no critical developments were identified in the postinfancy or preschool period, it is clear that the brain continues to develop and that any damage incurred during these periods may have long-term results. The critical brain areas that mediate reasoning (prefrontal cortex) (19) and spatial learning (hippocampus) (20) do not reach maturation in this period. Various types of learning such as sequential learning (21), spatial cognition (22) or inhibitory control (23) must wait until the brain area is ready to perform the task. Nutritional deficiencies will delay these performances for a long time (24,25).

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REFERENCES

Prevention and Control of Obesity in Preschool Children: Importance of Normative Standards

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INTRODUCTION

The combined objectives of promoting child growth while preventing obesity are often not recognized as intertwined components of good nutrition; rather, they are often considered to be opposite poles of the malnutrition spectrum. Providing complementary foods to young children with the worthy objective of preventing malnutrition without considering the need to avoid obesity in stunted children may in fact do potential harm. Nutrition programs addressed at preventing malnutrition may have built-in mechanisms that can easily promote positive energy balance and thus increase risk for obesity. This is particularly relevant when feeding underweight stunted children who may be of normal or even excessive weight for stature. Thus, it is of the utmost importance to define what is normal weight and height and to apply normative standards to assess growth and to establish energy intake recommendations that are consistent with good nutrition and health during childhood and beyond (1).

This manuscript examines recent advances in defining norms to assess the growth of young children, the latest energy intake recommendations for children released by Food and Agriculture Organization/World Health Organization/United Nations University (FAO/WHO/UNU), the need to include obesity prevention in the design and implementation of nutrition programs for children with a special emphasis in Latin America, and propose recommendations to prevent malnutrition from energy deficit and excess in countries undergoing rapid epidemiological changes.

NORMATIVE GROWTH STANDARDS FOR YOUNG CHILDREN

Reference Growth Standards to Define Normal Weight, Height and Body Mass Index

To assess normal growth we need an adequate reference of central tendency and variability in anthropometric indices. Because good health and nutrition are defined by the capacity to support normal growth, the reference/standards used to assess growth are fundamental for both clinical practice and to establish public health recommendations. Thus, the definition of “normal” growth is of paramount importance to secure the normal health and nutrition of populations. Normative gender- and age-specific data of weight, height and body mass index (BMI) are needed to define who is undernourished, normal, and obese. Anthropometry is only an indirect marker of body composition (lean body mass and fat stores), therefore, weight and length measurements serve only as proxy markers for increased or reduced adipose tissue energy stores. Weight, height and weight/height and BMI for age and sex have been used as indicators of nutritional adequacy in infancy, childhood and adolescence (2).

Present growth charts are based on what is observed growth for a normal reference population rather than recommended growth-based on health outcomes throughout the life course. The most commonly used growth charts are based on the National Center for Health Statistics (US)NCHS, implying that children growing in an affluent society in North America should be considered the standard of healthy growth. The NCHS growth reference served as the basis for the present WHO international growth standards for infants 0 to 36 months, which was derived from children growing in an affluent rural society in the town of Yellow Springs, OH (3). The present WHO infant growth norm has major flaws: it is derived from a nonrepresentative sample of
the population and the data are drawn from a group of predominantly formula-fed infants who received energy-dense complementary foods.

The WHO/UNU growth standards released in May 2006 correspond to a representative sample of disease-free individuals in 6 sites around the globe. The new Multicountry Growth Reference Standards (MGRS) were developed based on the growth of infants who were predominantly breast-fed for 4 to 6 months and appropriate complementary foods after weaning (4). In fact, infants fed according to present WHO recommendations and living under conditions that favor the achievement of genetic growth potential, grow less rapidly in weight than the present WHO/NCHS reference, particularly after 4 to 6 months. Present distributions of normal weight-for-age and weight-for-length are skewed toward higher values, relative to those observed in predominantly breast-fed infants; this may be a contributory factor to the increase in childhood obesity because normal children are being considered underweight and are thus prescribed additional energy. These drawbacks led a WHO Expert Committee in 1995 to support the development of a new growth reference. The multicountry (Brazil, Norway, India, Ghana, the US and Oman) growth reference study, mentioned above, is specifically designed for this purpose; data collection began in 1997 and was completed by 2003. Analysis of the data has been completed and new reference standards were released in May 2006. The study undertaken in diverse geographical areas included population-based samples of infants and children whose mothers were nonsmokers of middle to high income so that environmental conditions were not restrictive and caregivers followed the established WHO feeding recommendations. The research design combined a longitudinal study from birth to 24 months of age of 300 newborns per country, with a cross-sectional study of 1400 children ages 18 to 71 months per site. More than 13,000 healthy infants and children were involved in the study. The new international growth reference provides a scientifically reliable descriptor of physiological growth and a powerful tool for advocacy in support of good health and nutrition. Another objective is to support, based on actual evidence, the concept that human growth during the first years of life is similar across groups of children of different ethnic/genetic backgrounds (5). There are genetic differences in linear growth, but these appear to be of a similar nature across population groups. Adverse environmental factors by themselves or those that interact with genetic makeup explain differences in growth observed in low income groups. The corollary for this concept is that existing differences in growth are predominantly environmentally derived and can be subject to improvement. Prevalence estimates of undernutrition and obesity in children will clearly be affected to the extent that the new reference differs from the WHO norms being used. Most important, this reference sets the growth of the breast-fed infant as the normative standard. Optimal infant feeding, as presently defined by WHO, is exclusive breastfeeding for the first 6 months of life, followed by continued breast-feeding with adequate complementary foods for up to 2 years and beyond. The issue of whether this standard should be applied to all children 0 to 5 y requires ample discussion, yet for most the breast-fed infant represents the gold standard for infant growth. The long-term consequences of this pattern of growth remain to be fully determined, however. Existing national and international standards have defined normal growth based on the weight and length gain observed in apparently healthy children. This has led in practice to support the notion that “bigger is better.” This is a reasonable proposal if the objective is to enhance survival in infancy and early childhood in areas where malnutrition and infection in synergy claim the lives of infants and young children. However, it is certainly not the case in countries where deaths of young children are rare and the concern has shifted to the prevention of obesity and related burden of chronic disease (6). To make appropriate comparisons across countries and to monitor trends in childhood overweight prevalence it is crucial to have appropriate growth standards and to agree on a clear definition of childhood overweight and obesity. The former is available, at least for children 0 to 5 y, but the latter remains a problem.

**Reference Standards to Define Overweight and Obesity in Children**

There is a lack of consistency in the use of the terms overweight and obesity in children. The WHO Expert Committee on Physical Anthropometry provided in 1995 a definition for overweight and recommended that the term obesity not be used for children (3). More recently, the NCHS proposed to classify children in the upper end of the reference distribution as either at risk of overweight or overweight, again avoiding the use of the term obesity (7). However, in 1999, the International Obesity Task Force (IOTF) Expert Committee used the terms overweight and obesity to provide their recommendations for assessment of children from 2 to 18 y to be consistent with adult definitions (8). All of the recommendations take into account 2 levels of excess weight, but use of different definitions may lead to confusion in interpreting results, monitoring trends or comparing prevalence within and across countries. This is further complicated by the need to define the appropriate anthropometric indices and cutoff points that best predict long-term adverse health outcomes. The use of weight-for-height z scores to assess the nutritional status of children is still a common practice in pediatrics; recently BMI has been incorporated, after 2 y old, to achieve concordance with adult assessment. In 1995, the
WHO Expert Committee recommended the use of weight-for-height \(z\) score to define overweight in children under 10 y old (9). Body mass index is being progressively adopted as a valid measurement of obesity in childhood, adolescence and adulthood. Body mass index changes substantially with age and sex and thus recommendations are age- and sex-specific. The 2000 Centers for Disease Control (CDC) growth charts provide BMI-for-age curves for the US population. Based on the NCHS recommendations, children with BMI ≥ 95th percentile are classified as overweight, whereas children with BMI between the 85th and the 95th percentile are classified as at risk of overweight (10). The use of BMI curves based on projected adult cutoff points has been recommended by the IOTF. These cutoffs are based on age- and sex-specific percentiles for children that project to the adult cutoffs of 25 kg/m\(^2\) for overweight, and 30 kg/m\(^2\) for obesity (8). The IOTF approach has been considered to have a low sensitivity to detect excess adiposity; in fact, IOTF obesity cutoff projects to the 97th to 99th percentile values of the WHO standard. This may prove helpful in terms of specificity. Another limitation of the IOTF approach is that it does not provide a way to assess the full distribution of values, so BMIs in excess of the obesity cutoff cannot be quantified. When \(z\) scores are used as part of the evaluation, the magnitude of the excess can be established with greater precision.

At the population level, overweight and obesity prevalence vary depending on the definition used. We have demonstrated, using a large data set for school children across 13 y of monitoring, that obesity prevalence estimates determined using the IOTF cutoff points are significantly lower than those based on the WHO or the NCHS-CDC 2000 references (11). Despite differences in absolute values, trends are similar independent of the standard used. At the individual level, the use of different criteria has an impact on the assessment of the nutritional status both for underweight and overweight children. This is exemplified in Table 1, which uses 3 hypothetical children of equal height but different weights at each age between 2 and 5 y.

Table 1 shows weight-for-height and BMI-for-age for NCHS-CDC 2000; both measures show excellent agreement in the identification of overweight and obesity (4/4 and 3/4, respectively). The WHO 1978 scale compared with the BMI-for-age criterion of NCHS-CDC 2000 have an excellent concordance for overweight (4/4), but no agreement for obesity; the WHO 1978 criteria are systematically more tolerant. When comparing weight-for-height criteria, these agree in every case for the diagnosis of overweight, but in only 1 case when the diagnosis is obesity. Again, the WHO 1978 criteria are systematically more tolerant. There was scant agreement in the classification of overweight and obesity between BMI-for-age and the IOTF criteria—based classification, and the latter has a systematically lower sensitivity. In the case of undernutrition for both sexes and all ages, NCHS-CDC 2000 weight-for-height and BMI-for-age have excellent concordance and a higher sensitivity than the WHO 1978 criteria. This implies that more children would be diagnosed as underweight using either of the CDC indices as compared to WHO 1978 weight-for-height \(z\) score. These differences in estimates of both underweight and overweight have clear implications in terms of the preventive interventions to which children may be subjected to improve their nutritional status. Overall, these results support the idea that at this age, weight-for-height and BMI-for-age perform equally well as measures of nutritional status.

### TABLE 1. Nutritional status of hypothetical boys 2–5 y old using 4 different criteria

<table>
<thead>
<tr>
<th>Age, y</th>
<th>Weight, kg</th>
<th>Height, cm</th>
<th>BMI, g/m(^2)</th>
<th>Weight-for-height</th>
<th>BMI-for-age</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>10.5</td>
<td>85.5</td>
<td>14.4</td>
<td>5.7 &lt; -1.6 N</td>
<td>1.8 -2.1 U</td>
</tr>
<tr>
<td>14.0</td>
<td>85.5</td>
<td>19.2</td>
<td>88.8</td>
<td>1.2 O1</td>
<td>95.7 1.7 O1</td>
</tr>
<tr>
<td>14.5</td>
<td>85.5</td>
<td>19.8</td>
<td>94.0</td>
<td>1.6 O1</td>
<td>98.3 2.1 O2</td>
</tr>
<tr>
<td>3</td>
<td>12.5</td>
<td>95.0</td>
<td>13.9</td>
<td>6.3 &lt; -1.6 N</td>
<td>1.7 -2.1 U</td>
</tr>
<tr>
<td>16.0</td>
<td>95.0</td>
<td>17.7</td>
<td>86.1</td>
<td>1.1 O1</td>
<td>88.9 1.2 O1</td>
</tr>
<tr>
<td>17.0</td>
<td>95.0</td>
<td>18.8</td>
<td>95.7</td>
<td>1.7 O1</td>
<td>97.5 2.0 O2</td>
</tr>
<tr>
<td>4</td>
<td>14.5</td>
<td>103.0</td>
<td>13.7</td>
<td>7.6 &lt; -1.4 N</td>
<td>3.1 -1.9 U</td>
</tr>
<tr>
<td>18.5</td>
<td>103.0</td>
<td>17.4</td>
<td>89.1</td>
<td>1.2 O1</td>
<td>90.0 1.3 O1</td>
</tr>
<tr>
<td>19.5</td>
<td>103.0</td>
<td>18.4</td>
<td>97.0</td>
<td>1.9 O1</td>
<td>96.3 1.8 O2</td>
</tr>
<tr>
<td>5</td>
<td>16.0</td>
<td>110.0</td>
<td>13.2</td>
<td>4.9 &lt; -1.7 N</td>
<td>0.9 -2.4 U</td>
</tr>
<tr>
<td>21.0</td>
<td>110.0</td>
<td>17.4</td>
<td>90.1</td>
<td>1.3 O1</td>
<td>89.1 1.2 O1</td>
</tr>
<tr>
<td>22.0</td>
<td>110.0</td>
<td>18.2</td>
<td>97.0</td>
<td>1.9 O1</td>
<td>94.5 1.6 O1</td>
</tr>
</tbody>
</table>

Pctl indicates percentile; ND, nutritional diagnosis; U, underweight equal to \(<-2\) \(z\) score for WHO 1978; 85th percentile for CDC 2000; —, not defined in IOTF 2000; N, normal status; O1, overweight level 1 (1–2 \(z\) score for WHO 1978, 85th–95th percentile for NCHS-CDC 2000, equivalent to an adult BMI 25–29.9 for IOTF 2000); O2, overweight level 2 (2–3 \(z\) score for WHO 1978; ≥95th percentile for NCHS-CDC 2000, equivalent to an adult BMI ≥30 for IOTF 2000). 

\(z\) score not defined for IOTF 2000.
overweight and highlight the relevance of establishing an adequate reference population and cutoff points based on long-term health outcomes rather than populations that shift according to stage of epidemiological transition that they face (12,13). Given the need for a continuous indicator across age groups into adulthood we consider BMI to be the best measure of overweight and obesity. The need for specific cutoff values based on normative population or projected BMI into adulthood has not been fully agreed upon. The merit of the IOTF criteria in providing child BMI values projecting to adult BMI of 25 and 30 for overweight and obesity is offset by not having a continuous measure of the range. This is especially relevant for children who are above the obesity cutoff point; the IOTF criteria cannot discriminate whether a child is 3 or 5 SD above the median BMI for age. Acceptable international criteria to evaluate overweight and obesity in children is determined at the time, but there was insufficient data recognized at the time, but there was insufficient data on energy expenditure of young children, except for neonates and young infants. However, the expenditure approach to estimate energy needs was used in children older than 13 y based on estimates of basal energy expenditure, plus the energy required for normal growth and defined level of physical activity (17). The dissemination of the doubly labeled water method to assess total energy expenditure during the past decades, and the development of methods to assess activity levels applicable to young children, permitted measurements of daily energy expenditure in children from different parts of the world. This allowed the 2001 FAO/WHO/UNU committee to define recommendations based on actual expenditure.

Energy recommendations for infant and child age groups published by FAO/WHO/UNU in 2004 are based on actual measurements and estimates of total daily energy expenditure either by the doubly labeled water method or estimates based on heart rate monitoring during active periods coupled with individual calibrations of oxygen consumption. The energy needs for tissue deposition related to growth in infants, children and adolescents were added to the estimate of daily energy expenditure. In the case of infants, the new recommendations were based on breast-fed infants rather than formula-fed infants; for the first year of life, the mean values for the former are 5% to 10% lower than figures for formula-fed babies. Table 2 illustrates the changes in energy recommendations for breast- and formula-fed infants during the first year of life and the differences with respect to the recommendations given in the 1985 report.

The present recommendations based on expenditure are also substantially lower for children up to age 10 y in comparison with those derived on observed food intake as used in 1985 by FAO/WHO/UNU. Figure 1 compares the 2004 estimates with the 1985 estimates for boys and girls. The proposed energy requirements are 18% to 20% lower for boys and girls under 7 y, and 12% lower for boys 7 to 10 y (Table 2). From age 12 onward, the proposed requirements are 12% higher for both boys and girls.

### Table 2. Comparison of present estimates of energy requirements of infants with those calculated in 1985 FAO/WHO/UNU report (selected ages)

<table>
<thead>
<tr>
<th>Age, mo</th>
<th>All infants</th>
<th>Breast-fed</th>
<th>1985 estimates</th>
<th>% difference from 1985</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–1</td>
<td>469</td>
<td>430</td>
<td>519</td>
<td>−11</td>
</tr>
<tr>
<td>2.1–3</td>
<td>395</td>
<td>380</td>
<td>456</td>
<td>−13</td>
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<td>3.1–4</td>
<td>345</td>
<td>330</td>
<td>431</td>
<td>−20</td>
</tr>
<tr>
<td>4.1–5</td>
<td>345</td>
<td>330</td>
<td>414</td>
<td>−17</td>
</tr>
<tr>
<td>5.1–6</td>
<td>340</td>
<td>330</td>
<td>404</td>
<td>−16</td>
</tr>
<tr>
<td>7.1–8</td>
<td>330</td>
<td>330</td>
<td>395</td>
<td>−16</td>
</tr>
<tr>
<td>9.1–10</td>
<td>335</td>
<td>325</td>
<td>414</td>
<td>−19</td>
</tr>
<tr>
<td>11.1–12</td>
<td>335</td>
<td>330</td>
<td>437</td>
<td>−23</td>
</tr>
</tbody>
</table>

The energy recommendations for infants and children published by FAO/WHO/UNU in 1985, based on the work of the Expert Committee Group that met in Rome in 1981 (16), were estimated from observed energy intakes of children from industrialized countries who were growing optimally according to the Harvard Growth Standard (the best available measure at the time). To this, 5% was added to support growth in conditions prevailing in developing countries where infection was more prevalent and diets may have lower digestibility. The need to consider actual expenditure rather than intake was recognized at the time, but there was insufficient data on energy expenditure of young children, except for...
and girls, assuming moderate levels of physical activity. These modifications of the recommendations for infants and children should serve to correct the overestimations of the dietary energy needs of children from birth to 10 y. Interventions such as child feeding programs, formulated based on the 1985 recommendations, could have easily led to excess energy intake among target populations. The higher energy prescribed and the greater tolerance of the anthropometric indices with overweight and obesity could have contributed to the observed excessive weight gain among these children. This may have been a critical problem for children living in urban settings, especially in countries undergoing economic and dietary changes associated with modernization.

The 2004 recommendations include a need for physical activity to maintain fitness and health and to reduce the risk of developing obesity and diseases associated with sedentary lifestyles. Moreover, different requirements for populations with lifestyles that involve different levels of habitual physical activity, starting at 6 y old are given. Recommendations for physical activity levels based on classification of habitual activity consistent with good long-term health are provided. The energy requirement of an individual was defined by FAO/WHO/UNU as “the level of energy intake from food that will balance energy expenditure when the individual has a body size and composition and level of physical activity consistent with long-term good health; and that will allow for the maintenance of economically necessary and socially desirable physical activity. In children and pregnant or lactating women, the energy requirement includes the energy needs associated with the deposition of tissues or the secretion of milk at rates consistent with good health” (17). For infants and young children, energy needs are equal to the sum of expenditure and energy stored as growth. Total expenditure is the sum of several components: basal metabolism, thermal effect of feeding, thermoregulation and physical activity. A lower recommended energy intake for all children <10 y, except for those that are highly physically active as prescribed by FAO/WHO/UNU 2004, will contribute to the prevention of systematic energy excess and will stress the need to improve nutrient density of diets rather than increase energy intakes. For infants the new recommendations will serve to strongly support exclusive breast-feeding because as energy needs drop, the sufficiency of breast milk energy supply is prolonged. This means that for most infants, exclusive breast-feeding will provide sufficient energy for normal growth for at least 6 months and possibly beyond this period. FAO/WHO/UNU 2004 will also serve to stress the need to enhance nutrient density of complementary foods after 6 months to meet infants’ and children’s micronutrient needs rather than overemphasizing the need for high energy intakes to promote weight gain. If the energy needs are lower and the micronutrient needs are the same, then the micronutrient density of the diet becomes critical. Thus, both normative standards will act in synergy to prevent excess weight gain and to promote good linear growth in accordance with the only proven gold standard “the breast-fed infant.” This prescription has stood the test of successful human evolution for the past several million years. We still face the

<table>
<thead>
<tr>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>200</td>
<td>200</td>
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<td>220</td>
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<tr>
<td>440</td>
<td>440</td>
</tr>
<tr>
<td>460</td>
<td>460</td>
</tr>
</tbody>
</table>

**FIG. 1.** Energy recommendations for children and adolescents based on habitual energy intake as per FAO/WHO/UNU 1985 and derived from energy expenditure FAO/WHO/UNU 2004.
challenge of defining the optimal energy intakes and growth rates in early life, conducive to long-term health across the life course.

NUTRITION PROGRAMS FOR YOUNG CHILDREN IN TRANSITIONAL COUNTRIES: NEED TO INCLUDE OBESITY PREVENTION

Basic Considerations

To address food insecurity and protect vulnerable groups from the scourge of hunger and malnutrition, developing countries have implemented various forms of food supplementation and/or income transfer programs to prevent the consequences of malnutrition (18). It has been estimated that close to 1 of 5 Latin Americans lives in poverty conditions and can be considered undernourished/food insecure (19). However, these programs have the potential to induce energy excess unless they consider critical issues in the selection of beneficiaries and in the type of food supplement provided. In the case of income transfer, choices made by recipients of the programs may favor energy-dense, nutrient-poor foods that may also contribute to overweight and obesity in women of reproductive age and young children. A recent FAO survey with data from 19 Latin American countries found that >20% of the population—approximately 83 million people of an estimated 414 million in these countries—receive some level of food assistance benefits from nutrition-related programs (19,20). In contrast, the number of malnourished people in the studied countries was 10 million, 12% of the total beneficiaries of food programs. This indicates that nearly 9 of 10 beneficiaries may be of normal weight or even overweight. Nutrition programs have evolved beyond the immediate needs of the malnourished and have become part of the social and economic benefits demanded by populations living in poverty. The Brazil Zero Hunger Program, which is directed at those suffering from hunger, is predominantly an income-transfer program that provides food and other commodities and does not include biological or nutritional vulnerability in the criteria to select beneficiaries. In fact, the program has been criticized recently because the poor in Brazil are mostly stunted and overweight, rather than suffering from wasting (21).

The nature of the problem is exemplified in a simple manner in Fig. 2a, which presents the weight-for-age distribution of children in a typical developing country with high prevalence of underweight children. As depicted in Fig. 2b, if food is provided for all children, not just those who are underweight, then the whole curve will be displaced to the right, generating a significant proportion of overweight and obese children. The desirable outcome, if targeting is efficient, is the elimination of the tail below −2 SD without increasing the proportion of those >2 SDs; in this case, the distribution of weight-for-age for the population is normal, with few individuals underweight or obese. The evidence emerging from countries undergoing the epidemiological transition indicates that if food supplements are provided without careful targeting, the situation becomes similar to that depicted in Fig. 2b. Some planners may even consider this phenomenon to be an unavoidable consequence, whereas others suggest it as a desirable outcome because it serves as evidence of the impact of a successful intervention (22).

A critical issue in defining the nature of this problem is recognizing that underweight children are usually stunted, thus most malnourished children will be of low weight- and length-for-age, but will have a near-normal weight-for-length/height. In other words, they are underweight and stunted, but not wasted. Because recovery in length-for-age is incomplete if nutrition improvement occurs after 24 to 36 months of age, these children will gain significantly more weight-for-age than length-for-age when given additional food. In older children, little or no gain in length-for-age is observed (23). Later in the article, we examine these issues in various settings where additional food energy is provided to children who are underweight and evaluate the consequences in terms of obesity prevalence. We also analyze how supplementary feeding programs may contribute to rising obesity trends, what factors may explain this phenomenon and the potential strategies needed to avoid a rise in obesity as a byproduct of malnutrition prevention efforts.

FIG. 2. Model examining the effect of universal food supplementation of children on the distribution of weight-for-age. A, Baseline with a significant group of underweight (<−2 SD). B, Shift in distribution after universal food supplementation. Undernutrition has been reduced considerably, whereas overweight and obesity have increased.
Most programs do not have targeting criteria based on actual anthropometry but rather on socioeconomic condition. The benefits are given to all, independent of whether there is evidence of low body weight. Significant reductions in underweight and wasting have occurred in most countries; undoubtedly supplementary feeding programs have played an important role in this decline. Unfortunately, they may have also contributed to the rising trend in obesity (1). Stunting remains a problem in most developing countries, despite the virtual eradication of wasting in many (24). In this setting, providing food supplements may be beneficial for some, whereas it may be detrimental for others. Careful selection of beneficiaries of food assistance programs and determination of the right combination of nutrients/foods, education, and lifestyle interventions are required to optimize nutrition and health at each stage of the life cycle. This is a crucial problem that should be addressed before initiating specific programs (25).

Latin American Food and Nutrition Programs
Targeting Children and Adolescents

Information on those programs from selected countries (Colombia, Costa Rica, Cuba, Chile, Guatemala, Mexico, Peru and Venezuela) can be found at http://latinut.net/f-global/index.asp. A total of 40 nutrition or food programs target pregnant women and children, however, only 12 include anthropometric indices to select their beneficiaries. Most are targeted to the low socioeconomic status groups, based on biodemographic characteristics independent of whether there is objective evidence that people require extra energy or are underweight for stature. Moreover, FAO and other international bodies have defined hunger to meet the mandate of the World Food Summit and the Millennium Development Goals based on achievement of energy intake to meet theoretical energy needs. This has been labelled "undernourishment" and its the assessment is based on energy available from food balance sheets, energy needs of the population and distribution according to socioeconomic levels, with no actual measurement of any indicator of nutritional status. This in itself tends to overestimate the number of undernourished people, and because no provision to assess body weight or physical activity is made, is often in sharp contrast to the direct assessment of BMI of these populations (9). In areas of the world, such as Latin America and southeast Asia, where populations are progressively becoming urban and sedentary and energy availability is not a limiting factor, the FAO definition of undernourished misguides policy (it assumes that the problem is solved by providing food energy to poor populations). Under these conditions, poverty is related to adequate or even excess energy relative to physical activity levels and diet is of poor quality in terms of healthy foods, rather than the amount of energy (26). This requires that we incorporate the need to improve the quality of diets as a complement to food security. We analyzed these programs derived from data collected by Uauy and Rivera in the context of obesity prevention in developing countries and the considerations made in the introduction to this section.

Colombia has 6 widescale programs targeting children, adolescents and pregnant women; these programs are under the technical supervision of the Instituto Colombiano de Bienestar Familiar. Beneficiaries are from the lowest socioeconomic level from both urban and rural areas. The objectives of these programs include family support, improvement in nutritional status, promotion of breast-feeding and healthy lifestyle. All of these programs have national coverage and for targeting criteria use age and biological vulnerability. Four programs also include anthropometry to target beneficiaries who are mostly malnourished. The food that is distributed bienestarina provides between 30% and 80% of recommended energy units and proteins and can include ≥1 of the energy and protein requirements, respectively. The usual ingredients of bienestarina include a fortified vegetable mix made from powdered milk, soy flour, any cereal flour (rice, wheat or corn), legumes, sugar, molasses and oil.

Costa Rica has 4 programs with national coverage that target pregnant women, children and adolescents; 1 program gives away money to buy a specific menu and another 1 tries to reduce micronutrient deficiencies. None of the 4 programs include anthropometric indices in the targeting criteria. Cuba has 6 programs of national coverage, of which 5 have as main objective to reduce micronutrient deficiencies. Foods provided by these programs include either fortified pureed fruit or flour. Guatemala has 8 national programs and 3 regional programs that target pregnant women and children. They predominantly target malnourished populations; only 1 of them considers anthropometry (weight-for-height) for targeting purposes. These programs provide beneficiaries a food ration consisting of legumes, cooking oil and flour (a corn-soy blend). Other programs provide either micronutrient-fortified sugar or flour. Mexico has 6 large-scale food programs. One of the most important was called Progresa (the Spanish word for progress) but was renamed Oportunidades (the Spanish word for opportunities) (27). This is an incentive-based welfare program whose main objective is to invest in the nutrition, health and education of young children from poor families to improve their chances of obtaining better opportunities later in life. Apart from receiving a food supplement, the family receives money. Low-income families who are not beneficiaries of Oportunidades may participate in a program that provides a daily breakfast and a food package that provides 20% of the daily energy recommendations (includes cooking oil, legumes and corn flour to prepare tortillas). Oportunidades is an exception among the large-scale programs in Latin America.
because it includes anthropometric measurements as part of its targeting criteria.

In Peru, there are 4 programs targeting low-income pregnant women and/or children. Apart from socioecon-omic considerations, 3 of them include anthropometry to target beneficiaries. In general the supplement provides 30% of the energy recommendation and includes fortified specific foods such as baby food, cookies or a food package. Venezuela has 5 programs with national coverage, all of which target according to socioeconomic level. One of these programs applies subsidies to what are considered staple foods (corn flour, margarine, cooking oil, sugar, whole milk, canned fish and legumes). The other programs provide daily meals for vulnerable groups.

From this summary we conclude that only 1 of 4 food programs in Latin America includes anthropometry to target beneficiaries. The most commonly used anthropometric index for targeting purposes is weight-for-age. Because most underweight children in Latin America are stunted and not wasted, the target group may in fact be subjected to energy excess. Most energy-dense food supplements provided to children after 3 y of age, when there is a limited chance to gain length, may in fact lead to overweight and obesity (28). About 75% of the programs provide micronutrient-fortified supplements that are important in promoting linear growth, but unless bioavailability of micronutrients is taken into account, this may also be of limited value. Our analysis suggests that Latin American countries should reexamine the type of interventions in place and consider provision of micronutrient-ich supplements with limited energy except for populations or individuals who are wasted.

Chile, a Case Study for the Effect of the Nutrition Transition in Young Children

Chile is often presented as a paradigm of the success of supplementary feeding programs. Indeed, there is a close association between the presence of these massive and expensive interventions and the decline in malnutrition in all age groups. Close examination of these data demonstrate that for infants, preschool and schoolchildren, undernutrition based on weight-for-age was virtually eradicated by the late 1980s, and stunting rates remained low but significant until the mid-1990s. It is exactly at this stage of the transition that obesity needs to be considered in the implementation of programs and necessary changes need to be incorporated. In fact, over the past 2 decades the impact of the programs in reducing malnutrition was progressively lost, whereas the association with rising obesity prevalence has become notable (29).

The National Nursery Schools Council Program (JUNJI) created in 1971 under the Ministry of Education is of special relevance to our discussion of nutrition of preschool children. JUNJI provides child care as well as supplementary food for low-income infants and pre- schoolers. Coverage is close to 70% of those in need. In 2003, approximately 120,000 children under 5 y of age attended JUNJI. Of those, 95% were preschoolers from 2 to 5 y of age; the rest were infants under 2 y. The food distributed is programmed to cover 58% to 75% of children’s daily energy needs, depending on whether they attend a half-day or a full day. The energy supplied by age grouping is 800 kcal/d from 2 to 3 y and 900 kcal/d from 3 to 5 y. If a nutritional deficit (underweight) is detected, then an additional 100 kcal/d are provided. This program most likely has contributed to the notable decline in underweight and stunting observed in the preschool population during the past decade, but it may also be associated with the increase in obesity rates (29).

FIG. 3. A, Dramatic decline in undernutrition (evaluated by height-for-age, weight and weight-for-height). B, Rise in overweight and obesity and the parallel increase in the height of children. Prevalence (%) anthropometric indices below -1 SD (A) and above 1 SD (B).
obesity and the improved length of 6-y-old children; nearly half of the increase in obesity could be accounted for by the increase in length (30).

In addition, as shown in Fig. 4, we evaluated the change in the prevalence of obesity (BMI for age ≥95th percentile; CDC/NCHS) of children between March (school entry) and November (end of school year) for 1992 and 1996. The figure illustrates a marked rise in obesity in all age groups during this period. The comparison between March and November for the same year showed that in 1992, the largest increment in obesity was observed in 3-year-olds, whereas in more recent years, this was observed in 2-year-old children. The prevalence of obesity has remained stable from 1996 onward until recently, when a possible drop was observed.

The rise in obesity during the past decade has led to significant changes in the energy prescribed and the foods provided in an effort to curb the rise in obesity prevalence; these changes are summarized next.

**Changes in Criteria to Prescribe Energy Provided by the Program**

Initially, the program provided a fixed amount of calories which was not differentiated by age. Between 1970 and 1977, the energy content of the meals amounted to 1500 kcal/d, that is, every preschool child independent of age received the full daily energy recommendation based on FAO/WHO 1973 or 1985. In addition, children who presented a nutritional deficit received an extra 150 kcal/d. From 1987 onward, the energy content of the meals has been adjusted according to age and the child’s weight status. If the child presented a deficit (low weight-for-height), an extra supplement was provided. This remained the case until 1995, when the energy content of this additional supplement was reduced to 100 kcal/day and was used for the few children who required this extra food based on being underweight for their length.

These adjustments occurred between 1977 and 1987: first, the energy content of the meals was reduced to 1200 kcal/d (between 75% and 80% of daily energy needs) because it was determined that the children only stayed awake about two thirds of school time. In addition, the energy content of the meals was differentiated according to 3 age groups. This last classification only lasted 1 y because of implementation problems, and since 1985, only 2 age groups are in place: 2 to 3 and 3 to 5 y old. From 1988 until 1995, the energy content was further reduced to 1000 kcal/d and 1200 kcal/d, respectively.

**Adjustment of Energy Content**

In 1996, evaluation of the nutritional status of preschool children under JUNJI’s supervision showed high rates of overweight and obesity. In addition, there was a high prevalence of inactivity. These 2 considerations led to a further reduction of the energy content to 900 kcal/d.

![FIG. 4. Cross-sectional comparison of obesity (BMI >95th percentile) prevalence at start of school year (March) and end of school year (November) according to age in 1992 and 1996.](image-url)
for children ages 2 to 3 y and 1000 kcal/d for those from 3 to 5 y old. These modifications remained until 2001, when further reductions were made to 800 kcal/d and 900 kcal/d, respectively. This corresponds to an average of 60% of energy recommendations based on FAO/WHO/UNU 1985 (16) and ~72% of the recommendations published in 2004. (17). These changes were implemented initially in 2001 in one third of the country, and the process was completed by 2004. As stated above, if a child presents a nutritional deficit, then an additional 100 kcal/d is provided.

The potential impact of the nutrition programs in the rise of obesity was examined comparing the nutritional status of children at 2 y old when they entered JUNJI with that observed 3 y later when they were 5 y old. The analysis for 2 longitudinal follow-up time periods (1992–1994 and 1996–1998) are summarized in Table 3. The first study considered 8086 children. Of the 6238 children who entered the program with normal nutritional status, 1503 (24.1%) and 506 (8.1%) became overweight and obese, respectively, over the 3 y. Of the 1440 who were initially overweight, 730 (50.7%) became obese. In total, there was a 3-fold increase in the number of obese children from 408 to 1236. The second study period shown in Table 3 included preschool children from Santiago studied from 1996 to 1998. The proportion of normal and overweight children becoming obese was lower than was previously observed. However, the baseline data indicated that >10% were already obese on entry, and this figure increased by about half. Therefore, there was less of a rise during the program, but obesity was already high on entry.

The dramatic increase in obesity of young children during the past 15 years across the world, including Chile, is likely due to multiple factors acting in synergy. To document the effect of trends of economic and social changes affecting diet and physical activity on obesity prevalence of 6-y-old children in Chile, we conducted a correlation analysis of these data. The study revealed that social indicators such as gross national product per person, percentage living in poverty and social expenditure per person plus energy and macronutrient availability, car ownership, low birth weight prevalence and deaths caused by diarrheal disease were highly associated with obesity in childhood (31). The multivariate regression of these data indicated that changes in income and car ownership explained virtually all of the changes observed in the univariate model. The only 2 additional factors that entered into the multivariate analysis beyond income were percentage of fat energy units in the diet and the number of deaths from diarrhea as an index of enteric infections with a negative coefficient. In other words, less infection was linked to higher obesity prevalence.

The effect of food and nutrition programs could not be isolated from other factors, but because they were maintained stable or increased while the number of people living in poverty decreased, the net result was a major increase in the amount of food provided per beneficiary. This effect was further amplified because recent economic growth led to self-exclusion of high- and middle-income beneficiaries and thus there was a significant association between the increased availability of food provided by the programs with the increase in obesity. This association by no means proves causality. The necessary changes in the programs to decrease energy content while maintaining or increasing micronutrient supply were slow to come, but went in the right direction overall. Recent evaluations of obesity prevalence and incidence in preschool children suggest that the problem is being controlled although it has not been reversed.

**TABLE 3.** Comparison of nutritional status at entry and exit of preschool children participating in JUNJI during 3-y longitudinal follow-up

<table>
<thead>
<tr>
<th>Nutritional status at entry</th>
<th>Nutritional status 3 y later</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Normal</td>
<td>Overweight</td>
</tr>
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<td>Normal</td>
<td>4229</td>
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<tr>
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<td>612</td>
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<tr>
<td>Obese</td>
<td>59</td>
<td>106</td>
</tr>
<tr>
<td>Total</td>
<td>4629</td>
<td>2221</td>
</tr>
</tbody>
</table>


Conclusions

There is an urgent need to improve the evaluation of nutritional status and the categorization of undernutrition. The systematic measurement of stature needs to be incorporated into the assessment of nutritional status in all countries. This provides a way to separate individuals who are underweight from those who are stunted, of normal weight or overweight for their stature. The assessment of height provides a clear indication that the main nutritional problem of children in most developing countries is stunting and not underweight. This realization should lead to a rethinking of the interventions needed, placing a greater emphasis on the improvement of linear growth.

The recognition that stunting is the major nutritional problem should lead to strengthening the prescription of exclusive breast-feeding as a norm for young infants up to 6 months old. There is also a need to improve the...
micronutrient content of complementary foods. Iron, zinc, vitamin A and other micronutrients should be incorporated in the foods provided by government programs for infants and young children. Programs targeted at malnourished infants and children (defined based on insufficient weight for age or in poor weight gain) need to include assessment of weight-for-length as criteria for discharge after a trial of food supplementation. If a child continues to be underweight after a trial of food supplementation but weight for stature is normal or in excess of normal, then the need to keep the child in the program should be reconsidered, especially for children older than 18 months. Further energy intake may lead to weight gain in excess of the norm.

The acknowledgement of the rising rates of obesity in young children should lead to a careful reassessment of the energy needs of children participating in the feeding programs and to the improvement of the quality of the foods provided. Progressive increases in fruits and vegetables and lower fat content milk should be added to the specifications of preschool and school feeding programs. Health promotion, nutrition education and physical activity programs need to be an integral part of preschool and school programs. A clear strategy for the promotion of healthy foods, physical activity, reduction of psychosocial stress, tobacco control, and healthy environment is needed (32).

RECOMMENDATIONS

1. Promote and support exclusive breast-feeding for 6 months, with the introduction of complementary foods and continued breastfeeding thereafter—up to 2 y of age or longer, as mutually desired by the mother and infant.

2. Promote the appropriate introduction of safe, nutritionally adequate and developmentally appropriate complementary foods. This is critical after 6 months and must continue until 3 y of age to support optimal linear growth. Stunting is difficult to modify after 3 y.

3. Ensure that the needs of nutritionally at risk infants and children are met, giving special attention to linear growth of preterm and/or low birth weight infants. Prevent excess weight gain to decrease risk of obesity later in life.

4. Monitor growth and avoid rapid weight gain at all stages of life, especially in infancy. Children should maintain a healthy weight. Create an environment that supports healthy food choices and promotes physical activity patterns concordant with a healthy lifestyle.

5. Identify early on children at schools and health centers with individual and/or social risks for overweight and obesity, establishing dietary and physical activity measures to prevent unhealthy weight gain.

6. Implement programs for treatment of childhood obesity early to prevent present and future adverse consequences.

7. Monitor growth using appropriate standards and take necessary actions to prevent stunting in all children and avoid unhealthy weight gain in all children.

REFERENCES


Tackling the Child Malnutrition Problem: From What and Why to How Much and How

Milla McLachlan

Codirector, Full Circle Consulting, Boulder, CO

ABSTRACT

There is strong economic evidence to invest in improving the economic status of young children, yet programs remain underresourced. Returns on investment in child nutrition in terms of improved health, better education outcomes and increased productivity are substantial, and cost estimates for effective programs are in the range of $2.8 to $5.3 billion. These amounts are modest when compared with total international development assistance or current spending on luxury goods in wealthy nations. New initiatives to redefine nutrition science and to apply innovative problem-solving technologies to the global nutrition problem suggest that steps are being taken to accelerate progress toward a malnutrition-free world.

INTRODUCTION

The Adams family has done the sums; they have checked and rechecked their assumptions. Over the short-, medium- and long-term they and their business are going to benefit from investing in an insurance policy. It is not exciting, it does not make the news headlines, but they know it is essential, a very good thing. They can afford to buy it now; they can even pay cash for it. They have more than enough information, they are aware of what could happen if they do not do it. Yet they get distracted, their attention wavers, they move on to something else, and spend the money on their rifle collection instead.

Sometimes I think the global community is like the Adams family when it comes to tackling issues of hunger and malnutrition.

Nutrition programs, many of which are evidently sound economic investments, and unquestionably are “good things,” are chronically underfunded. Behrman et al. (1) make this all-too-familiar observation at the conclusion of their paper on nutrition investment opportunities for the Copenhagen Consensus (2). (The Copenhagen Consensus aimed to set priorities among the many available mechanisms to address major global challenges. A panel of 8 eminent economists, including 3 Nobel Laureates, was asked to review commissioned papers on 10 identified global challenges and answer the question, “What would be the best ways of advancing global welfare, and particularly the welfare of developing countries, supposing that an additional $50 billion of resources were at governments’ disposal?”) In fact, in their characteristically modest way they concede that their paper does not break new ground; it uses recent evidence to confirm what others have concluded before them, namely that the economic argument for investing in nutrition is solid. Why then does nutrition action remain underresourced?

Why does the gap between evidence and action persist? Do nutritionists simply need to work harder, communicate smarter, advocate more ardently? Or is it institutional arrangements and leadership that need refreshing? Or could it be that the guiding frameworks and approaches of the field are out of touch with the complexities of the nutrition problems of the 21st century?

The focus of this article is on the economic evidence for investing in nutrition. It first presents the economic argument and demonstrates that the question, how much? is being answered thoroughly and convincingly. It then argues that this evidence is not matched by action, and that equal rigor must now be applied to the question. There are encouraging signs that this is beginning to happen. An adequate response to the nutrition challenges of the 21st century requires nothing less.
TACKLING THE CHILD MALNUTRITION PROBLEM

INVESTING IN NUTRITION MAKES ECONOMIC SENSE

The nutrition community owes a debt of gratitude to Behrmann and coauthors for representing nutrition so effectively in the Copenhagen Consensus. Based on detailed analyses and using conservative estimates and discount rates, they lay out a carefully argued and convincing case that reducing the prevalence of low birth weight (LBW), addressing infant and child malnutrition and breast-feeding promotion, reducing micronutrient malnutrition, and investing in technology for agriculture in developing countries are sound development investment opportunities. The top economists who made up the Copenhagen Consensus panel concurred, and ranked the nutrition investments second, fifth, 11th and 12th among their recommendations for the best applications of a hypothetical $50 billion in additional development assistance (Table 1).

A person who is not an economist can hardly do justice to the intricacies of the economic theory underlying this work, and the detailed analysis used to arrive at the Copenhagen Consensus conclusions is beyond the scope of this article. Nevertheless, it is incumbent on nutritionists to speak the economists’ language if they want a seat at the table when resource allocation decisions are made. This article, therefore, attempts a brief overview of the economics of child nutrition from a practitioner’s perspective before turning to the pressing issue of turning evidence into action.

The following section explores 4 key economic questions related to child malnutrition. First, it explores the relationship between nutritional status and economic productivity. Then it asks what it costs to improve nutritional status, and whether the benefits from improving nutritional status outweigh the costs. Given the private benefits to investing in nutrition, it then asks whether public investment to improve nutritional status is justified on economic grounds. Finally, it weighs the aggregate cost to society of removing malnutrition as a public health problem.

<table>
<thead>
<tr>
<th>TABLE 1. Copenhagen Consensus: ranking investment opportunities (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project rating</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Very good</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>Good</td>
</tr>
<tr>
<td>4</td>
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<tr>
<td>5</td>
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<td>11</td>
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<td>12</td>
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<td>13</td>
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<tr>
<td>14</td>
</tr>
</tbody>
</table>

WHAT IS THE RELATIONSHIP BETWEEN NUTRITIONAL STATUS AND ECONOMIC PRODUCTIVITY?

It is well known that the relationship between nutritional status and individual productivity is bidirectional, that the pathways are complex, and that different nutritional conditions have different effects. Figure 1 provides a framework for understanding these relationships (Behrmann et al. [2004] make the point that we can make more accurate estimates by tracing causal relationships rather than associations. This involves controlling for endogeneity, in other words, they attempt to isolate the impact of nutritional status per se on the outcome variable in question, rather than merely capturing associations between variables. [Nutritional status may be an indicator for some other condition, for example, unknown intrahousehold dynamics, rather than being the factor which itself has a direct impact on the outcome variable, such as cognitive development]).

Other articles in this supplement lay out the extent and causes of malnutrition, detail the impact of malnutrition on physical and cognitive development, and propose effective intervention strategies. The present article briefly reviews the pathways through which nutritional status influences economic productivity, and presents consolidated information on economic losses caused by malnutrition. The key pathways are increased morbidity and mortality, health care costs, and productivity losses resulting from learning and schooling deficits and reduced stature. Based on the available literature, this article provides evidence that the benefits of addressing malnutrition conditions outweigh the costs of nutrition programs and considers the implications of these findings.

The focus is on fetal and young child malnutrition, given that the earliest years of a child’s life represent the period in which nutritional requirements per kilogram of body weight are highest, when the child is most
susceptible to infection, and when insufficient food, care and health have the most debilitating effects on growth and cognitive development. Furthermore, growth faltering at that time is at best only partially overcome later in life (3).

**Malnutrition, Morbidity and Mortality and Health Care Costs**

The synergy between malnutrition and infectious diseases is well established (4). In a widely quoted study, Pelletier and coworkers (5) estimated that 56% of child deaths can be attributed to the potentiating effect of malnutrition (including LBW), with most of those deaths linked to mild or moderate malnutrition, rather than severe malnutrition. Although severely malnourished children are more likely to die, they are far fewer in number. Children with mild, moderate or severe malnutrition would be, respectively, 2.5, 4.6 and 8.4 times more likely to die than children whose weights are within the normal range for their ages. Not only can a significant proportion of child deaths from common infectious diseases be attributed to malnutrition (measles, 44.8%; malaria, 7.3%; diarrhea, 60.7%; and pneumonia, 52.3%) but malnutrition also increases the likelihood of having an attack of malaria, diarrhea or pneumonia (but not measles) (6). There is also increasing evidence that fetal malnutrition predisposes to the metabolic syndrome later in life (7).

Behrman and coworkers (1) review a number of studies, which identify low birth weight as a significant contributory factor in neonatal and infant deaths. In an analysis of 12 national data sets, including those from Guatemala and India, it was found that a full-term infant weighing 2000 to 2499 g was 4 times more likely to die in the neonatal period than an infant weighing 2500 to 2999 g and 10 times more likely than an infant weighing 3000 to 3499 g. In the postneonatal period, these ratios were 2 and 4, respectively. With LBW, genetic rather than nutritional factors may play a greater role in mortality. A study in the United States found that genetics played an important role in neonatal death rates, but was less significant after 28 d. The study observed a 14% decrease in mortality, with a 450-g increase in body weight at birth.

With regard to micronutrient malnutrition, eliminating vitamin A deficiency can reduce mortality from all causes in children 0 to 4 y old, by \approx 13\% (8). Experimental field research found that twice-yearly supplementation with vitamin A reduced overall child mortality by 25% to 35% (9).

The value placed on saving a life has a significant impact on the calculated benefit to the society of averting LBW, reducing stunting or improving micronutrient status. Estimating the monetary value of a human life lost is controversial, however, and researchers have used a number of different approaches, none of which are without problems. One option is to use actual resource costs applied by a society to avert a death through an alternative technology (eg, measles immunization) rather than using an assumed “absolute” value a society may wish to ascribe to a life (1). Using this measure, Behrman et al. arrive at an average estimate of $1250 for saving an infant’s life in a developing country. The problem with this approach is that it would place a lower value on the life of a child in a country with a poorly developed health infrastructure than in a country with a sophisticated health care system. An alternative approach, proposed by the Copenhagen Consensus (2), is to assign an
among countries country comparisons are made difficult by the differences/city use at a cost in the US of higher risk for future hospitalization and outpatient facil-

hospital stays where births occur in hospital settings and LBW (not all caused by malnutrition) results in longer review of studies on the cost of LBW (1) conclude that health care costs through a number of mechanisms. A it would represent only 20 adult-years of earnings.

Countries with higher wage rates of for example $5000/y, average adult wage of for example $500/y would be saving a child factor of 80, but has the unrealistic implication that increases the benefits of averting a death from LBW by a arbitrary value of $100,000 to a life. Such a valuation

mortality and reduced productivity in adulthood. Malnutrition, Schooling, Learning and Productivity

Malnourished children tend to start school later, progress less rapidly, have lower attainments, and perform less well on cognitive achievement tests, even into adulthood. These indirect effects of malnutrition on productivity are substantially more than the direct effects of height on schooling and hiring.

Malnourished children may receive less education than their well-nourished peers for a number of reasons. Caregivers may invest less in their education or schools may use physical size as a rough indicator of school readiness, and thus bar children of short stature from entering school at the appropriate age. Malnourished children are also sick more often and so absent more often, and learn less well when they are in school. Studies show that delayed entry to school leads to lower expected lifetime earnings because of fewer years in the workforce (1).

In addition to its impact on adult productivity through less schooling, severe malnutrition also affects learning capacity or cognitive development directly; with consequent impact on schooling productivity and labor productivity. Birth weight and breast-feeding both correlate with cognitive development; malnourished children perform poorly on cognitive tests, have poorer psychomotor development and fine motor skills; have lower activity levels, interact less frequently with their environments and fail to acquire skills at normal rates (10).

Malnutrition, Stature and Earnings

As indicated earlier, growth deficits in the first 2 to 3 y of life are only partially regained during childhood and adolescence, particularly when children remain in poor environments. Stature at age 3 is strongly correlated with attained body size in adulthood in several countries (11,12). In Zimbabwe, Alderman and coworkers (13) found that children exposed to drought at ages 12 to 24 mo were malnourished in later childhood, whereas children who were older during the drought were not, suggesting that early childhood malnutrition (during the 12- to 24-month window) is not easily reversed. Several studies (14–17) found associations between smaller stature in adulthood and reduced earnings. In a study in urban Brazil, for example, a 1% increase in height corresponded to a 2% to 2.4% increase in wages and earnings for women and men in the market sector (18).

Table 2 summarizes findings from several studies on productivity losses resulting from deficits in cognitive ability, schooling and stature in Asian countries (19).

Malnutrition and National Economic Productivity

Several studies have attempted to express the impact of nutritional factors on individual productivity in terms of national economic productivity. These estimates are useful to graphically demonstrate the impact of malnutrition and have been used effectively in advocacy campaigns. They are based on a series of assumptions about the linkages between individual productivity and national productivity, and often do not take account of other intervening variables, such as infrastructure development, including health and schooling, and are therefore more difficult to substantiate. Because of these limitations, authors are generally conservative in their estimates. Table 3 provides a summary of findings from a number of studies in India, Pakistan, Bangladesh and Vietnam (19).

WHAT DOES IT COST TO IMPROVE NUTRITION? DO THE BENEFITS OUTWEIGH THE COSTS?

Doing cost calculations as part of an impact evaluation of direct and indirect approaches to improving nutritional

<table>
<thead>
<tr>
<th>Table 2. Summary of productivity losses associated with malnutrition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of malnutrition</td>
</tr>
<tr>
<td>----------------------</td>
</tr>
<tr>
<td>Protein–energy</td>
</tr>
<tr>
<td>malnutrition</td>
</tr>
<tr>
<td>Iron deficiency</td>
</tr>
<tr>
<td>Vitamin A deficiency</td>
</tr>
<tr>
<td>Iodine deficiency</td>
</tr>
</tbody>
</table>

**TABLE 3.** Estimates of productivity costs of malnutrition (19)*

<table>
<thead>
<tr>
<th>Country</th>
<th>Stunting</th>
<th>Iodine deficiency</th>
<th>Iron deficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>1.4</td>
<td>0.3</td>
<td>1.25</td>
</tr>
<tr>
<td>Pakistan</td>
<td>0.15</td>
<td>3.3</td>
<td>0.6</td>
</tr>
<tr>
<td>Vietnam</td>
<td>0.3</td>
<td>1.0</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Losses including childhood cognitive impairment associated with iron deficiency

<table>
<thead>
<tr>
<th>Cognitive only</th>
<th>Cognitive + manual work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>1.1</td>
</tr>
<tr>
<td>India</td>
<td>0.8</td>
</tr>
<tr>
<td>Pakistan</td>
<td>1.1</td>
</tr>
</tbody>
</table>

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*Selected countries, as percent of gross domestic product.

status is a difficult and costly undertaking. Unfortunately, gathering cost information is not considered theoretically interesting by most academics (J. Hoddinott, personal observation), and has tended to be neglected. More attention is now being given to program evaluations, and programs are being encouraged to collect more detailed costing information. To specify the economic gains from better nutrition more accurately, accurate information on the costs and effectiveness of programs is needed.

Evidence compiled from available studies (1) indicates that the benefits of effective interventions to address key nutrition conditions exceed the programmatic costs by a considerable margin, even when a high discount rate is used to put less weight on the long-term benefits of the investment, and when the upper limits of cost calculations are used. Table 4 provides a summary of the calculated monetary value of benefits to be derived from specific measures to address malnutrition conditions, and the programmatic costs, based on the best-available information.

**IS PUBLIC INVESTMENT TO IMPROVE NUTRITIONAL STATUS JUSTIFIED?**

The benefits of investing in nutrition outweigh the costs but are not sufficient for motivating the use of public money for such activities. At first glance, one would argue that nutrition is a private good; after all, most of the benefit accrues to the individual in better quality of life, better education, better job prospects, and ultimately better lifetime earnings. However, there is often insufficient private incentive for families to invest in nutrition. This may be due to a lack of information on the benefits of good nutrition. If capital and insurance markets do not work optimally, families may also not see benefits in investing in young children’s nutrition. They may recognize that preventive action would not protect children from illnesses in the absence of proper affordable health care and sanitation. Furthermore, if unemployment is high and future employment prospects low, parents may not see the value of investing in their children’s growth.

The social benefits of investing in nutrition may be considerable. Improved nutrition may decrease the likelihood that communicable diseases will spread in a community. A novel perspective proposed by Harold Alderman (personal observation) is that in communities where malnutrition rates are high, short and thin children may be the norm, and parents may not recognize the need to attend to their children’s nutritional status. Under such circumstances, if some children in the community grow well, then the norm may indeed be challenged and begin to shift toward taller and sturdier children, with parents

**TABLE 4.** Benefits and costs of selected nutrition interventions* (1)

<table>
<thead>
<tr>
<th>Opportunities and targeted populations</th>
<th>Benefits (US$)</th>
<th>Costs (US$)</th>
<th>Benefits–costs (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reducing LBW for pregnancies with high LBW probabilities</td>
<td>580–986</td>
<td>200–2000</td>
<td>0.58–4.93</td>
</tr>
<tr>
<td>Treatments for women with asymptomatic bacterial infections</td>
<td>580–986</td>
<td>92–460</td>
<td>1.26–10.71</td>
</tr>
<tr>
<td>Drugs for pregnant women with poor obstetric history</td>
<td>580–986</td>
<td>28–280</td>
<td>4.14–35.20</td>
</tr>
<tr>
<td>Improving infant and child nutrition</td>
<td>5952–8929</td>
<td>133–1064</td>
<td>5.6–67.1</td>
</tr>
<tr>
<td>Breast-feeding promotion in hospitals</td>
<td>376–653</td>
<td>40</td>
<td>9.4–16.2</td>
</tr>
<tr>
<td>Integrated child care programs</td>
<td>280–400</td>
<td>0.58–5.0</td>
<td>15–520</td>
</tr>
<tr>
<td>Intensive preschool programs with nutrition for poor families</td>
<td>44–50</td>
<td>0.25</td>
<td>176–200</td>
</tr>
<tr>
<td>Reducing micronutrient deficiencies</td>
<td>82–140</td>
<td>10–13.4</td>
<td>6.1–14</td>
</tr>
<tr>
<td>Iodine (per women of childbearing age)</td>
<td>75–130</td>
<td>0.25–5.0</td>
<td>15–520</td>
</tr>
<tr>
<td>Vitamin A (preschool children &lt;6 y)</td>
<td>37–43</td>
<td>1–10</td>
<td>4.3–43</td>
</tr>
<tr>
<td>Iron (per capita)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>44–50</td>
<td>0.25</td>
<td>176–200</td>
</tr>
<tr>
<td>Iron (pregnant women)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>82–140</td>
<td>10–13.4</td>
<td>6.1–14</td>
</tr>
<tr>
<td>Dissemination of new cultivars for higher yields</td>
<td>8.8–14.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dissemination of iron- and zinc-dense rice and wheat varieties</td>
<td>11.6–19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dissemination of vitamin A–dense “golden rice”</td>
<td>8.5–14</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Estimates are based on extensive assumptions, subject to considerable uncertainties, and are indicative only. Discount rates of 3%–5% apply.
finding reasons to invest in their children’s nutrition, in line with the new norm. It can also be argued that in cases in which governments are already investing substantially in education and health services, investment in nutrition can help to improve the efficiency of those investments and is therefore justifiable on efficiency grounds.

If a policy objective is to achieve greater equality through the use of public funds, then a finance minister will be interested to know whether investing in nutrition would benefit the poor at least as much as or more than the wealthy. Given that malnutrition rates are higher among the poor than the rich, it may be argued that the benefits of malnutrition reduction initiatives are likely to be concentrated among the poor. Of course, although nutrition programs can have this impact, the design and implementation of the programs themselves will determine whether they are in fact pro-poor.

CAN SOCIETY AFFORD IT?

Having made the case that it makes economic sense to invest in improving children’s nutrition and that cost-effective intervention approaches exist, the question remains whether countries and society at large can afford the outlay needed to address malnutrition. What will it cost?

A number of recent initiatives have included total cost estimates for selected interventions and countries. Given the uncertainties that surround these numbers, they are best used as indicative figures. What they suggest is that for most interventions, the costs are affordable to the global community. How they will be financed and specifically, how to deal with recurrent costs and building sufficient implementation capacity to absorb the additional development financing are hotly debated topics in the broader development community.

A study for the Millennium Project Task Force on Hunger (20) provides estimates for a 10-year global investment program. The study concluded that an annual investment of between $2.8 and $5.3 billion would provide broad coverage with vitamin A and iron supplements, fortification of commonly consumed foods, and community-based action in countries with the highest levels of childhood malnutrition (Table 5) (20).

Using different assumptions and cost estimates, the analysis for the Copenhagen Consensus (1, 2) estimated that it will cost about US$ 2.8 billion annually to reach 25% of eligible mothers and children with interventions to improve LBW, improve infant and child nutrition and provide micronutrient supplementation and fortification to vulnerable groups. The authors estimate that it would become progressively more expensive and administratively more challenging to reach vulnerable groups, as malnutrition rates improve.

### TABLE 5. 10-y nutrition investment program cost estimates (20)

<table>
<thead>
<tr>
<th>Micronutrient supplementation</th>
<th>$billion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin A for under-5s at $1.50/child (full coverage)</td>
<td>7.5–15.00</td>
</tr>
<tr>
<td>Iron folate/pregnancy at $14/pregnancy at 50–100 million pregnancies</td>
<td>7.0–14.00</td>
</tr>
<tr>
<td>Integrated IDD control</td>
<td>1.0–1.5</td>
</tr>
<tr>
<td>Micronutrient fortification</td>
<td></td>
</tr>
<tr>
<td>Wheat flour</td>
<td>0.85</td>
</tr>
<tr>
<td>Maize meal flour</td>
<td>0.84</td>
</tr>
<tr>
<td>Cooking oil</td>
<td>0.70</td>
</tr>
<tr>
<td>Biofortification</td>
<td>0.15</td>
</tr>
<tr>
<td>Community-based health and nutrition programs</td>
<td></td>
</tr>
<tr>
<td>Focus: South Asia and priority 12 sub-Saharan African countries</td>
<td></td>
</tr>
<tr>
<td>100 million children × 2 y at S5–S10/y</td>
<td>10.0–20.0</td>
</tr>
<tr>
<td>Total</td>
<td>28.0–53.0</td>
</tr>
</tbody>
</table>

For fortification programs, the public sector share is estimated to be <25% of the total cost. IDD indicates iodine deficiency disorders.

Can we afford to stop malnutrition? (21) (Table 6), it is evident that money is not the limiting resource in achieving global nutrition goals.

### HOW IS THE ECONOMIC EVIDENCE FOR NUTRITION INVESTMENT BEING USED?

How many more studies and reviews documenting nutrition as a sound investment are needed before investment in nutrition will increase substantially? There are a

### TABLE 6. Can we afford to stop malnutrition? (21)

<table>
<thead>
<tr>
<th>Annual expenditure, $billion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cosmetics in the US</td>
</tr>
<tr>
<td>Ice cream in Europe</td>
</tr>
<tr>
<td>Perfumes in Europe and the US</td>
</tr>
<tr>
<td>Pet foods in Europe and the US</td>
</tr>
<tr>
<td>Cigarettes in Europe</td>
</tr>
<tr>
<td>Alcoholic drinks in Europe</td>
</tr>
<tr>
<td>Military spending in the world</td>
</tr>
</tbody>
</table>
number of cases in which economic data were effectively used to increase investment in nutrition. For example, beginning in 1975, Berg skillfully used economic data to show that nutrition programs could be seen as investment rather than simply consumption and thus stimulated World Bank investment in nutrition (22). The use of the Modeling Program Profiles to estimate the economic cost of malnutrition, in Bangladesh for example (23), has also been credited with helping to convince policy makers of the need to invest in nutrition. However, as mentioned earlier, Behrman and coworkers (1) point out that in spite of the evident favorable cost–benefit ratios for nutrition programs, investment in nutrition remains stagnant.

Is more of the same needed? Should nutritionists try to convince ministers of finance and heads of development agencies of the economic merits of dealing with malnutrition and of investing in proven, cost-effective interventions? Yes, indeed, they should. Nutritionists need to be economically literate, able to speak with economists and finance ministers and understand enough of their language to speak with confidence in their forums. They need to make the arguments with country-specific data, offer solutions based on sound evidence, emphasize the short- and medium-term benefits, and not overstate the case. In particular, it is important to stress the need for complementary developments, including programs to improve women’s status, address infectious diseases and improve water and sanitation as well as employment and income growth; otherwise families will not be able to take advantage of the benefits that accrue from improved nutrition. Furthermore, the figures seldom speak for themselves; skillful advocacy and careful timing helped to lead from evidence to action in the cases cited above.

Will more of the same be enough to address the evidence-action gap mentioned earlier? Unfortunately, there are several factors that make the task of increasing action on nutrition difficult and contribute to the intractability of the global nutrition problem. For example, the interests of policy makers and their constituencies may be remote from the interests of poor women and children. Even in families, children and women may have too little voice to be taken into consideration when families make decisions about allocation of resources. Nutrition must compete for attention with sectors that are better organized and institutionalized. It shares with other preventive approaches the characteristic that the problem, and its benefits when removed, is generally not immediately visible. “Slow, silent catastrophes” simply do not generate and maintain public interest the way crises do (24). The list goes on, and the literature is replete with conjecture about the causes of the gap between evidence and action and the need to close it. It is time to stop mentioning the evidence-action gap as the footnote to learned papers and talks and start doing something about it, and in the process, developing a deeper understanding of the problem. As Kurt Levin has said, “You cannot understand a system unless you change it” (25).

In 1992, Alan Berg noted the gap between evidence and action. He proposed that more attention needed to be given to implementation capacity, and he called for the development of a cadre of “nutrition engineers” who would help to resolve the implementation issues that hampered the successful realization of lofty nutrition policy goals (26). In a similar vein, Heaver (27) proposed systematic attention to building organizational capacity to address the evidence-action gap in nutrition. It is imperative that capacity development and organizational arrangements for nutrition be addressed in a more systematic manner. Organizational arrangements through which nutrition policy decisions are made and implemented at global, regional and national levels are changing. For example, civil society and nongovernmental organizations have become key actors, as has the private sector. The new reality is that the complex social challenges of the 21st century require that the 3 sectors of society (public, private and civil) find ways to work together toward solutions that would benefit all. Uncomfortable as it may be, given their different perspectives and ways of working, partnerships are the way forward for solving complex global problems (28).

In addition, there is a need to develop the nutrition policy process as a field of study. The same rigor should be applied to studying the policy process as is evident in epidemiological and economic studies of nutrition. A review of the current state of policy studies in nutrition shows limited activity and little coherence in this field. Most studies are of the case study variety and lack an explicit theoretical framework. In cases in which a theoretical framework is made explicit, the rationale for selecting the approach over another is seldom made clear (29). This rather haphazard approach means that studies are not building on one another, they are difficult to compare across studies, and progress in developing the field has been slow.

In contrast to other practice-oriented fields, such as rural development or social work, nutrition does not have a long history of theorizing about its policy and practice. Consequently, there is little vested interest in particular approaches and theories. There is therefore a great opportunity to find innovative solutions to the how question of the Introduction. By drawing on the most up-to-date literature and experience in other fields, as well as on practical experience of nutrition policy processes, robust and rigorous analytical approaches can be developed to understand how nutrition policy change processes work.

A number of recent initiatives suggest that nutrition is in fact on the cusp of a great leap forward on this front. For example, some are paying attention to the underlying assumptions informing nutrition science and suggesting that new paradigms are emerging. The New Nutrition
Science Project, a joint undertaking of the International Union of Nutrition Sciences and the World Health Policy Forum, has set itself the task of “redefining policy research programs.” This initiative should provoke lively discussion and help to shape the conceptualization of nutrition theory and practice. Others are addressing the policy process directly. Thus, nutrition policy researchers (29,32) have proposed that the policy sciences approach (33,34) be adopted as a meta-framework for policy research programs. The policy sciences approach is comprehensive, covering such dimensions as social processes, decision processes, and problem orientation. It makes explicit the role of the policy analyst and promotes the use of multiple methods, acknowledging that there are multiple ways of knowing, and that moral goals are inherent in the policy process. Closer to the field, still others are applying new thinking on complex social problem solving to nutrition. For example, in India, UNICEF, in collaboration with Synergos and Hindustan Lever, are working with local stakeholders in the state of Maharashtra to test a social technology for solving complex social problems (35). The technology, known as the U-Process draws on phenomenology, dialogue and collaborative action research to develop a shared understanding of systems and the capacity to design innovative solutions together and implement them (36). Innovations like these in the areas of the field’s basic assumptions, its policy processes and social change technologies are a rich resource for learning to answer not only the what, the why and the how much of nutrition, but also the all-important action question, how, to achieve the desired nutrition goals.

CONCLUSIONS

Economic evidence reviewed for this article indicates that it makes sound economic sense to invest in improving the nutritional status of young children. The question of how much is being answered thoroughly and the evidence is convincing. Not only are the returns on investment in terms of improved health, education, and productivity substantial but addressing malnutrition is also clearly cost effective and affordable. Because this evidence is not being matched by action, it is now necessary to focus on the how question, to ensure faster progress toward a malnutrition-free world. There are encouraging signs that this is beginning to happen in innovative programs and global initiatives. The nutrition challenges of the 21st century require nothing less.

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Successful Food-Based Programmes, Supplementation and Fortification

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ABSTRACT

This review highlights interventions and delivery mechanisms to alleviate macro- and micronutrient deficiencies in preschool children. These deficiencies can be addressed through an integrated combination of improved dietary intake, supplementation, commercial and home-based fortification of complementary foods. Several developed and developing countries have implemented successful approaches to eliminate protein-energy malnutrition and micronutrient deficiencies with sustained impact. These include provision of oral supplements in capsule, tablet or syrup form. Certain micronutrients (e.g., vitamin A) can be provided as high-dose supplements twice per year. Most other vitamins and minerals (e.g., iron, zinc, iodine) need to be provided in daily doses. Fortified complementary foods provided through public feeding programmes and commercially marketed foods have also made a positive impact. There is growing evidence of the impact of home-based fortification of complementary foods using premixes in single-serving sachets. The fortification of commercially marketed staple foods such as cereal flours, cooking oils and dairy products could have a small but significant impact on preschool children. Cereal flours with iron, folic acid and other nutrients have expanded rapidly, with evidence of impact. A key need is to deliver micronutrients to remote and impoverished populations in an affordable and sustainable manner. Government commitment, clear policy and programme direction, advocacy and communication combined with a strong public–private partnership is essential for successful programmes. Often a period of voluntary fortification needs to be followed by mandatory requirement to ensure full compliance and sustained impact. The review concludes that proven technologies, communications and infrastructure can be harnessed to ensure that the nutrient needs of preschool children are met. When administered systematically with the commitment of and participation by the public and private sectors, most of the major deficiencies can be bridged on a sustained basis, contributing to improved health and well-being of millions of children around the world. *JPGN 43:S47–S53, 2006.* Key Words: Micronutrient deficiencies in preschoolers—Targeted public programmes—Commercially marketed foods—Food industry policy—Mandatory/voluntary enrichment.

INTRODUCTION

It is now well established that the major damage caused by malnutrition takes place in the mother’s womb and during the first 2 y of life. This damage is often irreversible and causes lower intelligence and reduced physical capacity, which in turn reduce productivity, slow economic growth and perpetuate poverty. Countries risk a “lost generation” unless they improve nutrition addressing both protein-energy and micronutrient needs for preschool children, the stage of life when the body and brain experience maximum growth and development potential.

Protein-energy malnutrition, resulting in people being underweight or stunted, and micronutrient malnutrition continue to be major health burdens in developing countries. Such malnutrition prevents as many as one third of the world’s people from reaching their physical and mental potential. Malnutrition combined with a poor diet and infectious disease forms a vicious cycle, with 1 condition affecting the others. Consequently, malnutrition is the most important risk factor for the burden of disease in developing countries and is directly and indirectly responsible for about half of all deaths in young children (1). Although higher incomes and better food security improve nutrition over the longer term, malnutrition is not simply the result of food insecurity; many children in food-secure environments are underweight or stunted because of inappropriate infant feeding and care practices, poor access to health services or poor sanitation. Child nutrition is an essential element in human development and is best improved in the context of coordinated investments in primary health care and early and basic education.
Much more attention, therefore, needs to be given to the betterment of nutrition via an integrated combination of health and nutrition education, improved dietary intake, supplementation and commercial and home-based fortification of complementary foods and staple foods more broadly. There are proven and cost-effective methods available that can greatly accelerate the improvement in nutrition. In addressing malnutrition, a combination of interventions involving the promotion of breast-feeding, improving food availability and micronutrient bioavailability and increasing food consumption, food fortification and pharmaceutical supplementation will need to be emphasized and implemented in a complementary manner. These factors need to go well beyond conventional health and nutrition systems and be based upon enabling people and communities so that they will be capable of arranging for and sustaining an adequate intake of micronutrients, independent of external support. Strategies are necessarily multisectoral and integrated interventions with strong social communications, evaluations and surveillance components.

Optimally, we should be able to meet nutrient requirements through the food we eat. Maybe we will reach that goal one day, but we are not there yet. For several reasons—economic, geographic, social and cultural—this has not been a practical solution, and even if this were possible there are issues related to the lack of bioavailable minerals and vitamins from staple diets. This inability to meet energy requirements is exacerbated by commonly consumed foods and beverages, including rice, wheat, corn, legumes, tea and coffee being high in inhibitors and low in enhancers of micronutrient absorption. The objective of this review is to identify successful and effective interventions to alleviate malnutrition in preschool children.

**ADDRESSING MALNUTRITION THROUGH COMMUNITY-BASED PROGRAMMES**

The best window of opportunity for addressing malnutrition lies between pregnancy and 2 y of age. Improving maternal knowledge and care during pregnancy to address low birth weights, especially in Asia, and infant feeding and caring practices, such as exclusive breast-feeding and adequate and timely complementary feeding, are critical to improving nutrition outcomes. Well-designed and consistent nutrition education approaches aimed at changing specific practices are key. In addition, because moderate and mild malnutrition are not readily apparent, regular monitoring of children’s weights on a growth chart is important so that mothers know whether their children are growing properly and can see the benefits of changes in practices.

During the past 20 y successful programmes have been developed in several countries using a combination of nutrition education or counselling, either with or without growth monitoring, especially about maternal care and rest during pregnancy; exclusive breast-feeding and appropriate complementary feeding practices; education on how to care for sick children; and links to essential health services. Some programmes have also provided micronutrient supplements and/or food supplements for children and pregnant and lactating women; this, however, implies there is a need for good training and fostering counselling skills. The programmes are targeted to children < 2 y of age. Successful, large-scale child growth promotion programmes were established in the 1980s in India’s Tamil Nadu state, Indonesia and Thailand, and are ongoing in Bangladesh, Honduras, Madagascar and Senegal, among others. Such programmes led to a sharp decline in severe malnutrition in the first 1 to 2 y, with a slower rate of decline in moderate and mild malnutrition thereafter. A recent cross-country review of successful programmes concluded that they led to an average decline of 1 to 2 percentage points per year in rates of malnutrition in young children, 2 to 4 times the 0.5% rate calculated as the average secular trend in the absence of such programmes (2).

Malnutrition in young children is also being addressed in several countries through facility-based services such as the Integrated Management of Childhood Illness Program, developed in 1992 with the aim of prevention or early detection and treatment of the leading childhood killers. Although these programmes focus on treatment of childhood illnesses, they also emphasize prevention of illness through education on the importance of immunization, micronutrient supplementation, and improved nutrition, especially breast-feeding and infant feeding (3).

**SUPPLEMENTATION PROGRAMMES**

Oral supplements in capsule, tablet or syrup form provide immediate relief to vulnerable populations and age groups with special micronutrient needs (eg, pregnant and lactating mothers, preschool children). Certain micronutrients, such as vitamin A, can be provided as high-dose supplements twice per year. Most other vitamins and minerals (eg, iron, zinc, iodine) need to be provided in daily doses. In some cases supplementation for women during adolescence and through the childbearing years, especially during pregnancy, needs to be continued indefinitely.

A clear success story is the improvement in the vitamin A status of preschool children using high-dose supplementation. Vitamin A supplements lend themselves to distribution through a campaign approach because children require only 2 annual doses. Vitamin A supplementation (VAS) has been associated with a reduction in excess mortality of up to 35% among preschool children in populations in which vitamin A deficiency is endemic. In 1998 the World Health Organization recommended
administering VAS with routine and other immunization contacts as a way of integrating provision with other health services. As National Immunization Day campaigns became widespread, many countries integrated VAS and oral polio vaccine distribution, enabling large numbers of children to receive at least 1 VAS dose annually. At least 90 countries routinely provide vitamin A supplements to young children in developing countries. More than 75% of all young children in countries where vitamin A deficiency is known to be common received high-dose vitamin A capsules in 2002, compared to only about one third in 1994 (4). Countries as different as Nicaragua (5), Niger (6) and Nepal (7) have reached coverage levels >80%.

A good example that clearly establishes the effectiveness of VAS is Nicaragua, where coverage has gradually increased in both rounds since 1994 and levels >70% have been sustained since 1999, with levels >80% since 2003. The average coverage rate by round from 1994 to 2001 amounted to 78% in first rounds and 78% in second rounds. The latter is a remarkable achievement because obtaining high second round coverage rates has been a formidable challenge for many countries. Only 1% to 2% of the total coverage has been achieved through non-national health campaign routine health service distribution. A 2000 National Micronutrient Survey carried out about 4 months after the second health campaign of 1999, revealed a dramatic reduction (72%) in the prevalence of vitamin A deficiency in children 12 to 59 mo of age, from 31.1% in 1993 to 8.6% in 2000 (8). This significant improvement may be mostly attributed to the cumulative effect of VAS as a result of the consistently high coverage rates in children over the 6-y period preceding the survey, given the absence of other specific interventions during the same period. Successive rounds of supplementation may have gradually increased serum retinol levels over time.

As polio National Immunization Days phase out, or in some cases terminate abruptly, there is a need to develop alternative delivery mechanisms to ensure that VAS reaches all eligible children twice each year. (Recent assessments by UNICEF and the Micronutrient Initiative have found that many countries are working to implement integrated packages of health services for their populations, and phasing out “vertical programmes,” including stand-alone VAS distribution [unpublished data, 2004].) Governments and international institutions are turning to alternative supplement delivery channels as a means of sustaining these gains (eg, piggybacking on the Day of the African Child, World AIDS Day in Tanzania [H. Masanja et al., unpublished data]) or creating twice-yearly national micronutrient days, following the Philippines’ and Niger’s examples. Clearly, VAS must be more closely integrated with other interventions such as deworming, malaria prevention, and antenatal checks. The challenge is thus to ensure not only adequate reach with such packages but also to integrate VAS into protective child survival and health services in a sustainable manner.

Iron supplementation has proved more challenging than VAS because the supplement must be taken daily and sometimes has unpleasant side effects; consequently, there have been problems with the logistics of supply and sometimes with compliance among clients. As a result 40% to 60% of the children in most developing countries continue to suffer from iron deficiency anaemia and many more have functionally significant iron deficiency. Prevalence rates are particularly high and devastating in their functional consequences for children ages 6 mo to 2 y, when the brain is continuing to grow. Indonesia and Thailand are among the few developing countries that have made the most progress in reducing anaemia. In Thailand between 1986 and 1996, anaemia prevalence in pregnant women fell from 40% to 15.5% and anaemia in children ≤5 y old declined from 40.6% to 25.2%. Based on such successes, guidelines have been developed to guide effective iron supplementation programmes and replicate proven programme models (9).

In settings where the risk of zinc deficiency is high and where other strategies may be difficult to implement in the short term, the distribution of zinc supplements as prophylaxis may be considered. The efficacy of supplemental zinc to improve specific health outcomes among high-risk population groups has been well demonstrated in a variety of geographical settings. However, country-level assistance is required for the design and integration of zinc supplementation strategies within existing health programmes (10).

Given the multiplicity of deficiencies, the idea of providing multiple micronutrient supplements for infants and preschool children is appealing. More research is needed to identify both physiological and health outcomes and the relative value of alternative micronutrients and potential competition between them, from absorption to physiological outcome.

FOOD FORTIFICATION

Food fortification involves the identification of commonly eaten foods that can act as vehicles for ≥1 micronutrients and lend themselves to centralized processing on an economical scale. Fortification, when imposed on existing food patterns, may not necessitate changes in the customary diet of the population and does not call for individual compliance. It can often be dovetailed into existing food production and distribution systems. For these reasons, fortification can often be implemented and yield results quickly and be sustained over a long period of time. It can thus be the most cost-effective means of overcoming micronutrient malnutrition. The World Bank has reported that “No other technology offers as large an opportunity to improve lives
Food fortification is aimed to provide meaningful levels of the nutrient, usually 30% to 50% of the daily adult requirements, at normal levels of consumption of the food vehicle. The levels also need to take into account variations in food consumption so that the safety of those at the higher end of the scale and impact on those at the lower end are ensured. They should also consider proportioned intakes by young children to ensure efficacious and safe dosages.

The most successful global fortification experience is the fortification of salt with iodine. A number of countries have successfully iodized their salt supplies, thus reducing goiter and cretinism, preventing mental retardation and subclinical iodine deficiency disorders, and contributing to improving national productivity. There has been remarkable growth in salt iodization application globally during the past decade. A significant proportion of the populations in more than 110 countries have access to iodized salt (12). As of 2004 nearly two thirds of the salt consumed in the developing world is being iodized, protecting nearly 70 million newborns each year from the threat of mental impairment caused by iodine deficiency.

Many countries are progressing toward the goal of universal salt iodization. Most of the salt used for human and animal consumption in Latin America is iodized. Bolivia, Peru and Ecuador, formerly severely affected countries, are now free of iodine deficiency. In many Asian countries, including Bangladesh, China, Indonesia and India, salt iodization is rapidly gaining ground. In sub-Saharan African countries including Nigeria, Madagascar, Eritrea and Cameroon, salt iodization levels are >80%. Once established in a country, salt iodization is a permanent and long-term solution to the problem of iodine deficiency. Toxicity issues are negligible and cost considerations fairly small, amounting to only 1 to 3 cents per person per year. Although considerable progress has been made in streamlining control programs through salt iodization in several countries, producer compliance, quality assurance, logistic problems and bottlenecks remain. The challenge is to systematically identify and tackle these constraints through effective advocacy, social communications, monitoring of salt iodine levels, regulation and enforcement. Salt, which forms the ubiquitous part of our diets, can also carry a range of other nutrients including iron, zinc and vitamin A.

Fortification of other staple foods such as flour, oils, sugar, condiments, dairy products and a range of processed foods with other minerals and vitamins is also growing in the developing world. Potential food vehicles can be visualised as a 3-tiered pyramid (Fig. 1).

Fortifying less expensive staple foods at the base of the pyramid results in broader dissemination of micronutrients throughout the population, particularly in the poor. Also, because basic and value-added foods are processed from staple commodities, fortifying foods at the base of the pyramid results in fortifying products throughout the food chain. Often a period of voluntary fortification needs to be followed by mandatory requirement to ensure full compliance and sustained impact.

Cereals are important food vehicles for fortification. Although several foods could be used for carrying micronutrients, wheat flour and maize meal are excellent vehicles because they are staple foods in many parts of the world and exist as key ingredients in so many food preparations. When micronutrient deficiencies are population-wide and result from a combination of low intake and/or low bioavailability, fortification of commonly consumed cereal flours with iron, folic acid and other vitamins offers a number of strategic advantages because cereals flours are widely and regularly consumed, and mostly processed in centralized facilities with established distribution and marketing capacity. Costs of fortification range from 3 to 10 cents per person per year. For these reasons, cereal fortification has played a major role in improving the health of the world populations at large. Nearly 40 countries now fortify flour. In Latin America flour fortification covers significant numbers of people and sugar fortification has taken hold in Central America. There is growing interest and action on wheat flour fortification in south and southeast Asia. In Africa the fortification of wheat and maize flours with multiple nutrients has been made mandatory in South Africa and Nigeria.

Folic acid fortification of cereal flours is having a remarkable impact on reducing women’s risk of having a baby born with spina bifida or anencephaly. Food fortification was determined to be the best strategy for increasing blood folate levels because the critical period for adequate intake of folic acid is in the first weeks of pregnancy, before most women know that they are pregnant and begin taking supplements. In the United States the fortification of enriched cereal grain products with...
Fortified complementary foods began in 1996. By 1999 the National Health and Nutrition Examination Survey conducted by the Centers for Disease Control and Prevention found that the average level of folate in the blood of US women of childbearing age had almost tripled in 5 y (13). In Canada, where fortification of flour, pasta and cornmeal became mandatory in 1998, a study in Ontario showed that the incidence of neural tube defects had fallen to 0.8 cases/10,000 pregnancies, down from 16.2/10,000 in 1995 (14).

Developed countries have long fortified milk and breakfast cereals with vitamin A as well as other vitamins and minerals, but in developing countries sugar has so far been the most successful vehicle. Guatemala’s sugar fortification programme has virtually eliminated vitamin A deficiency. Significant reductions have also been noted in El Salvador and Honduras, where fortification was combined with supplementation (15). Sugar fortification and VAS were also combined in Zambia beginning in 1998, with demonstrated success in urban areas (16). In much of Africa and Asia the poor do not consume as much sugar as they do in Latin America, however, so other countries such as Nigeria, Morocco, Yemen, Bangladesh and Pakistan are experimenting with fortifying wheat flour or cooking oils with vitamin A.

FORTIFICATION OF COMPLEMENTARY FOODS

The fortification of commercially marketed staple foods such as cereal flours, cooking oils and dairy products could have a small but significant impact on preschool children. (Infants and children under the age of 24 mo consume a different dietary pattern than do older individuals.) There are no major differences in consumption among children ages 2 y and older. Industrially produced fortified complementary foods are recommended by pediatricians worldwide as an essential part of a nutritionally adequate infant diet beyond the age of 6 mo and are complementary with breast milk and home-prepared foods. Fortification, especially of iron and zinc, is essential to meet the micronutrient requirements of infants. Beyond the superior micronutrient content of industrially fortified complementary foods over home-prepared rice porridge and other traditional infant foods, this approach possesses advantages of delivering micronutrients of higher bioavailability, higher energy density and protein quality, not to mention safety and convenience.

From the food technology perspective, the challenge is to increase both the energy density of complementary foods and levels of micronutrients at an affordable price. From the public health perspective, we need a combination of proper regulation that protects infant health yet supports industrial innovation and strong public education on appropriate infant feeding practices and psychosocial care of the infant.

TARGETED FORTIFICATION THROUGH SUPERVISED PUBLIC PROGRAMMES

Fortification of foods that are targeted to vulnerable and low-income groups needs high priority. There are several opportunities in developing countries that if taken advantage of and applied could make a vast difference to millions of people suffering from micronutrient deficiencies.

Fortified complementary foods provided through public feeding programmes and commercially marketed foods have also had a positive impact. In some states in India food provided to children and to mothers under the Integrated Child Development Scheme in cooked or ready-to-eat form is micronutrient enriched. In Ecuador the Ministry of Public Health developed a complementary feeding programme that sought to prevent poor growth, anaemia, and other micronutrient deficiencies by targeting all infants and young children between 6 and 24 mo of age living under conditions of extreme poverty by providing micronutrient-fortified complementary foods such as Mi Papilla specifically designed to meet their unique nutritional needs (17). It contracted the production and distribution of the food to a private company through a competitive bidding process. This enabled the health workers to focus on providing health services and nutrition counseling. During health center visits for well- or sick-child care, coupons for the fortified complementary food are provided to eligible children. Mothers or caregivers can redeem these coupons for Mi Papilla at a nearby pharmacy or store selected by the community as the distribution point. At the final survey, the hemoglobin levels in children in the programme group were significantly higher and they were significantly less likely to be anemic compared with children in the nonprogramme group (27.6% vs 44.3%).

In Mexico under the Progresa programme, a large incentive-based development programme that today reaches 4.5 million families and included a nutritional component, children and pregnant and lactating women in participating households received fortified nutrition supplements, and the families received nutrition education, health care, and cash transfers. Progresa was associated with better growth in height and haemoglobin values among the poorest and younger infants (18).

Nutrition interventions are also an important component of social planning in Chile. Since the 1950s, the National Supplementary Food Program administered by the Chilean Ministry of Health through primary care health centres has provided free milk-based complementary foods to children from birth to 5 y. The monthly health care programme, which includes growth and development monitoring, breast-feeding promotion and...
immunization and education in nutrition, is offered in conjunction with the National Supplementary Food Program. Since 1999 the programme has delivered free of cost 2 kg/mo of a full-fat powdered milk to 70% of infants from birth to 18 mo. Lactating mothers consume this milk until their infants are weaned. The milk is fortified with iron, ascorbic acid, zinc and copper. The programme has helped reduce anaemia in Chilean infants from 21% to around 1% (19).

Where fortified foods are not available, there are multiple ways to deliver micronutrients to enable mothers to either add them to the cooking pot or to mix them into what they feed their infants. These food supplements are available as water-dispersible or crushable tablets, sprinkles or spreads that can be added to complementary foods just before feeding infants and young children. These supplements are designed to provide up to the full level of the Recommended Dietary Allowance for vitamins and minerals in a small volume at a low cost and are easily integrated into existing food practices.

Fortified lozenges, containing a combination of vitamins and minerals: vitamin A, vitamin C, zinc, iron and folic acid, offer a new approach to providing micronutrients to beneficiaries who are children between 2 and 5 y, adolescent girls and pregnant and lactating mothers. In India lozenges are distributed to children and mothers on a daily basis along with the regular supplementary food provided through the Integrated Child Development Scheme. The distribution is supported by a strong communications component imparted to the mothers. Some advantages of this approach are that distribution is simple, measured quantity of micronutrients can be ensured and compliance is high.

MICRONUTRIENT-RICH STAPLE FOODS

Breakthroughs in plant breeding and nutritional genomics could simplify and hasten the development of nutrient-rich varieties of crops. New efforts to enhance the micronutrient content of staple foods such as rice, maize, sweet potato, cassava, common beans and wheat that are consumed by poor people in developing countries through plant breeding are showing promise. Advanced biotechnology tools, such as genome mapping and marker-assisted selection, could enable us to identify, select, and transfer desirable traits, including those linked to high micronutrient content for nutrients such as iron, zinc and β-carotene, from 1 variety to another with or without transfer of genes across species (20). By producing plants that are dense in minerals and vitamins, a process referred to as biofortification, we could have crop varieties with improved nutritional content in the staple foods people already eat. This can be a feasible means of reaching malnourished populations in relatively remote rural areas with limited access to health programmes through which supplements are channelled or to commercially marketed fortified foods.

Research so far has focused on 5 crops: rice, wheat, maize, cassava and common beans and 3 nutrients: iron, zinc, and β-carotene. For all of these crops, there is adequate genetic variation in concentrations of β-carotene, other functional carotenoids, iron, zinc, and other trace minerals in varieties available in germplasm banks to increase micronutrient densities through conventional breeding by a multiple of 2 for trace minerals and by higher multiples for vitamin A. A new 10-year challenge programme of Consultative Group on International Agricultural Research known as Harvest Plus proposes to further increase the micronutrient content of these crops through conventional breeding, test their nutritional efficacy and then widely disseminate them in developing countries for adoption by farmers.

DELIVERY AND SUSTAINABILITY

A key need is to deliver and distribute micronutrients to remote and impoverished populations in an affordable and sustainable manner. Government commitment, clear policy and programme direction, advocacy and communication combined with a strong public–private partnership is essential for successful programmes. We have also realized that addressing malnutrition cannot happen through stand-alone vertical programmes. We have also become much more effective in inserting nutrition into broader health and social development goals, rather than wait for them to be addressed to serve the cause of nutrition. We must focus increasingly on intersecting micronutrient programmes with major development challenges. These challenges include HIV/AIDS, malaria, hookworm and reproductive health and emergency programmes. In addition, nutrition should be included on the agenda of important reproductive and child health initiatives. Vitamin A deficiency should be placed on the agenda of ophthalmologists. Similarly, iron deficiency needs to become a priority in early child development, school health and maternal health programmes.

A programming environment is emerging globally and at the individual country level. The move from projects to programmes, from financing and implementing vertical disease-specific projects to sector-wide approaches and budget support, as well as a reinvigorated focus on multisectoral action, poverty reduction and issues of equity, are part of this new environment. The role of civil society and the private sector is becoming more important in global health and nutrition. At the same time, progress on results has never been higher on the agenda of both development partners and developing countries. These changes call for new approaches in moving the nutrition agenda forward, accelerating the move from project to more coordinated programme approaches.
repositioning nutrition appropriately in country-development strategies, reorienting existing large-scale investments to maximize impact and improving implementation quality.

CONCLUSIONS

It is often said that malnutrition persists because of a lack of an expert consensus on its assessment and treatment coupled with weak policies and ineffective programs. These are only partial reasons. In the wider picture technological problems are not nearly as serious as operational ones related to making programmes work in communities where malnourished people live. Issues of demand, supply and logistics, communications and community participation, partnership building across a wide spectrum of players; both public and private, are equally important to ensure the success and sustainability of efforts to eliminate malnutrition in large populations. Many of these needs interact and are mutually reinforcing.

The reality is that policymakers are faced with overwhelming development challenges and limited resources to address them. Pathogenic environmental mycobacteria or micronutrient deficiencies are rarely at the top of the policy agenda. It is our task, therefore, to demonstrate to policymakers that with a small investment in micronutrient programs, countries can make tremendous inroads in reaching a number of other development goals including reducing infant and maternal mortality and building up health and immunity to infectious diseases. Through these actions the burden on the health care system can be reduced, improving the ability of children to benefit from education and school programmes in later years.

The time is right for a rededicated initiative to eliminate the global malnutrition problem. We have new technologies, improved communications, and an expanded public infrastructure through supervised feeding programmes. In parallel, by demanding the supplements and fortified foods that they need, consumers enable themselves to achieve their full social, physiological and economic potential. By eliminating malnutrition through complementary public-private-civic sector initiatives we can make an enormous difference to the health and well-being of millions of children around the world.

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Solutions to Nutrition-related Health Problems of Preschool Children: Education and Nutritional Policies for Children

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ABSTRACT

Objective: By reviewing the literature, lessons learned and experience regarding the nutrition-related health problems of preschool children, draw conclusions and make recommendations on education and nutrition policies for young children.

Results: The most common causes of under-5 mortality in low-income countries have been identified as neonatal disorders, diarrhoea, respiratory infections, malaria, measles, and in some developing countries, AIDS. More than half (56%) of all child deaths have underlying malnutrition and undernutrition as a contributing factor. Children must have optimal growth and physical and intellectual development to learn and achieve their potential in society. Solutions include both preventive and curative interventions at all levels and include both improved health and education systems. Recent focus has been on health systems interventions that address averting deaths by cause for the 42 countries that account for 90% of worldwide under-5 deaths (the majority in sub-Saharan Africa). However, parallel or multisectoral interventions must be addressed to all children at risk for death, poor health and compromised growth and development. Adequate health care and nutrition is a human right, legally established in the Convention on the Rights of the Child.

Conclusions: Improved health and nutrition will lead to enhanced economic development, but having a poverty focus appears to be essential, if poor people are not to be marginalized further. The HIV/AIDS pandemic illustrates this challenge clearly. The role of education, especially girls' education, in improved health and nutrition status of children and birth-spacing is now clear, as is improving women's status. Increases in female status and education have been estimated to account for half of the reduction in child malnutrition rates during the past 25 years.


INTRODUCTION

More than 10 million children younger than 5 y old die every year. If proven interventions were to be applied, then more than 60% of these deaths could be averted (1). A few countries account for a large proportion of all child deaths, with more than 50% of global deaths occurring in just 6 countries, and 90% of deaths occurring in 42 countries, most of them in sub-Saharan Africa and in south Asia (2). More than half of all deaths from infectious diseases have underlying malnutrition and undernutrition as a contributing factor (3,4).

Measures of poor access to food, undernutrition and poverty are also strongly correlated, so that countries with food insecurity also have high prevalences of stunted and underweight children. In these same countries, large numbers of people live in conditions of extreme poverty, struggling to survive on less than US$1/d. Although poverty is undoubtedly a cause of hunger, malnutrition and undernutrition, poor health and nutrition are also conversely causes of poverty. Numerous studies have confirmed that hunger seriously impairs the ability of the poor to develop their skills and reduces the productivity of their labour (5–9).

Poor nutrition and inadequate education have pervasive effects on health and well-being and addressing these will have both direct and indirect benefits for child survival, growth and development (5–9). Alleviating poverty and addressing geopolitical factors such as fair trade and debt relief must also be addressed if sustainable solutions are to be had (10). Although understandable, the decision of the Bellagio Child Survival Study Group (11), when they examined the reasons for sustained high levels of child mortality, not to address interventions with a more distal focus or ones that would normally be implemented by sectors other than health (eg, maternal...
eduction, reduction in crowding) meant that their suggested solutions were largely dependent on health facilities and systems (2). In many of the countries most affected these systems appear to be on the verge of collapse (12). Associated shortages of qualified staff are due to a severe “brain drain” to affluent countries (13), a high turnover and difficulty in training (14), as well as an infrastructure suffering from a lack of investment in countries where poor health care is the norm. Donors have not been investing in health systems, although this may be changing (15).

This article outlines the current burden of health and disease globally, especially as related to nutrition, with an emphasis on poorer countries. It then looks at the relationships between nutrition, ill-health and education, examines solutions policies directed at all 3 and finally suggests some solutions to nutrition-related health problems of preschool children, with an emphasis on education and nutrition policies. The underlying contention of the article is that the impacts of nutrition are bidirectional in terms of education (ie, improved education leads to improved nutrition and improved nutrition leads to better educational attainments). In turn, both of these lead to improved health and economic development. The title of the article implies a biomedical model of identifying nutrition-related health problems of preschool children, and then addressing them one-by-one. However, we believe that a broader approach is required for a sustainable and equitable improvement in both nutrition and education. To understand what the determinants of preschool nutrition are and to address these factors, it is necessary to also examine the health and nutrition of older children and adults, especially women. The article therefore addresses programs that improve education, adolescent and adult health and nutrition, and those including education that intervene at key stages of the life cycle, at critical “windows of vulnerability,” and that must be applied and supported at several levels of policy development and application (16).

CURRENT BURDEN OF ILL HEALTH AND DISEASE, WITH AN EMPHASIS ON NUTRITION

Nearly two thirds of deaths in the 42 countries occur in just 19 countries where the predominant causes are pneumonia, diarrhoea, and neonatal disorders (2). A World Health Organization (WHO) estimation in 2002 gave ≈15% as that part of the global burden of disease that can be attributed to the joint effects of childhood and maternal underweight and micronutrient malnutrition (17). A later estimation of the portion of global burden that would be removed by eliminating malnutrition is 32% (18). Because this was based on the effects of malnutrition on mortality and morbidity from infectious disease only, it is still a conservative figure, despite being higher than previous estimates, mainly through including micronutrient malnutrition, which was estimated to save 18% of the global burden of disease if it were to be eliminated.

So, what are the nutrition-related problems of preschool children mentioned in the title? As noted above, undernutrition is a contributing factor to mortality from infectious disease in more than half of all under-age 5 deaths. Other nutrition-related problems that have been shown to have an impact on growth, development and learning may be divided into 4 categories, further demonstrating the need for a life cycle approach. As seen in Table 1 factors act across the maternal and antenatal period, the infant and young child, at school, and the home environment.

For children under 5, undernutrition is caused directly by the interaction between a lack of nutritious food, the prevalence of common childhood illnesses such as diarrhoea and respiratory infections, and the impaired ability of caregivers to nurture their children because of resource or knowledge constraints. Eight of the 15 major risk factors of disease identified globally are nutrition-related: underweight, iron deficiency, vitamin A deficiency, zinc deficiency, high blood pressure, high cholesterol, high body mass index (overweight and obesity), and low fruit and vegetable intake (17). Child

<table>
<thead>
<tr>
<th>Categories</th>
<th>Nutrition</th>
<th>Education</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maternal and antenatal</td>
<td>Iodine deficiency</td>
<td>Mother’s education</td>
</tr>
<tr>
<td></td>
<td>Iron deficiency and other anemias</td>
<td>Mother’s health</td>
</tr>
<tr>
<td></td>
<td>Undernutrition of mother</td>
<td>Women’s status</td>
</tr>
<tr>
<td></td>
<td>Lack of adequate weight gain during pregnancy</td>
<td>Poverty</td>
</tr>
<tr>
<td>Infant and young child</td>
<td>Not breast-feeding</td>
<td>Hunger and attention and learning problems</td>
</tr>
<tr>
<td></td>
<td>Iodine deficiency</td>
<td>Play and lack of stimulation</td>
</tr>
<tr>
<td></td>
<td>Iron deficiency and other anemias</td>
<td>Educational level of parents</td>
</tr>
<tr>
<td></td>
<td>Undernutrition and inappropriate complementary feeding</td>
<td></td>
</tr>
<tr>
<td>School environment</td>
<td>Hunger (eg, lack of breakfast)</td>
<td>Poor facilities</td>
</tr>
<tr>
<td></td>
<td>Poor water and sanitation</td>
<td>Lack of stimulation</td>
</tr>
<tr>
<td></td>
<td>Helminths</td>
<td>Gender bias</td>
</tr>
<tr>
<td>Home environment</td>
<td>Poverty and food insecurity</td>
<td>Educational status of mother (and less of father)</td>
</tr>
<tr>
<td></td>
<td>Lack of stimulation</td>
<td>Lack of education information</td>
</tr>
<tr>
<td></td>
<td>Intra-household distribution</td>
<td>Lack of support/ appropriate home environment for study</td>
</tr>
</tbody>
</table>
Malnutrition is increasingly recognized to be largely determined during the period of foetal and infant growth, when maternal nutrition has its strongest influence. In policy terms, it is therefore necessary to recognize that women make up the majority of the world’s poor (19) and, in many situations, are particularly disadvantaged in terms of nutrition and health (20).

The UNICEF schematic provides a framework showing direct causes of undernutrition: food security, care, health systems and environment (Fig. 1) (9). It then depicts that distal forces such as the political environment are every bit as important. This is particularly true of the chronic nature of the nutrition problem. When siblings in poor families are close in age, they compete for these constrained resources as well as for maternal care, further increasing the likelihood of malnutrition in this high-risk group (21). In 2005, despite apparently abundant global food supplies, at least 120 million children under 5 suffered various forms of malnutrition. The devastating results included underweight children, stunted growth, more severe infections, physical and cognitive disabilities, and the premature death of nearly 6 million children each year from the underlying causes of undernutrition (2). Alarming, the main killers of children in 1980 were the same as they are today (22).

Undernutrition remains a formidable global development challenge because it is both a cause and a manifestation of poverty. *Malnutrition* is used here to address both the prevailing chronic epidemic of undernutrition reflected in underweight and stunting in children and the emergence of overweight and obesity; both affect the more disadvantaged people in most populations. Worldwide, more than 180 million children under age 5—nearly 1 in 3—are stunted or low height for age. Stunting, along with underweight, is implicated in more than half of all child deaths and is a major contributor to ill health and cognitive underdevelopment in children (23). About 1 billion adults in developing countries are underweight, and an estimated 1.6 billion are anaemic, contributing to lower resistance to infection.

**FIG. 1.** Causes of malnutrition (undernutrition and overnutrition) and death (9). * Resulting in malabsorption, bacterial overgrowth and nutrient loss in the gut.
impaired work capacity, and reduced economic productivity (24). In addition, foetal malnutrition threatens survival, growth, and development in childhood (6) and increases the risk of chronic diseases later in life (31,41).

**RELATIONSHIPS BETWEEN NUTRITION AND EDUCATION**

The first years of life, including foetal life, are the most important periods in terms of mental, physical, and emotional development. It is during these critical windows of time that most of the basic human capital is formed. It is also the time, between 6 and 24 mo of age, that most growth failure occurs (25). Periods of increased risk are found particularly at 3 to 6 mo and 9 to 18 mo (26,27). Problems in the 3- to 6-mo period are related to nonexclusive breast-feeding or not breast-feeding at all, and a too-early introduction of complementary foods and solids. Much of the risk at 9 to 18 mo is related to inadequacy of nutrients in complementary feeding, cessation of breast-feeding, and increases in diarrhoeal disease associated with exposure to pathogens in foods.

Stunting is associated with many negative outcomes, including increases in morbidity and mortality, lower achievements in school, reduced labour capacity and smaller adult stature (28), and in later life increased risk of chronic diseases such as diabetes, hypertension and heart disease (31,41). The ability of the older child who was formerly malnourished to learn, communicate, analyze and socialize effectively and adapt to new environments is profoundly affected by early nutritional status. Poor prenatal, infant, and child nutrition impedes behavioural and cognitive development, potential work productivity and reproductive health (29). Early intellectual damage due to anaemia, iodine deficiency, and chronic undernutrition in the infant and young child can only partially be reversed in later life (30). The damage to cognitive development and attainment of schooling among these children is likely to be long lasting. Early undernutrition also contributes to increased risk for chronic disease in adulthood (31,41). Women who were stunted as young girls can be subject to increased obstetric risk later in life and are more likely to have low birth weight babies.

Identifying the constraints to achieving gender parity in education, it is notable that mother’s education is a key determinant (ie, children whose mothers had no education are more than twice as likely to be out of school). Other factors include poverty and geographic location. The impact of inadequate nutrition and hunger on the ability to learn and concentrate has been conclusively shown (32–34). School enrollment, attendance, progression and learning capacity both improve with improved nutrition of the preschool- and school-age child (32,35).

Smith and Haddad (36) have convincingly demonstrated that in the 63 developing countries they studied, improvements in women’s education were associated with the reduction of malnourished children by 50% between 1970 and 1995. Many studies on women’s status and childhood nutritional status have demonstrated that a woman’s status has an impact on the nutritional status of her child (37). Because women with higher status (relative to men) have better nutritional status themselves, they are better cared for and provide higher-quality care to their children (38). Across countries, relative resources controlled by women tend to increase the share spent on education (39). Educated girls and women have fewer children, seek medical attention sooner for themselves and their children and provide better care and nutrition for their children (40). Education of poor girls and young women also helps reduce child and maternal mortality, enhances economic productivity, improves health and nutrition and protects girls from abuse, exploitation and exposure to HIV (35).

**NUTRITION AND EDUCATION PROGRAMS**

Programs addressing both nutrition/health and cognitive and physical development (and hence readiness for schooling) that have been evaluated and shown to have had some impact are briefly considered for both developed and developing countries in the following.

**Early Childhood Programs in Developed Countries**

Until recently it would have been considered somewhat unusual for programmes aimed at infants and preschoolers from developing and industrialized countries to be discussed in 1 paper. As noted from a WHO/FAO (Food and Agriculture Organization) report (41), increasingly problems of undernutrition, chronic diseases and food insecurity exist in all countries worldwide; in some of the poorer countries of the world, food insecurity and obesity are observed in the same households (42). Countries in Europe, particularly in eastern and northern Europe have long perceived a government’s obligation to ensure adequate nutrition for all children through the education system (eg, the “Oslo lunch”). In Australia and the United Kingdom, primary school-children in the 1950s received one third of a pint of milk every school day. The United States had a more targeted approach based on socioeconomic need. Other countries such as Chile started with programmes for all children, which were highly successful in a country that was poor at that time (43). Although it is recognized that obesity is now more of a problem than undernutrition, it is politically unacceptable to halt the programme (Uauy, personal communication), and which probably should not happen because it is more important to alter the kinds of foods being supplied to disadvantaged children. Here we briefly describe 2 major, US-based programs as...
illustrative of 1 possible approach taken by an affluent country.

The Special Supplemental Nutrition Program for Women, Infants and Children (WIC) is the largest supplemental nutrition program in the industrialized world serving ≈7.5 million participants annually. WIC participants are from low-income families, and the program targets pregnant, breast-feeding and non-breast-feeding postpartum women, and infants and children up to their fifth birthday. It provides supplemental foods, nutrition education and serves as an adjunct to health care. Pregnant women and preschool-age children receive ≈900 supplemental kilocalories per day from a food package including milk and/or cheese, eggs, cereal, juice and peanut butter. Breast-feeding mothers are given a somewhat larger package of supplemental food. Non-breast-fed infants receive iron-fortified formula and iron-fortified cereal. WIC is operated by the US Department of Agriculture (USDA) at the national level through local health centres and local health authorities at the community level.

The WIC program began in 1972 as a 2-year pilot project serving 100,000 people with a total budget of US$20 million. In 2004, WIC served 7.5 million people with an annual budget of US$5.235 billion in fiscal year 2005. Despite the exponential growth in the funding and participation in WIC, the program initially had a stormy history. In 1972 the USDA attempted to block the release of funds designated for WIC. A major argument against the creation of WIC was that evaluations of supplemental food programs in poor countries around the world had failed to demonstrate significant improvements in neonatal outcome or preschool nutritional status (44). Indeed, a later seminal report by Beaton and Ghassemi (45) of more than 200 supplementation schemes worldwide concluded that the programs were expensive for the benefit produced. Some policy makers therefore argued that the WIC program was unlikely to be effective in a country as wealthy as the United States. Ultimately the USDA was sued, lost the case and the WIC program was implemented.

From the mid-1970s to the mid-1980s a series of evaluations of the WIC program were conducted. Although each of the studies had different strengths and weaknesses, taken together they collectively indicated that WIC participation is associated with significant improvements in neonatal outcomes, haematological status, dietary intake and nutritional status. This body of evidence also concluded that the positive effects were most dramatic in the higher-risk individuals; thus the effects of WIC on birth weight and increased gestational age were most pronounced in teenage, underweight, and unmarried females, particularly those who smoked tobacco products.

Head Start (3–5 y olds) and Early Head Start (<3 y old) serve the same target low-income population as WIC and together are a comprehensive child development program that aims to prepare children for success in school by providing education, health, nutrition and social services components for children and their families. In addition to educational activities, Head Start provides meals and snacks, which provide at least one third of nutrition requirements. Children who arrive at Head Start without breakfast are given a morning meal. Infants and toddlers are given foods that are appropriate to their developmental needs. In 2000 Head Start served 857,664 children through 2060 agencies throughout the United States. The Head Start program has an ongoing monitoring system. The latest findings from 2004–2005 (47) indicate:

- Head Start preschoolers were twice as likely as non–Head Start preschoolers to use center-based care in 2003.
- The largest impact on cognitive development of children is in prereading skills. In a comparison of 3 and 4 y olds in Head Start to the lower risk cohort of all 3 and 4 y olds in the United States, researchers found that Head Start participation of 1 y cut the gap in cognitive skill levels to half of what would be expected without the program.
- Among the 3-y-old age group, the frequency and severity of behaviour problems reported by parents were lower for children in the Head Start group compared with children in the non–Head Start group.
- For both 3 and 4 year olds in Head Start, dental health was better than for non–Head Start children of a similar age.

The nutritional profile of the at-risk WIC population has changed from 1972 to the present day. Similar to the experience in Chile, problems of overweight and obesity are more common in the preschool population than underweight, low energy intake and nutritional deficiencies. Research is under way to identify new approaches combining WIC services to prevent overweight and obesity (46,48). The challenge will be that healthier, lower energy (calorie) foods tend to be more expensive per unit of dietary energy and if fresh, logistics and availability are often constrained in poor populations (46). Nevertheless, the evaluations have demonstrated the synergistic effects of such food-based interventions in improving cognitive skill levels while having a positive impact on health, nutritional and behaviour problems.

**Early Childhood Development Programs in Developing Countries**

Much of the work in developing and transitional economy countries has been relatively small-scale research or pilot studies. Chile and several centrally
planned economies have been among exceptions to this but have been, again except for Chile, relatively under-evaluated and rarely bought to scale (43,48). A review by WHO demonstrated the potential of combining interventions that enhance early childhood development and those that improve child health and nutrition into an integrated model of care. WHO was able to conclude this by reviewing a series of efficacy studies as well as scaled-up effectiveness interventions (34). The effectiveness studies included Integrated Child Development Services from India, Head Start from the United States, Services from India, Head Start from the United States, and the Tamil Nadu Nutrition Project from India (51). In Africa a large nutrition programme was initiated in 1982 in the Iringa region of Tanzania with the assistance of UNICEF and WHO and has since been partly replicated in many other African countries. The scheme addressed food production, infant physical growth monitoring and health-related activities. Communities and villages in the Iringa region set up their own day care centres, with the villagers paying from their own resources for up to 70% of the wages of the day care attendants. In 4 y the prevalence of moderate undernutrition dropped from 30% to 37% and that of severe undernutrition from 6% to 2%. Attendance at the weighing clinics rose from 25% to 80% (55,56).

The WHO review of interventions for physical growth and psychological development (34), since confirmed by other evaluations, was able to demonstrate from such large-scale programs the following:

- Nutritional interventions significantly improve physical growth in poor and malnourished populations.
Combined interventions to improve both physical growth and psychological development have an even greater impact in disadvantaged populations at risk for malnutrition.

Full-scale programs that include both nutrition and psychological components have been implemented throughout the world.

The effects of such combined programs are often greatest for children <3 y old and those who are most malnourished (eg, in Jamaica) (32), and these findings have obvious conclusions for policy.

It is important to define what the large-scale interventions require to be achieved at a minimum to be seen as successful. Purely in terms of growth, several critical studies have questioned the total success of the Tamil Nadu project and Bangladesh Integrated Nutrition Project because evaluations (internal and external) were not able to demonstrate significant improvement in nutritional status due to the interventions’ inputs. There were however, many other gains documented, particularly in terms of nutrition knowledge and practices of caregivers, antenatal care and immunisation coverage (53). Specific components such as child growth monitoring, strengthening the health infrastructure, health education, and women’s activities have had variable success. As in other nutrition success stories, government and community commitment are essential. Longer sustainability has been more difficult to ensure. The high levels of inputs required of the donor community can lead to failure when these cease, and thus larger antipoverty efforts are also essential. Environmental factors such as a tradition of local participation, supported by national policies that can improve basic equity, literacy, local governance and engagement are crucial for the success of such programs.

SOLUTIONS

If the reality were as simple as the title of this article, the solutions would not be still being discussed here. What we have done is to take an evidence-based approach on what may work. Some factors are clear: interventions need to be supported through all levels of policy and administration, integrated, properly financed and sustained. Successful examples, such as Chile (43) and other evaluations have shown various positive impacts (29,34,56–58). It is often the case that solutions are proposed that take a problem analysis and then make a link with a needs assessment. The loose relationship between the 2 analyses results in a long list of program and policy options. A more challenging task is to match the problem with the needs and then prioritise actions. It is important to be able to assist policymakers and programmers to respond to the problem analysis by developing models that show how the amount and allocation of funding is related to the achievement of goals, such as reduction of undernutrition prevalence and expansion of prevention of anaemia, and to outcomes such as improved growth and development.

Adequate and targeted human and financial resources are required (16,59), as well as improved ways to track such investments. As noted by the Commission on Macroeconomics and Health, a substantial proportion of the required funds for programs aimed at improving health and national development by addressing nutrition and education, amongst other inputs, could be largely mobilised from within the countries themselves; for a set of essential interventions costing $34/person/y and for all age groups, even the least-developed countries could raise $15/y by 2007, leaving $19 to come from international assistance (59). As also noted by the Bellagio Child Survival Study Group in 2003, human resources are at least as important as financial resources, especially at the country and community levels.

There are 4 levels of policy that will have positive effects on nutrition and education outcomes and the resultant additional and larger national impacts of such outcomes. As WHO has demonstrated, policies that promote integrated programs addressing nutrition and early childhood development have a synergistic outcome (34). These levels could be grouped as family/community (micro); district/health systems (meso); national policies (macro); and global (or mega) (Fig. 1, Table 2).

Family/Community

Family/community would correspond in Figure 1 to inadequate dietary intake and disease, as well as part of the underlying causes such as insufficient household food security and inadequate mother and child care. It has been demonstrated that an estimated 66% of the >10 million deaths among children under 5 y could have been prevented by interventions that are available today and are feasible for implementation in low-income countries at high levels of population coverage (2). Breast-feeding and oral rehydration therapy alone are estimated to be able to prevent 13% to 15% of all under-age 5 deaths, respectively. Complementary feeding could reduce 6% of all under-age 5 deaths, zinc to reduce diarrhoea and pneumonia deaths by 5% and vitamin A could reduce 2% of all under-age 5 deaths (60). Hence, among children living in the 42 countries with 90% of child deaths, this group of effective nutrition interventions could save about 2.4 million children each year (25% of all deaths).

The key long-term nutrition improvement lies in family and community action to prevent and treat undernutrition. This requires harnessing the resources of governments, civil society, and the private sector to empower individuals, families, and communities with knowledge and to support them with services, including universal access to reproductive health services. It also requires...
much greater emphasis on enhancing nutrition knowledge at the household level. This means increasing people’s access to both formal and informal sources of nutrition education and information. It also means standardising messages based on best practices, tailoring the communication method to local cultural norms, investing in the measurement of impacts, and systematising the use of information across all aspects of nutrition programming. Micronutrient deficiencies can be addressed through supplementation, home fortification and other food-based interventions. Public action should include strong community initiatives to support breast-feeding. The HIV/AIDS pandemic has illustrated that in resource-limited settings, exclusive breast-feeding by HIV-infected mothers may be lifesaving if done for the first 6 mo. Increasing women’s income and control over family assets is critical. Focusing on disadvantaged groups and ensuring opportunities for girls’ education will make a difference, as will efforts to address inequity in gender roles and women’s entitlements.

**District/Health Systems**

Policies and programs are needed that address the scaling-up of known positive household behaviours, including feeding practices, especially exclusive breast-feeding and appropriate complementary feeding (27), but also adequate micronutrient intake and appropriate intrahousehold food distribution, and health-seeking behaviours and knowledge. Insufficient household food security and mother

### TABLE 2. Matrix of possible nutrition intervention recommendations by the 3 levels of causation in Figure 1

<table>
<thead>
<tr>
<th>Immediate causes (family/community)</th>
<th>Underlying causes (district and national systems)</th>
<th>Basic causes (institutional/political/global)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inadequate dietary intake</td>
<td>Insufficient dietary quality</td>
<td>Formal and informal institutions</td>
</tr>
<tr>
<td></td>
<td>Inadequate household food security</td>
<td>Women’s status</td>
</tr>
<tr>
<td>Accessibility</td>
<td>Home gardening</td>
<td>Women’s education</td>
</tr>
<tr>
<td></td>
<td>Improved intra-household distribution</td>
<td>Inequities and discrimination</td>
</tr>
<tr>
<td></td>
<td>Home-based fortification</td>
<td>Inequities in global trade structure (eg, by</td>
</tr>
<tr>
<td></td>
<td>Biofortification</td>
<td>reducing agricultural subsidies in wealthy</td>
</tr>
<tr>
<td></td>
<td>Home gardens</td>
<td>countries)</td>
</tr>
<tr>
<td></td>
<td>Inadequate maternal and child care</td>
<td>Poor governance and corruption</td>
</tr>
<tr>
<td></td>
<td>Microcredit</td>
<td>Facilitative legislation for fortification</td>
</tr>
<tr>
<td></td>
<td>Nutrition education (especially females)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Targeted food subsidies</td>
<td></td>
</tr>
<tr>
<td>High levels of disease</td>
<td>Insufficient health services</td>
<td>Economic structure</td>
</tr>
<tr>
<td>Prevention</td>
<td>Strengthen health services by increased allocations (and donor)</td>
<td>Inequities and income disparities</td>
</tr>
<tr>
<td></td>
<td>Free access for very poor people</td>
<td>Global investment in agricultural/</td>
</tr>
<tr>
<td></td>
<td>Global measures (eg, to restrict recruitment)</td>
<td>horticultural research and development</td>
</tr>
<tr>
<td></td>
<td>Career structures for nutritionists</td>
<td>Inequitable impact of globalisation on very</td>
</tr>
<tr>
<td></td>
<td></td>
<td>poor people (eg, by explicitly pro-poor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>policies)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ensure appropriate private sector</td>
</tr>
<tr>
<td></td>
<td></td>
<td>involvement (eg, fortification)</td>
</tr>
<tr>
<td>Therapeutic</td>
<td>Child survival interventions, including neonatal actions such as micronutrients</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Appropriate complementary feeding</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Water and sanitation measures Reduction of discrimination and marginalisation</td>
<td></td>
</tr>
</tbody>
</table>

A more detailed discussion of intervention options can be found in publications from, eg, the United Nations (eg, FAO, UNICEF, WHO), projects of government bilateral agencies (eg, A2Z, FANTA; the Micronutrient Initiative) and international nongovernmental organisations (eg, HKI, Save the Children) (1,5–7,9,11,14–16,25,27,32,36,38,41,43,44,46,72).
and child care are reflected at this level, because although they have the most impact at the household level, the causes are usually beyond the control of the household.

Starting life as a low birth weight baby leads to poor child nutritional status and is directly related to the mother’s health before and during pregnancy. Expanding access to reproductive and antenatal health care and ensuring adequate nutrition has been conclusively demonstrated to greatly enhance the health of mothers and their children (61). Improvement of nutrition education delivered through health services has been shown to decrease the prevalence of stunted growth in childhood in areas where access to food is not a limiting factor (14). Conversely, food distribution serves as a strong incentive to use health care services (62).

Efforts to increase educating women and girls are essential. The provision of food to children at school is only the basic element of a school feeding program and will have only a relatively minor impact on nutritional status at that age. However, food for schoolchildren represents a contribution of food and nutrients as well as an income transfer for the family and often additional resources for the school and community. The primary objective of a snack or meal is to alleviate short-term hunger (63,64). Meals provided early in the day to alleviate hunger will result in children being more attentive and to children being enrolled for longer periods (32). Nevertheless, it is critical for a school to provide a minimum standard of educational quality for a snack or meal to be effective. Although school meals have been shown to improve enrollment and attendance (50,65,66), food alone is insufficient to bring about changes in educational outcomes. It is the combination of well-motivated and well-trained teachers, appropriate curricula, support and related materials, and infrastructure together with good nutrition and health care (eg, deworming, micronutrients) that translates into improved performance (63,64).

**National Policies and Actions**

Few of the above interventions will be effective in a nonsupportive environment. The supportive environment must be provided by functioning national governments or sometimes subnational or even district governance. The importance of supporting action at community and district levels can be demonstrated by the changes in iodine sufficiency when, for example, national legislation or regulations on the appropriate iodisation of salt are not enforced or are rescinded, as happened in India (which has wisely reimposed a national mandate that all salt should be iodized; Schultink, personal communication, 2005). Both formal (government) and informal (nongovernmental) institutions are essential, as is a functioning and responsible private sector.

In Thailand, where nutrition has improved remarkably, women enjoy high literacy, high participation in the labour force, and a strong place in social and household-level decision making. Within India, women have similarly better relative status in Kerala as compared to other states and the state has better health, social and nutrition indicators and, not coincidently, the highest levels of female education (67). There are other examples: Chile, Costa Rica, Cuba, Sri Lanka (and others), where even at relatively low per capita income, health indicators remain far better than in other countries with higher per capita incomes (15,68). Conversely, in settings that experience little nutrition improvement despite economic growth, social discrimination against women is common (67). In Pakistan, for example, widespread discrimination against girls and women is high and child malnutrition rates are among the highest in the world, as is the proportion of low birth weight infants, at 25% (67).

Poverty-oriented approaches are much more likely to be accepted in environments characterised by a strong commitment to equity among policymakers and programme managers. Developing and maintaining such a commitment to equity is more probable if policymakers, programme managers, and communities feel that they are being involved in policy formulation. Several types of monitoring and reporting can provide useful information for policymaking: the simple measurement of health status and programme use disaggregated by socioeconomic status, gender, or ethnic group; another is the establishment and monitoring of health objectives in terms of health status or service use among disadvantaged groups. Food distribution often does not have clearly stated objectives, lacking specificity and clear time frames (62). Nevertheless, a subsequent review of food supplementation programs by Ghassemi a decade after his earlier review (45) was much more optimistic. He considered food supplementation to be a further type of intervention, especially as an income distribution device, and for improving nutritional outcomes in the poorest people. The establishment of monitoring mechanisms to track progress among the targeted groups reinforces their effectiveness (69). Equity must be a priority in the design of interventions and delivery strategies, including accountability at national and international levels (69). The first goal of the Millennium Development Goals (MDGs), poverty and hunger reduction, should be brought together with the other goals, producing synergistic effects on under-age 5 y child survival and development through mechanisms already proven (16).

**Global**

The importance of both nutrition and education to a nation’s development has been acknowledged in the
importance given to these 2 sectors by the Millennium Declaration and the MDGs: 8 goals accepted by virtually all nations, affluent and least developed (40). Political, ideological and economic structures are seen as the most basic causes, and the causality is likely to be stronger with increasing globalisation. It is contended that by extending the coverage of crucial health services, including specific interventions, to the world’s poor, millions of lives each year would be saved, poverty reduced and economic development accelerated, and all of these results would help promote global security (59). International goals are 1 mechanism at this level; the MDG’s are partly an expression of humanitarian concern, but they are also an investment in the well-being of the rich countries as well as the poor (59). Malnutrition and disease breeds instability in poor countries, with rebounds to the security of rich countries. A high infant mortality rate was found to be 1 of the main predictors of subsequent state collapse in a study of state failure during the period 1960 to 1994 (59). International agreements and trade and other global agreements and laws can have both positive and negative effects on education and nutrition at the community level. At present, the evidence suggests (at least in sub-Saharan Africa) that the impact of these international trade laws have been largely negative for the poor (10). Others have also argued that 1 of the negative impacts of globalisation has been a substantial reduction of public spending, particularly in the areas of education and health care (70).

CONCLUSIONS

In terms of possible solutions, 4 levels have been discussed: (1) microlevel changes at community and household levels, especially in terms of gender equity and nutrition education and scaling-up of proven child survival interventions; (2) known and proven interventions at a district level, such as strengthening health systems and making them more effective and accessible; (3) national, such as pro-poor development and economic policies, policies towards parity in education and improved accessible health systems; and (4) global policy and the reduction of inequities (Table 2). To implement these proven interventions, there is a need to prioritise choices for interventions, apply them based on negotiated actions with the affected communities and individuals; and support them by appropriate policies and programmes. There is at this point no need to reinvent wheels. Differential rates of improvement in stunting were recently reported to be due to improved immunisation rates, improved water and sanitation and improved female literacy rate, as well as economic and agricultural variables, none of which is a surprise (71). Achieving the MDGs would address the nutrition-related concerns and educational needs (eg, cognitive development, forming social skills and preparedness for schooling) of under-age 5 y old children (16). The challenge, which is now being heard, for example, at the G8 Summit and at the UN High Level Plenary in New York, is whether resources and commitment will be sufficient.

Of the measurable health goals, the world is further from achieving the one for child mortality—a two-thirds reduction by 2015—than any other (72). Universal education may seem a relatively straightforward goal, but it has proven as difficult as any to achieve. So many countries around the world that will fall far short of the MDGs in the remaining 9 y to 2015 points to an urgent need to change course (73).

In conclusion, the reasoning and evidence above suggests the following:

- To accelerate economic development, it is necessary to improve health, nutrition, education and gender parity.
- To improve each one of these will have a positive impact on the others, and conversely, not addressing one will impede progress in another: consequently programs need to be integrated.
- Equity is both a right and an obligation, but it will also accelerate the development process. To ensure equity, governments must take an active role. Reliance on market forces alone is not appropriate when there are extremely poor populations and weak infrastructures for health, education and other systems. Consequently, both government and global commitment are essential.
- For improved outcomes in the under–age 5 y age group, there is a need to address life stages outside of this period, particularly maternal and antenatal health, nutrition and education; thus antenatal programmes are essential, as is breast-feeding promotion and appropriate complementary feeding. Accelerating programmes aimed at adolescents seems logical based on the available evidence, but further assessment of their impact is needed.
- Improvement of community involvement continues to be invoked, but is still infrequently done adequately; the same could be said of upfront planning for monitoring and evaluation.
- Biomedical or vertical models to address nutrition-related health problems are insufficient, although effective nutrition education and other nutrition interventions can be delivered successfully through health services.
- Structural and political changes are also needed to support interventions, as are adequate and consistent family, community and donor support.
- Although apparently not cheap, interventions such as those outlined above are cost-effective, especially when contributions to national economic development are assessed properly.
- The achievement of the MDGs remains an appropriate overarching policy goal to provide
solutions to nutrition-related health problems of preschool children.

REFERENCES


Priorities in Nutritional Rehabilitation

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ABSTRACT

This review examines nutritional rehabilitation and stresses nutrition prophylaxis or prevention because for school-age children, health promotion and disease prevention are the keys to a healthy childhood.

Key Words: Nutrition—Rehabilitation—Global risk factors—Malnutrition—Obesity—Iron deficiency anaemia. © 2006 Lippincott Williams & Wilkins

INTRODUCTION

Although the focus of this article is nutritional rehabilitation, “rehabilitation” suggests that the insult has already occurred and that an intervention is needed to ameliorate the problem. This review stresses nutrition prophylaxis or prevention because these are the keys to a healthy childhood.

Research on children in the preschool age range is limited, therefore, this article identifies the most important contributors to morbidity in preschool children. The 10 leading risk factors globally in terms of burden of disease they cause are shown in Table 1 (1). Together, these factors account for more than one third of all deaths worldwide. Of these 10 causes, 5 have direct relevance to preschool-age children, and 3 of the 5 are nutrition related. Clearly, nutrition has a huge bearing on the health of preschool-age children. The 3 nutrition-related causes include underweight, obesity and iron deficiency. This review focuses on these 3 conditions, on what the literature has to say about nutritional rehabilitation and prevention and what has been dubbed the “nutrition paradox” (2,3). This paradox is described as having underweight, obesity and micronutrient deficiencies in the same country, even in the same household at the same time.

UNDERWEIGHT

All ages are at risk, but underweight is most prevalent among children under 5 years of age, and the World Health Organization (WHO) estimates that globally 27% of children in this age group are underweight. It is estimated that underweight was associated with 3.4 million deaths in 2000, including about 1.8 million in Africa and 1.2 million in countries in Asia. Underweight is considered to exist as a contributing factor in 60% of all child deaths in developing countries (1). Excluding North America and western Europe, there is a strong gradient of increasing child underweight with increasing absolute poverty (see Fig. 1). The strength of the association varies little across regions. People living on <$1/d generally are at 2- to 3-fold higher relative risk compared with people living on >$2/d. Clearly, poverty or the eradication of poverty will have a huge impact on underweight in children.

The etiology of underweight and growth deficits has been widely studied. Underweight and growth deficits are linked to impairment in terms of physical work capacity, cognitive skills and increased risk of morbidity and mortality. Thus, as reflected in the WHO documentation, these 2 factors are important. Underweight in preschool-age children is a combination of low birth weight, inadequate quantity and quality of complementary foods, limited breast-feeding and limited variety of appropriate postweaning foods. Combined with these nutritional causes of underweight are environmental conditions that predispose to poor child care practices and recurring infections. A lack of sanitary conditions, especially clean drinking water and refrigeration, exist as the cause of recurrent enteric infections, which lead to anorexia and chronic poor food intake.
Although it has been argued that there is a genetic component to the poor growth of preschool-age children in the developing world, several lines of evidence suggest that environment, including the social, political and economic environment, and not genetics explains growth faltering and underweight. Indeed, the consensus of research is that physical growth and development are sensitive indicators of the quality of the social, political and economic environment (4). For example, changes in birth weight and growth of children who emigrate to the developed world tend to support the role of environment. Ramakrishnan and Yip have documented that the mean birth weight of Chinese infants born in China are lower than Chinese infants born in the United States (5). Chinese infants born in industrialized countries do not show the typical growth faltering seen at 4 to 6 months of age. Wheeler and Swee (6) studied Chinese infants living in London in the 1980s. The families provided traditional Chinese foods as well as popular English foods to their children. These children grew at a similar rate to their UK counterparts for the first 2 to 3 years of life. Secular growth changes also reflect the role of environment in determining growth potential. Secular changes in growth in Chinese children in both China and Hong Kong between the 1960s and 1980s suggest that environmental constraints affected growth in the past. Growth and development surveys of children under 7 years of age in China reported a marked increase in both weight and length of infants from 1975 to 1985. This improved growth was possibly the result of the better economy and food availability. During the same time period, a similar change was observed in 2- to 18-year-old Hong Kong children and adolescents. It is interesting to note that as early as the mid-1980s there was a tendency for Hong Kong Chinese children to be overweight.

The second example is the migration of Mayan refugees from Guatemala to the United States (4). Guatemalan Mayans illustrate the "genetics versus environment" argument because at one point in history, they were considered a "pygmy" people of the Americas. They are, in fact, not pygmies. Comparing the height of Mayan children in their home villages versus those who moved to 2 cities in the United States, they are taller, heavier and carry more fat and muscle mass than Mayan children living in Guatemala. Within the same generation, Mayan children ages 4 to 14 years old growing up in the United States average 5.5 cm taller than their age-peers living in Guatemala. It is believed that the short stature of a population is a proxy for an ecology for human development that results in nutritional deficiency, excessive energy expenditure and poor health. Migration, in many cases, breaks the cycle of poverty into which Guatemalan Mayans are born. The political economy of Guatemala in the mid-1990s created an ecology for human development that deprived most Guatemalan Mayans of sufficient food, health care, drinking water, education and other basic needs. At the same time, the political economy of the United States offered economic, nutritional, educational and public health benefits unavailable to most Guatemalan Mayans.

The sample in Florida and California described by Bogin and Loucky (4) is, on average, taller than any...
samples of low-socioeconomic-status Lados of Guatemala. However, this American sample of the children of refugees is still significantly shorter in stature than the other ethnic groups in the towns in which they live. These results suggest that human phenotypes change at different rates for different traits. The present generation of Mayan refugee children is likely to be in the first stage of a process of increasing stature from generation to generation. Classic examples of this secular trend in growth of migrant children and more recent follow-up studies of these same populations show that over time the height of each generation of the children of migrants continues to increase until it converges on that of the host population. Perhaps the best example of this phenomenon comes from Mexican immigrants to the United States who have become taller on average, with each generation, since the 1930s. The most recent generation of US-born Mexican Americans under 12 y old has mean heights that are equal to the National Center for Health Statistics references (7).

Much of the existing research on the factors influencing plasticity in human phenotypes focuses on the physical environment, for instance, the hypoxia of high altitude, the cold and heat of extremes in latitudes or the nutritional stress experiences in traditional agricultural communities. Often, little can be done to alter the physical environment and variation in human physical and behavioural phenotypes is ascribed to inevitable accommodations to them. However, all people live within social, economic and political environments that also have powerful effects on human phenotypes. It is the author’s hope that much can be done to change the social, economic and political environment to influence growth and undernutrition through peaceful change.

OBESITY

In his preamble to the 2002 WHO World Health Report, Dr Gro Harlem Brundtland stated, “Two of the most striking findings in this report are to be found almost side by side. One is that in poor countries today there are 170 million underweight children, over three million of whom will die this year as a result (1). The other is that there are more than one billion adults worldwide who are overweight and at least 300 million who are clinically obese. Among these, about half a million people in North America and Western Europe combined will have died this year from obesity-related diseases. Could the contrast between the haves and the have-nots ever be more starkly illustrated?” It has recently been suggested by Dr Benjamin Caballero that the combination of underweight in children and overweight in adults occurs at the same time in the same household in developing countries. He called this a nutritional paradox (2).

The nutritional paradox is most frequently found in developing countries undergoing economic transition. Nutritional transition may be defined as a country in the midst of changes in diet, changes in food availability and changes in lifestyle. These transitions typically occur in countries experiencing socioeconomic and demographic changes. Examples of these countries include Kyrgyzstan, Indonesia, Russia, Brazil and China. In such countries, as many as 60% of households with an underweight family member also have an overweight one, a situation that has been dubbed the “dual-burden household” (3). According to WHO statistics, among middle-income countries (ie, those with a per capita gross national product [GNP] of $3000/y), overweight ranks fifth among the top 10 causes of disease burden, right below underweight (1). This is the same position held by underweight as a cause of disease burden in the developed world.

Traditionally, obesity has been linked with affluence and abundance, whereas undernutrition has been linked with poverty. As Caballero has suggested (2), it was anticipated that as developing countries improved their economic status and their GNP, undernutrition would improve and obesity would become worse, especially among members of the upper socioeconomic classes. The relationship between the economic status of a country and the prevalence of obesity is not straightforward, however.

HEALTHY RISK FACTOR TRANSITION

The nutritional transition encompasses changes in a range of risk factors and diseases. Traditionally, the dietary energy intake of the poorest people in a country may be limited by their inability to purchase enough food and the high energy demands of manual labour and daily survival activities. It is difficult for this group to achieve a net positive energy balance and therefore to gain weight. In more urbanized developing countries with a higher GNP, widespread access to television and mechanism would favour sedentary activities and reduced daily energy expenditure. At the same time, as a country develops and more people buy processed food rather than growing and buying raw ingredients, an increasing proportion of energy tends to be drawn from sugars added to manufactured food and from relatively cheap oils. Alongside the change in diet, changes in food production and the mechanics of work and leisure result in a decrease in physical exercise. Thus, the consequent epidemic of diet-related noncommunicable diseases, including obesity, diabetes, hypertension and cardiovascular disease coexists with residual undernutrition, especially micronutrient undernutrition, and is projected to increase rapidly. For example, in India and China a shift in diet towards higher fat and lower carbohydrate is resulting in rapid increases in overweight among all adults in China and mainly among urban residents and high-income rural residents in India. Countries that have completed the transition to
overnutrition are experiencing a continual increase in levels of obesity, as high-fat, high-energy and low-exercise lifestyles permeate their society. However, such a transition may not be inevitable, and a key challenge for policymakers is to generate a healthier transition.

It is somewhat self-evident that improvement in per capita GNP in countries in economic transition does not benefit all citizens equally. However, children under age 5 y are particularly at risk in this time of transition. For example, data from The World Bank show that the rates of poverty and underweight have actually increased among children under 5 y of age in urban areas of countries in socioeconomic transition. The reasons are not as esoteric as may be imagined. For example, families that move from rural to urban areas usually lose the ability to grow their own food, lose their contact with extended family and become dependent for their food on a cash market. It is also more likely that women who move to the city will join the labour force and therefore become less available to feed their children frequently or prepare food at home, relying more heavily on nonfamily-based child care and inexpensive commercially prepared foods for themselves and their families. Much of this store-bought food is high in fat and energy but low in micronutrients such as iron and zinc. For example, on a per-energy unit basis, a 5-y-old boy needs 5 times as much iron in his diet as an adult man. Cheap energy-dense, nutrient-poor foods may adversely affect the growth and micronutrient status of the child but at the same time may provide sufficient energy units for the adult to gain excessive weight.

The relationship between GNP per capita and dietary fat intake, expressed as a proportion of energy from fat, was studied for 88 countries and recently updated to include 121 countries (X. Guo et al., unpublished observation, 1999). Not surprisingly, there was a strong positive relationship between the 2; in other words, fat intake was higher in richer countries. There is 1 example, however, that goes against this trend: the Republic of Korea. Based on the regression equation between GNP per capita and dietary fat intake and using statistics from 1996, one could predict that the proportion of energy from fat in the Republic of Korea would be 35.5%. The actual percentage of energy from fat was 16.7%. This low level of fat intake may be part of the reason for the lower level of obesity in the Republic of Korea as compared with many other Asian countries. There are not many examples of societies successfully dealing with their own nutrition transition, but Korea is one example that is worth highlighting. The study, entitled Nutrition Transition in the Republic of Korea, describes a unique nutrition transition that has occurred in the Republic of Korea, a country that modernized earlier than most Asian countries. The analysis uses secondary data on economics, dietary intake, anthropometry and causes of death, including a series of comparable nationally representative dietary surveys (eg, the National Nutrition Survey).

The study addresses the question of why the fat intake in the Republic of Korea is low. The authors suggest 3 possible answers: (1) rice is still the staple food in Korea, so carbohydrate intake remains high; (2) cooking styles use small amounts of fat because traditional Korean cuisine adds small amounts of sesame oil to vegetables after they have been boiled or steamed, as opposed to Chinese cooking in which foods are stir fried in oil (with stir-frying, there is a tendency to use more oil as the availability of oil increases); (3) there has been a strong, sustained national movement to retain the traditional Korean diet and cooking methods. Mass media campaigns promote local foods, emphasizing their higher quality and the need to support local farmers. A unique training programme is offered by the Rural Development Administration. Since the 1980s, the Rural Living Science Institute has trained thousands of extension workers to provide monthly demonstrations of cooking methods for traditional Korean foods such as rice, kimchi (a form of pickled and fermented Chinese cabbage) and fermented soybean food. These sessions are open to the public in most districts in the country, and the programme appears to reach a large audience. Although the combination of these 3 interventions may explain the low fat intake, with the lowering of trade barriers there is a trend to increasing obesity in young children, even in Korea.

MICRONUTRIENT DEFICIENCIES

A major impact of the nutrition transition, as previously mentioned, is the ingestion of relatively large amounts of energy-dense but nutrient-dilute foods. Because of the relatively high requirements for micronutrients by preschool children, they are at highest risk during the period of nutritional transition, but women of reproductive age and pregnant women are also at high risk for micronutrient deficiencies. For example, rates of iron deficiency and anaemia were higher in 2000 than they were in 1990. Thus, the control of micronutrient deficiencies is also high on the global priority list. We have done a reasonably good job in controlling iodine and vitamin A deficiencies with iodised salt and vitamin A capsules; however, the international nutrition community has not yet solved the problem of iron deficiency.

Recent WHO/UNICEF estimates suggest that the number of children with iron deficiency anaemia is >750 million (8). Iron deficiency is the most common preventable nutritional problem despite continued global goals for its control. Historically, the problem of iron deficiency anaemia in children largely disappeared in North America when foods fortified with iron and other micronutrients became available. In this group,
the prevalence of iron deficiency anaemia has fallen from 21% in 1974 to 13% in 1994 (5). Although pockets of infants and children remain at risk, generally the eradication of iron deficiency in the West is recognized as a successful public health accomplishment. This solution has not worked in developing countries, where commercially purchased fortified foods are not available or are not used.

In the developing world, there are 3 major approaches available to address iron deficiency: dietary diversification to include foods rich in absorbable iron, fortification of staple food items including wheat and the provision of iron supplements. When dietary or fortification strategies are not logistically or economically feasible, supplementation of individuals and groups at risk is an alternative strategy. For the past 150 y or more, oral ferrous sulphate syrups have been the primary strategy to control iron deficiency anaemia in infants and young children (9). However, adherence to them is often limited due to a combination of their unpleasant metallic aftertaste, dark staining of the child’s teeth and abdominal discomfort (10). Thus, despite the ongoing work of the UN Standing Subcommitte on Nutrition and others to solve the problem of poor adherence in infants and young children, all of the interventions to date have been universally unsuccessful (8–10). Our program in Toronto, the Sprinkles Global Health Initiative, has come up with what we believe to be 1 solution to the problem.

**TABLE 2.** Dose and derivation of Sprinkles Complete Micronutrient Formulation for home fortification of complementary foods for infants and young children, 6–24 mo old

<table>
<thead>
<tr>
<th></th>
<th>WHO*</th>
<th>IOM DRI</th>
<th>Lutter and Dewey^</th>
<th>Upper limit</th>
<th>Sprinkles</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>6–11 mo</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin A, µg RE</td>
<td>400</td>
<td>500^3</td>
<td>400</td>
<td>250</td>
<td>300</td>
</tr>
<tr>
<td>Vitamin C, mg</td>
<td>30</td>
<td>50^4</td>
<td>30</td>
<td>70–140</td>
<td>1000</td>
</tr>
<tr>
<td>Vitamin D, µg</td>
<td>5</td>
<td>5^5</td>
<td>5</td>
<td>1–2</td>
<td>25</td>
</tr>
<tr>
<td>Vitamin E, µg a-TE</td>
<td>NA</td>
<td>5^6</td>
<td>NA</td>
<td>NA</td>
<td>2000</td>
</tr>
<tr>
<td>Vitamin B₁₂, mg</td>
<td>0.3</td>
<td>0.3^7</td>
<td>0.5</td>
<td>0.18</td>
<td>NA</td>
</tr>
<tr>
<td>Vitamin B₉, mg</td>
<td>0.4</td>
<td>0.4^8</td>
<td>0.5</td>
<td>0.18</td>
<td>NA</td>
</tr>
<tr>
<td>Vitamin B₆, mg</td>
<td>0.3</td>
<td>0.3^9</td>
<td>0.5</td>
<td>0.22</td>
<td>NA</td>
</tr>
<tr>
<td>Vitamin B₃, µg</td>
<td>0.5</td>
<td>0.5^10</td>
<td>0.9</td>
<td>0.26</td>
<td>NA</td>
</tr>
<tr>
<td>Folic acid, µg</td>
<td>80</td>
<td>80^11</td>
<td>160</td>
<td>41.5</td>
<td>300</td>
</tr>
<tr>
<td>Niacin, mg</td>
<td>1.5</td>
<td>4^12</td>
<td>6</td>
<td>3.3</td>
<td>10</td>
</tr>
<tr>
<td>Iron, mg^13</td>
<td>9.3</td>
<td>11</td>
<td>5.8</td>
<td>7–11</td>
<td>40</td>
</tr>
<tr>
<td>Zinc mg^14</td>
<td>4.1</td>
<td>3</td>
<td>4.1</td>
<td>4–5</td>
<td>5–7</td>
</tr>
<tr>
<td>Copper, mg</td>
<td>NA</td>
<td>0.22^15</td>
<td>NA</td>
<td>0.2–0.4</td>
<td>1</td>
</tr>
<tr>
<td>Iodine, µg</td>
<td>NA</td>
<td>130^16</td>
<td>90</td>
<td>90</td>
<td>200</td>
</tr>
</tbody>
</table>


Based on adequate intake (AI) estimates.

Assuming medium bioavailability (10%).

Assuming moderate bioavailability (30%).

THE STRATEGY

Our research group at the Hospital for Sick Children in Toronto conceived of the strategy of home fortification with Sprinkles, single-dose sachets containing micronutrients in a powder form, which are easily sprinkled onto any foods prepared in the household. We hypothesized that this would be a successful method to deliver iron and other micronutrients to children at risk (11). The idea of Sprinkles was formulated in 1996, when a group of consultants determined that the prevention of childhood iron deficiency anaemia was a UNICEF priority, yet the available interventions including syrup and drops were not effective (11).

In Sprinkles, the iron provided as ferrous fumarate is encapsulated within a thin lipid layer to prevent the iron from interacting with food. This means that there are minimal changes to the taste, colour or texture of the food upon adding Sprinkles. Other micronutrients including zinc, iodine, vitamins C, D and A, and folic acid may be added to Sprinkles sachets. Any homemade food can be fortified with the single-dose sachets, hence the term home fortification. Two formulations have been developed, a nutritional anaemia formulation (Table 1) and a complete micronutrient formulation (Table 2).

Over the past 5 y, we have completed 7 community-based trials in 4 different countries (12). The goal of these studies was to test the efficacy of Sprinkles in diverse...
settings. When we pooled data from 2 of our studies that compared Sprinkles to the reference standard, ferrous sulphate drops, we had a total of 518 anaemic infants (haemoglobin < 100 g/L) who were given 1 of 2 ferrous sulphate doses providing 15 or 40 mg of elemental iron as ferrous sulphate and 318 similar infants who received 1 of 4 doses of iron from Sprinkles providing 12.5, 20, 30 or 80 mg of elemental iron as microencapsulated ferrous fumarate. This gave us >97% power (α = 0.05) to detect whether the mean difference in end of study haemoglobin concentrations between ferrous sulphate and Sprinkles regimens was within ± 5 g/L (a range of equivalence). Using a random effects model for study and dose that adjusted for baseline haemoglobin, we found no significant difference between Sprinkles and drops.

We further examined this through quantile-quantile plots of haemoglobin concentrations at the end of the studies for Sprinkles and ferrous sulphate drops. The overlaid plots of haemoglobin concentrations of the Sprinkles and drops groups demonstrate that these 2 distributions overlapped at all quantiles. These plots clearly indicate that the haemoglobin response to the 2 different forms of iron were equivalent. Thus, we have concluded that Sprinkles are as efficacious as the current reference standard for the treatment of anaemia. Overall, 55% to 90% of the anaemic infants who were provided with Sprinkles were cured.

Each stage in the evolution of the Sprinkles intervention has been evaluated in a controlled manner. We determined that the use of encapsulated iron did not appreciably change the taste or color of the food to which it was added; we showed that the haemoglobin response in anaemic infants was equivalent to the current standard of practice; and we documented the acceptability of Sprinkles among caregivers who used Sprinkles in their homes. Finally, through various partnerships, we have developed a successful model to scale up the intervention for countrywide use. A review of the progress and development of the Sprinkles initiative has recently been published (12).

In summary, the present review has identified the top 3 risk factors in terms of burden of disease, affecting preschool children. The impact of each factor on this age group has been assessed, and at least 2 examples of successful approaches to rehabilitation have been suggested.

REFERENCES

Danone Institutes are not-for-profit organisations contributing to improving the quality of the diet and therefore the health of all people. With this objective, Danone Institutes promote evidence-based scientific knowledge in diet and nutrition and disseminate relevant knowledge on diet and nutrition to professionals in fields such as health care, education and media as well as to the public.

Danone Institutes gather internationally renowned scientists in diet and nutrition from independent organisations (e.g., universities, research centres) who are committed to taking a multidisciplinary approach combining medicine, biology and human sciences.

**ETHICS**

Danone Institutes are independent from the Danone Company. They define their own programs to be relevant in their local environment.

- They have no commercial objective
- They act freely and independently
- They function on the basis of guidelines that guarantee a clear and democratic organisation
- Danone Institute publications never contain any commercial/advertising information

**HISTORY**

The first Danone Institute was created in France in 1991. Since then, an international network of 15 local Danone Institutes has been developed in Belgium, Canada, China, Czech Republic, France, Germany, Israel, Italy, Japan, Mexico, Poland, Russia, Spain, the United States and Turkey. Today, more than 200 renowned experts in diet and nutrition are involved in this unique international network. In each country, the local Danone Institute develops specific programs including the following:

- Research support through grants, credits, awards, fellowships and scholarships
- Publication of research findings
- Organisation of scientific conferences
- Publication of newsletters and books for professionals (e.g., health care professionals, educators, journalists)
- Organisation of training and education sessions for professionals (e.g., health care professionals, journalists)
- Production of pedagogic material, leaflets, booklets, television and radio programs, computer games for parents, pregnant women, children, teenagers, and older adults

An international entity was created in 2004 to develop international activities such as research support and scientific conferences or publications, to enhance collaborations between Danone Institutes and/or their members and to promote the sharing of experience between Danone Institutes.

The programs offered by Danone Institutes may deal with any food or nutrient that could have an impact on human health. They are generally focused on major public health nutrition issues.

**ACTIVITIES**

- **Support for research:** To date, Danone Institutes have funded more than 700 research studies, which accounted for more than €11 million.
- **Prizes and awards:** More than 40 prizes and awards have been attributed to outstanding professional initiatives for more than €600,000.
- **Symposia, workshops and educational meetings:** Since 1991, more than 140 events involving top-level scientists have reached more than 30,000 health professionals.
- **Publications related to health and nutrition:** Seventy-five publications and 6 newsletters present professionals with overviews of recent developments, promote consensus and/or explore controversies about relevant issues.
- **Education programs for the public:** More than 70 programs (e.g., nutrition lectures, distribution of folders and brochures) geared towards the public have been organised.

**SPECIAL FOCUS ON PERINATAL AND CHILD NUTRITION**

Proper nutrition during pregnancy and childhood is increasingly understood to be a major determinant of growth, development and future health. Therefore, Danone Institutes consider that encouraging good nutrition in
pregnancy and childhood is the key to improving public health. For this reason they dedicated a large part of their activities to perinatal and child nutrition. The most recent programs include the following:

- **Support for research:** (1) award of the 2005 Danone International Prize for Nutrition (€120,000) to David J.P. Barker (University of Southampton, UK, and Oregon Health and Science University, Portland) for his innovative research work on the developmental origin of chronic adult disease leading to the so-called Barker’s hypothesis; (2) partnership with the European Union Childhood Obesity program to test the possible relationship between the level of early protein intake and the later risk of obesity; (3) award of several grants to local research programs.


- **Publications:** “Early Nutrition and Later Consequences: New Opportunities,” proceedings of a European Union–supported workshop organized at the 2nd World Congress of Pediatric Gastroenterology, Hepatology and Nutrition (Danone Institute International 2005)

- **Educational programs for professionals:** (1) “The Course in Pediatric Nutrition,” created in 1998 by Danone Institute of Italy. This annual 2-d course, given by teachers of the pediatric clinic of the University of Milan with the support of the Italian Society of Pediatric Nutrition, provide extensive and most recent practical knowledge on children’s diets to pediatricians. This course, acknowledged by the Italian Ministry of Health as part of the program of Continuous Medical Education, is now available online for individual training at www.istitutodanone.it. (2) The corpulence program developed by Danone Institute of France, encourages health professionals to monitor the evolution of the body mass index of children and open a dialogue with parents on childhood obesity. This program, in line with the national plan of the French Ministry of Health, comprises a series of leaflets and posters for health professionals and parents.

- **Educational programs for the public:** (1) “Healthy Diet, Healthy Growth”, a television program produced by Danone Institute of China, aims to educate mothers with children 6 to 16 y old about what constitutes a healthy diet. Fifty-two episodes of 10 min each were shown on 5 national television channels. (2) “Celebrating Healthy Eating,” a nutritional education program developed by Danone Institute US, specifically designed for preschool children. The curriculum is distributed nationally to early child educators. Families can read about nutrition news, create recipes for children, and learn about children’s books about nutrition. Teachers have access to educational information, lesson plans and activities on different food groups. Tools are now available online at www.celebratehealthyeating.org. (3) Computerised nutrition games for children were recently developed by Danone Institute of Czech Republic and Danone Institute of Poland for children ages 7 to 10 y and 6 to 9 y, respectively. Both games presenting dietary and nutritional information in a fun and interactive way are intended to help children develop healthy eating habits and contribute to preventing childhood obesity.

Readers are encouraged to read more information about the Danone Institutes and their activities at www.danoneinstitute.org.