Global Burden of Malnutrition and Infection in Childhood

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Malnutrition and infection play a major role in causing the preventable deaths and disabilities that occur in much of the developing world, especially among young children. Malnourished children suffer loss of precious mental capacity, fall ill more often, and grow up with lasting mental or physical disabilities. Most nations at the 1990 World Summit for Children pledged, among various goals for children’s improvement, to reduce mortality in infants and children aged younger than 5 years by one third of the 1990 levels or to 50–70/1,000 live births, and to reduce severe and moderate malnutrition among children aged less than 5 years (under-5) by half. Despite concerted efforts catalyzed by both international and national initiatives at various levels toward nutritional improvement, the global impact on nearly all forms of malnutrition is falling far short of that required to meet the health goals for children by the year 2000.

Viewed globally, however, the improvements in infant and child health in the past 50 years have been spectacular, and overall reductions in under 5 and infant mortality are accelerating in much of the world. Nevertheless, regional and even national data on malnutrition and infection in children often hide variations between and within countries (1).

In this chapter, we will consider the situation relating to malnutrition and infection, their consequences and burden, from a global and regional perspective. Such an assessment would provide a clear understanding of the impact of malnutrition and infection, which is essential in the management of nutrition-related health research and action programs designed to prevent and control childhood malnutrition.

MALNUTRITION–INFECTION SYNERGISM

Inadequate dietary intake, both in quantitative and qualitative terms, and disease are immediate causes of malnutrition and deaths of young children. They reinforce
each other synergistically. Malnutrition causes debility and children in particular are susceptible to developing infections that can become extensive and serious. Also, certain infections and parasitic diseases have a profound influence on nutritional status, mediated by changes in dietary intake, absorption, nutritional requirements (especially for energy and protein), and loss of endogenous nutrients. Malnutrition takes several forms, which often appear in combination and make a mutual contribution to the overall picture, including protein-energy malnutrition and deficiencies of micronutrients such as vitamin A, iron, iodine, and other related trace minerals. Infants and young children have immature immune systems, and they may be vulnerable to the immunodepressive effects of marginal or moderate hypovitaminosis. For instance, although vitamin A status influences the response to infection, infections can also induce a state of vitamin A deficiency, a fact that has been well documented during measles infection in developing countries. More recently, low plasma retinol concentrations have also been reported in a substantial proportion of children with measles in the United States (2). Iron deficiency also depresses immunity. Zinc deficiency has a general effect on infectious disease, again at least partly through the immune system. Whereas much of the attention paid to iodine deficiency has been related to its effects on brain development, it appears also to have an effect on immunity.

Protein-energy malnutrition is known to have a depressant effect on the immune system. Deficiencies of vitamin A, riboflavin, iron, and zinc, which are often associated with protein-energy malnutrition, have a profound influence both on the host’s response to infection and on rates of microbial proliferation. Even mild forms of malnutrition have been shown to have an adverse effect on immunocompetence and, hence, on morbidity and mortality. The mechanisms leading to growth failure and clinical malnutrition operate through anorexia, changes in metabolism, malabsorption, and behavioral changes affecting feeding practices, leading eventually to malnutrition in the face of limited nutritional reserves (3,4).

CAUSES OF MALNUTRITION

An understanding of the complex causes of malnutrition helps one appreciate the magnitude of the problem. Malnutrition is not a simple problem with a single, simple solution. A multitude of interrelated determinants is implicated in its cause, which necessitate a series of multifaceted and multisectoral approaches in addressing malnutrition. Among the factors that precipitate conditions leading to childhood malnutrition, infection, and death are poverty, ignorance, and disease; inadequate food; an unhealthy environment; social stress; and discrimination, most of which persist throughout much of the developing world.

Interest in the relations between nutrition and infection, and in the environment in which they occur, was stimulated by Scrimshaw et al. (5) (Fig. 1). A conceptual framework of the causes of malnutrition, developed in 1990 as part of the United Nations Children’s Fund (UNICEF) nutrition strategy, finds application in this context (6). In this framework, the causes of malnutrition are multisectoral, embracing food,
health, and caring practices. They are also classified as immediate causes (individual level), underlying causes (household or family level), and basic causes (societal level), whereby factors at one level influence those at the other levels. Among the underlying causes of inadequate dietary intake and infectious disease, inadequate access to food at the family level, insufficient health services, an unhealthy environment, and lack of proper care for children and women are most evident. At the basic level, malnutrition is a consequence of disease and inadequate dietary intake, but
many other factors—social, political, economic and cultural—are involved apart from the physiologic causes.

This framework has been used at national, district, and local levels to help plan effective actions to improve nutrition in children. Thus, while viewing the global burden of malnutrition and infection, the interplay between the two most significant immediate causes of malnutrition—inadequate dietary intake and illness, which create a vicious circle—must be carefully considered. A malnourished child whose resistance to illness is compromised, falls ill and malnutrition worsens. Children who enter this malnutrition–infection cycle, as commonly occurs in developing countries, quickly enter a potentially fatal cycle as one condition feeds off the other.

GLOBAL MAGNITUDE OF CHILD MALNUTRITION

Low Birthweight

Nearly one third of all babies born in the world are of low birthweight. Globally, the World Health Organization (WHO) estimates that 25 million low birthweight infants (weight at birth < 2,500 g) are born each year, constituting 17% of all live births, nearly 95% of them in the developing world. The incidence of low birthweight varies between regions of the world, with levels of 32% in South Asia (but 9% in eastern Asia), 11% to 16% in Africa, and 10% to 12% in Latin America and the Caribbean. Born underweight and fed with suboptimal breast-feeding practices, low birthweight infants are at increased risk of protein-energy malnutrition and illness. Low birthweight is an important indicator of fetal–intrauterine nutrition and can lead to stunting in the young child. Low birthweight is a major problem in Asian countries, associated with both neonatal and postneonatal mortality. Analyses in selected Asian countries reveal very high rates of low birthweight in Bangladesh and India (50% and 30%, respectively) (1,7).

Protein-Energy Malnutrition

It is estimated that 168 million children under 5 years of age, or 27% of the world’s children in this age group, are currently malnourished, as measured by weight-for-age (−2 SD National Center for Health Statistics (NCHS) median). Currently, more than 76% of these live in Asia (mainly southern Asia), 21% in Africa, and 3% in Latin America. As many as 206 million children are stunted—shorter than they should be for their age—and shorter than could be accounted for by any genetic variation in developing countries (1).

The prevalence of childhood malnutrition in various regions is shown in Table 1 (8–10). South Asia suffers by far the worst incidence of child undernutrition among all the regions in the developing world, including Sub-Saharan Africa. Some 17% of under-5 children were found to be wasted during the period 1985–1995, as compared with an average of only 9% in developing countries as a whole and 7% in Sub-Saharan Africa. Similarly, as many as 60% of children in south Asia were stunted, compared with 41% in the developing world and 39% in Sub-Saharan Africa.
TABLE 1. Regional variation in childhood malnutrition

<table>
<thead>
<tr>
<th>Region</th>
<th>Low weight for height (% wasted)</th>
<th>Low height for age (% stunted)</th>
<th>Low weight for age (% underweight)</th>
<th>Low birthweight babies (% LBW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Asia</td>
<td>17.1</td>
<td>59.5</td>
<td>58.3</td>
<td>33</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>15.5</td>
<td>64.6</td>
<td>65.8</td>
<td>50</td>
</tr>
<tr>
<td>Bhutan</td>
<td>4.1</td>
<td>56.1</td>
<td>37.9</td>
<td>—</td>
</tr>
<tr>
<td>India</td>
<td>19.2</td>
<td>62.1</td>
<td>63.9</td>
<td>33</td>
</tr>
<tr>
<td>Maldives</td>
<td>6.3</td>
<td>—</td>
<td>—</td>
<td>20</td>
</tr>
<tr>
<td>Nepal</td>
<td>14.0</td>
<td>69.0</td>
<td>70.0</td>
<td>26</td>
</tr>
<tr>
<td>Pakistan</td>
<td>9.2</td>
<td>50.0</td>
<td>40.4</td>
<td>25</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>12.9</td>
<td>27.5</td>
<td>38.1</td>
<td>25</td>
</tr>
<tr>
<td>East and South-East Asia</td>
<td>5.2</td>
<td>33.3</td>
<td>23.6</td>
<td>11</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>7.0</td>
<td>38.8</td>
<td>30.2</td>
<td>16</td>
</tr>
<tr>
<td>Middle East/North Africa</td>
<td>8.8</td>
<td>32.4</td>
<td>25.3</td>
<td>10</td>
</tr>
<tr>
<td>Latin America/Caribbean</td>
<td>2.6</td>
<td>22.7</td>
<td>12.0</td>
<td>11</td>
</tr>
<tr>
<td>Developing countries</td>
<td>9.1</td>
<td>40.7</td>
<td>33.9</td>
<td>19</td>
</tr>
</tbody>
</table>

LBW, low birth weight
From UNDP (8), UNICEF (9), FAO (10).

The prevalence of underweight is seen in Table 2. More than half the world’s underweight children are found in south Asia: 85 million of a global total estimated at about 160 million (11). Underweight, even in mild form, increases the risk of death, inhibits cognitive development in children, and leads to reduced fitness and productivity among adults. It perpetuates the problem from one generation to the next, through malnourished women having low birthweight babies.

Figure 2 shows prevalence trends of underweight among children between 1985 and 1995 and the projection up to 2010 (11). Figure 3 indicates the percentage of malnourished children from 1993 projected up to 2020 (12). In South Asia (of which India accounts for more than 70% of the population), the prevalence is approximately 50%. This is 50% higher than in the next region, South-East Asia, where approximately one third (32% in 1995) of the children are underweight. It appears that the global rate of progress is inadequate for achieving the 1990 World Summit Year 2000 goal of reducing levels of moderate and severe malnutrition. The rate of reduction in malnutrition worldwide during successive intervals since 1980 shows a relative decrease but falls far short of what is required. The persistently slow reduction in the

TABLE 2. Underweight children (0–60 months) by region, 1985–1995

<table>
<thead>
<tr>
<th>Region</th>
<th>Percent underweight (millions)</th>
<th>Numbers underweight (millions)</th>
<th>Trends (pp/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Asia</td>
<td>55.3</td>
<td>50.1</td>
<td>49.6</td>
</tr>
<tr>
<td>South-East Asia</td>
<td>39.8</td>
<td>34.2</td>
<td>33.1</td>
</tr>
<tr>
<td>China</td>
<td>22.7</td>
<td>17.8</td>
<td>16.6</td>
</tr>
<tr>
<td>Total</td>
<td>34.3</td>
<td>30.7</td>
<td>30.4</td>
</tr>
<tr>
<td>Total 0–4</td>
<td>476.6</td>
<td>523.3</td>
<td>533.5</td>
</tr>
</tbody>
</table>

From United Nations (11).
The magnitude of global malnutrition is alarming, owing to its powerful impact on infant and young child mortality.

**Micronutrient Deficiencies**

Deficiencies in the intake or absorption of vitamin A, iron, and iodine have serious consequences for health and mental and physical function. The estimated prevalences and numbers affected by these three deficiencies are given by region in Table 3 (13–15). At the other end of the malnutrition spectrum are found the nutritional problems arising from childhood obesity, which will also be discussed below.
TABLE 3. Prevalence of vitamin A, iodine, and iron deficiencies by region

<table>
<thead>
<tr>
<th>WHO region</th>
<th>Vitamin A deficiency</th>
<th>Iodine deficiency orders</th>
<th>Anemia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Children (0–5 yr)</td>
<td></td>
<td>All women (15–49 yr) with low Hb</td>
</tr>
<tr>
<td></td>
<td>(xerophthalmia 1991)</td>
<td></td>
<td>(around 1988)</td>
</tr>
<tr>
<td></td>
<td>No. (millions)</td>
<td>No. (millions)</td>
<td>Region</td>
</tr>
<tr>
<td></td>
<td>Prevalence (%)</td>
<td>Prevalence (%)</td>
<td>No. (millions)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Prevalence (%)</td>
</tr>
<tr>
<td>Africa</td>
<td>1.3</td>
<td>39</td>
<td>Africa</td>
</tr>
<tr>
<td></td>
<td>1.4</td>
<td>8.2</td>
<td>59.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>44</td>
</tr>
<tr>
<td>Eastern Asia</td>
<td>1.0</td>
<td>12</td>
<td>Latin America</td>
</tr>
<tr>
<td></td>
<td>2.8</td>
<td>4.7</td>
<td>32.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>31</td>
</tr>
<tr>
<td>Latin America</td>
<td>0.1</td>
<td>30</td>
<td>Asia (includes India and China)</td>
</tr>
<tr>
<td></td>
<td>0.2</td>
<td>7.0</td>
<td>335.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>45</td>
</tr>
<tr>
<td>South-East Asia</td>
<td>10.0</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>(Includes India)</td>
<td>4.2</td>
<td>5.9</td>
<td></td>
</tr>
<tr>
<td>Western Pacific</td>
<td>1.4</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>(Includes China)</td>
<td>1.3</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>13.8</td>
<td>211</td>
<td>427</td>
</tr>
<tr>
<td></td>
<td>2.8</td>
<td>5.7</td>
<td>44</td>
</tr>
</tbody>
</table>

Pregnant <11 g/dl; nonpregnant <12 g/dl.
From WHO (13–15).
Iodine Deficiency

Iodine deficiency, resulting from a low intake of iodine in the diet, exists in most regions of the world. Up to 1990 it was estimated that about 40 million infants—one third of all babies born each year in the world—were at risk of mental impairment because of inadequate iodine in the maternal diet. The other consequences of iodine deficiency include goiter, increased rates of stillbirths and abortions, and infant deaths. Severe mental and neurologic impairment occurs in babies of iodine-deficient mothers. In 1997, because of the worldwide increase in the use of iodized salt, 12 million children were expected to be spared that risk. The number of babies born as cretins was expected to have fallen by more than half, from approximately 120,000 in 1990 to fewer than 55,000 worldwide (16).

Iron Deficiency

Iron deficiency, which is the most common nutritional disorder in the world, affects 1 billion people, particularly women of reproductive age and preschool children in the tropical and subtropical zones, and has a serious impact on school children. With dietary iron supply trends deteriorating in most regions, prevalence rates, particularly in Sub-Saharan Africa and south Asia, may be increasing and this is consistent with the decline in the dietary supply of iron (17). Intestinal helminth infections, especially from hookworm, which cause gastrointestinal blood loss, are one of the major causes of iron deficiency anemia. Other causes include malaria and other micronutrient deficiencies (e.g., vitamin A deficiency). Data on anemia prevalence in children are inadequate and scattered in south Asia, where it is uniformly high. Studies show that severe anemia is found among 44% of Afghan children, 73% of preschoolers in Bangladesh, 67% of Indian preschool children, 78% of Nepalese children, and 65% to 78% of Pakistani children (18).

Vitamin A

Vitamin A deficiency is one of the most common nutritional deficiency disorders in the world. WHO has estimated that more than 250 million children worldwide have deficient vitamin A stores. In 1991, WHO reported that nearly 14 million preschool children had eye damage caused by vitamin A deficiency and approximately 10 million of these children live in Asia. Global progress is being made in combating the ocular effects of vitamin A deficiency, but the subclinical forms need to be fully controlled. Subclinical vitamin A deficiency is common in school children and adolescents in several settings in south Asia (18). Vitamin A deficiency in preschool children has marked implications for reduced growth and can lead to increased risk of mortality, morbidity, and blindness, although the immediate health consequences for school children and adolescents are not completely known (19).
Folic Acid Deficiency

Folic acid deficiency has been shown to incur risk of neural tube defects in industrialized and eastern European countries. However, information is sparse on the epidemiology of folic acid deficiency in developing countries. In rural Mexico, Black et al. (20) did not identify folic acid deficiency but identified vitamin B$_{12}$ deficiency (21) among children, pregnant, and nursing women.

Zinc Deficiency

Zinc deficiency in mild and moderate forms, which is likely to be widespread, was largely overlooked until recently (22). It contributes to growth stunting in young children in many regions (23). Often protein-energy malnutrition, especially "low height for age," results from poor diet quality, including low levels of bioavailable zinc, rather than from an inadequate quantity of either protein or energy. Zinc deficiency may be a major cause of morbidity in young children, as shown by studies in India and elsewhere (24).

Obesity

An increasing number of nutritional problems have arisen from affluence, changing dietary habits, and changing lifestyles. Obesity in childhood merits attention in this regard.

Childhood obesity and its consequences are seen to be emerging as a global problem. Data from 79 developing countries and several industrialized countries suggest that approximately 22 million under-5 children are overweight by WHO standards ($\geq 2$ SD above the reference median weight for height). Obesity affects almost 10% of school children in industrialized countries and high rates are also emerging in the developing world.

In the United States, the prevalence of overweight (defined by the 85th centile of weight for height) among those 5 to 24 years of age from a biracial community of Louisiana showed an approximately twofold increase between 1973 and 1994. Similar trends were noted in Japan: the frequency of obese children aged 6 to 14 years increased from 5% to 10% between 1974 to 1993. Early obesity leads to an increased likelihood of obesity in later life, as well as an increased prevalence of obesity-related disorders (25).

In developing countries, increasing levels of childhood overweight and obesity indicate that these countries may be carrying a double burden in terms of nutritional problems into the next century. In Thailand, for instance, the prevalence of obesity among school children aged 6 to 12 years rose from 12.2% in 1991 to 15.6% in 1993 (26). In a recent study of Saudi Arabian children aged 6 to 18 years, the prevalence of obesity was found to be 15.8% (27).

Obesity is associated with various problems in children and adolescents, the most prevalent being the psychosocial consequences in adolescence and the persistence of
obesity into adulthood, which in turn leads to a number of health consequences ranging from an increased risk of premature death to several nonfatal but debilitating complaints that affect the quality of life.

The wider implications of these trends in childhood malnutrition, which include the coexistence of undernutrition and overnutrition, especially in developing countries, may well be imagined, and an urgent call to address this burden awaits health professionals and workers.

**REEMERGENCE AND EMERGENCE OF OLD AND NEW DISEASES**

Despite an increasing coverage of immunization, which has been widely implemented through the WHO’s expanded program on immunization since 1974, children are still slipping through the safety net, and this includes many of the world’s poorest children, who are particularly vulnerable to disease. Sub-Saharan Africa fares the worst: each year almost half the children who should receive the necessary three doses of DPT vaccine to prevent diphtheria, pertussis, and tetanus do not receive them. Although coverage rates in the rest of the world are higher, the fact is that 26 million infants do not receive their three DPT shots (28).

Previously controlled diseases, including diphtheria, are noted to be reemerging, and measles continues to thrive in the cities of Africa and Asia, especially in deprived neighborhoods. Just 20 countries now account for 85% of measles deaths in children under 5: approximately 722,000 children die each year from measles, half of them in Africa, and 23,000 in India alone. Measles immunization coverage has remained static or slipped in 32 of the 44 poorest countries since 1990, including Burundi (25% decline in coverage), Papua New Guinea, Yemen (23%), Malawi (14%), Benin (13%), and Mali (12%) (28).

In India, with the national immunization program, measles, pertussis, and diphtheria deaths are now 80% less than preimmunization levels. But immunization coverage remains disparate, with up to 30% of children receiving no vaccination at all. The primary healthcare system continues to have difficulty in addressing health risks. Of all curative healthcare, 70% to 90% is delivered by the private sector. One of five children with acute respiratory infection receives no treatment. Of infant deaths, 15% to 20% are caused by lower respiratory tract infections. Although deaths from diarrheal dehydration have decreased, only 43% of mothers know about oral rehydration therapy, and only 26% report ever having used it (29).

Some of the poorest nations, Cambodia for example, have more than doubled their measles immunization rates, from 32% in 1990 to 72% in 1996. Guinea’s coverage rate stands at 61%, compared with only 18% in 1990 (28). These are examples of political will in truly committed nations which should steer health actions toward addressing childhood diseases.

Rheumatic fever and rheumatic heart disease (the most common cardiovascular disease in children and young adults) are examples of how social and economic factors and subsequent improved health and medical care, have contributed to and then accelerated the decline of a disease that was once widely prevalent in developed
countries. Currently, limited evidence suggests little decline in the occurrence of rheumatic heart disease in developing countries over the past few decades. Meningococcal meningitis is another childhood disease that occurs in all parts of the world. In the 1980s, an epidemic wave of meningococcal meningitis spread over Asia and Africa. In nonepidemic years, at least one million cases of bacterial meningitis are estimated to occur, which may double in epidemic years (1).

Although some of these common infectious diseases of childhood are coming under control through a combination of health promotion, prevention, and simplified standard treatment regimens, children are also threatened by another emerging new morbidity, the acquired immunodeficiency syndrome (AIDS). Globally, the new morbidity from AIDS is closely associated with behavioral problems and, therefore, is much more difficult to prevent than diseases that have been well known. AIDS presents a crucial challenge, with globally some 1,600 children under 15 years of age being infected with the human immunodeficiency virus (HIV) every day. The vast majority of these cases occur through mother-to-child transmission (30). WHO projects that with the present growing trends, by the year 2000 more than 13 million women will have been infected and 4 million will have died of AIDS. Their uninfected infants will comprise a growing group of potential orphans. By 2000, as many as 10 million children under age 10 may be orphaned as a result of maternal AIDS in Sub-Saharan Africa alone, and the projected deaths from AIDS may increase child mortality rates by as much as 50% in parts of Sub-Saharan Africa. Alarming trends are also noticed in South-East Asia.

With the increase of HIV infection, it seems that tuberculosis in children (especially pneumonia and meningitis) is not yet decreasing, even though immunization coverage with bacille Calmette–Guérin (BCG) is high (1). This new morbidity will certainly contribute to rapidly rising social and economic costs, both at the micro-economic level and at national levels, and it may even reverse the long-term effects of child health improvement initiatives.

On the whole, a need exists to bolster the health infrastructure, the inputs of workers, and the supply of affordable vaccines, and above all to maintain our technical and political structures. Governments need to assess priorities and closely view the true value of preventive strategies that can alleviate the global burden of disease in the long term.

MORTALITY OUTCOMES

The mortality caused by malnutrition and infection is the critical problem, the most vulnerable groups being developing fetuses and children up to the age of 3 years. Folate deficiency in expectant mothers can cause birth defects in infants (e.g., such as spina bifida), all of which have serious implications for a child’s quality of life. Vitamin A deficiency, even in its mild form, impairs the immune system, reducing children’s resistance to diarrhea, which kills nearly 1 million children annually. New findings strongly suggest that vitamin A deficiency is a cause of maternal mortality as well, especially among women in impoverished regions (31). Vitamin A defi-
ciency among preschool children in Nepal causes an estimated 14,000 to 20,000 Nepalese children to die of infections annually (32). Of nearly 12 million under-5 children who die each year in developing countries, mainly from preventable causes, the deaths of more than 6 million (54%) are either directly or indirectly attributable to malnutrition (Fig. 4) (33,34).

The nature of these deaths disguises the complex sequence of events leading to repetitive episodes of infection, which are accompanied by loss of appetite and decreased food intake, and the increased demands on the child's energy that the illness makes each time.

The burden of maternal mortality that looms large in Southeast Asia is another important area of concern. It is estimated that 585,000 maternal deaths occur in the world every year, and all but 6,000 are in the developing world. Southeast Asia alone contributes 40% of the world total. Women die from hemorrhage, infection, high blood pressure, obstructed labor, unsafe abortion, and a range of diseases that are aggravated by pregnancy (e.g., malaria, hepatitis, and rheumatic heart disease) (7).

The maternal mortality rate in India is the second highest in the world, estimated to be between 385 and 487/100,000 live births (29). Contributory factors include poor nutrition and lack of general healthcare during pregnancy. Negative social practices still inhibit healthcare services and family planning education efforts. Women require the correct knowledge and confidence to take better care of themselves to ensure a better pregnancy outcome. In this regard, discrimination against women is seen as a major cause of malnutrition and mortality. For instance, striking disparities exist in the prevalence of maternal anemia, low birthweight incidence, weight gain during pregnancy, supplementary feeding practices, sanitation, and hygiene in south Asia as compared with Sub-Saharan Africa.

In India, some discernible relations exist between the survival of female children and the mother's characteristics. The female child of the young mother is at particu-
FIG. 5. Major causes of death among children aged less than 5 years in the developing world, 1995.

The mortality risks of child malnutrition are also influenced biologically by natural defenses and nutrition: the physical, microbial, social, and cultural environments. The living conditions of communities and societies, the prevalence and modes of transmission of infectious disease agents, and the nutritional status of the child are among the strongest immediate determinants that set different levels of under-5 mortality rates around the world. The decline in deaths among under-5s in developed countries since the late 1940s has been largely attributable to improvements in sanitation, water supply, housing, food supply and distribution, and general hygiene. However, in many countries (e.g., Afghanistan, Guinea, Liberia, Malawi, Mali, Mozambique, Niger, Sierra Leone, and Somalia) that have been unable to make or sustain progress over the years, under-5 mortality rates are still above 200 (37); in others, the levels are declining only slowly, at a rate of no more than 1% to 2% per year.

In the developing world in 1995, approximately 7.5 million children died from one, or frequently more than one, of five conditions: malaria, malnutrition, measles, acute respiratory infections, and diarrhea. Seven target countries with infant deaths of 40% or more per 1,000 live births have been identified in Southeast Asia (7). Among these countries, Bangladesh, India, Indonesia, and Nepal account for ap-
proximately 40% of the global acute respiratory infection deaths. Poor access to health services, low utilization of government health facilities, and poor outreach of existing programs are major contributory factors to acute respiratory infection deaths. Malaria also exists as a major cause of child death in large areas of the world, taking a major toll on child growth and development. In parts of Africa where malaria is common, nearly one third of childhood malnutrition is caused by malaria. The major causes of death among under-5 children in developing countries (1) are shown in Figure 5.

NEONATAL DEATHS

Although the causes of nearly 4 million stillbirths occurring worldwide are difficult to assess, research shows that nearly half of all stillborn babies are the result of maternal complications during labor and delivery. WHO (1) shows that 2 million babies are either born dead or are born alive only to die within their first 28 days of life. The negative effects of maternal malnutrition in perinatal life and the risk of fetal mortality are higher among stunted populations who have poor pelvic development. Many stillbirths can be circumvented and result in perfectly normal infants if appropriate care is given at birth. More than two thirds of the nearly 4.8 million newborn deaths are among fully developed babies born at term and apparently well equipped for life; however, at least four of every five newborn deaths are caused by infection, birth asphyxia, congenital anomalies, birth injury, and problems linked to preterm birth (Fig. 6) (1).

In 1997, an estimated 275,000 neonatal tetanus deaths occurred, which from the 1980s had been drastically reduced in most countries, with Brazil, Vietnam, and

![FIG. 6. Causes of neonatal death, 1995.](image-url)
China recording greatest progress (1). However, in Nigeria deaths soared from 23,000 in 1990 to 37,000 in 1997 (up by 62%). Neonatal tetanus results from tetanus spores being introduced through poor hygiene during childbirth, often exacerbated by traditional childbirth practices, such as the use of clarified butter or even cattle dung to “heal” the umbilical stump.

Helping these babies to survive and grow up healthy does not require sophisticated equipment but calls for preventive measures and prompt additional care.

LOW BIRTHWEIGHT—A CONSEQUENCE OF POOR MATERNAL NUTRITION

In developing countries where large proportions of women are short and underweight, the number of low birthweight infants is particularly high (30% in south Asia, 10% to 20% in other regions) (38,39), with the incidence of low birthweight being highest in low income groups. A sex difference has also been noted in mean birthweights: female infants tend to weigh less than male infants (40).

Maternal prepregnancy nutrition affects intrauterine growth and birthweight, with anemia and low maternal hemoglobin concentration having distinct influences on birth and delivery outcomes and the quality of the offspring’s life. Infants who start with the initial handicap of low birthweight, despite of their being full term, do not recover from their initial handicap and under these conditions of deprivation, a vicious cycle of malnutrition is set up.

LOW BIRTHWEIGHT AND THE DEVELOPMENT OF CHRONIC DISEASE

Valuable insights into the influence of intrauterine nutrition on the development of diet-related diseases in later life have emerged recently. Links are emerging between malnutrition in early life—including the period of fetal growth—and the development later in life of chronic conditions such as coronary heart disease, diabetes, and high blood pressure, giving the countries in which malnutrition is already a major problem new causes for concern (41).

Examination of fetal and placental size and the risk of hypertension in adult life has shown that the highest blood pressure levels occur in subjects who had been small babies with low birthweight but heavy placentas. Maternal dietary imbalances in critical periods of intrauterine life can trigger a redistribution of fetal resources, affecting a fetus’s structure and metabolism in ways that predispose to later cardiovascular and endocrine diseases (42).

In terms of health and development, the low birthweight child is at a particular disadvantage because of the risk of malnutrition and infection. An additional risk to the infant may come from the fact that iron deficiency and anemia in the mother can also produce alterations in brain function and impair schooling later. The mortality rate of low birthweight infants is estimated to be 86/1,000 births (43). Those who survive have greater mortality rates and poorer neurologic development.
TABLE 4. Global burden of disease and injury attributable to selected risk factors, 1990

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Deaths (thousands)</th>
<th>As % of total deaths</th>
<th>YLLs (thousands)</th>
<th>As % of total YLLs</th>
<th>YLDs (thousands)</th>
<th>As % of total YLDs</th>
<th>DALYs (thousands)</th>
<th>As % of total DALYs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malnutrition</td>
<td>5,881</td>
<td>11.7</td>
<td>199,486</td>
<td>22.0</td>
<td>20,089</td>
<td>4.2</td>
<td>219,575</td>
<td>15.9</td>
</tr>
<tr>
<td>Poor water supply, sanitation, and, personal and domestic hygiene</td>
<td>2,668</td>
<td>5.3</td>
<td>85,520</td>
<td>9.4</td>
<td>7,872</td>
<td>1.7</td>
<td>93,392</td>
<td>6.8</td>
</tr>
<tr>
<td>Unsafe sex</td>
<td>1,095</td>
<td>2.2</td>
<td>27,602</td>
<td>3.0</td>
<td>21,100</td>
<td>4.5</td>
<td>48,702</td>
<td>3.5</td>
</tr>
<tr>
<td>Tobacco</td>
<td>3,038</td>
<td>6.0</td>
<td>26,217</td>
<td>2.9</td>
<td>9,965</td>
<td>2.1</td>
<td>36,182</td>
<td>2.6</td>
</tr>
<tr>
<td>Alcohol</td>
<td>774</td>
<td>1.5</td>
<td>19,287</td>
<td>2.1</td>
<td>28,400</td>
<td>6.0</td>
<td>47,687</td>
<td>3.5</td>
</tr>
</tbody>
</table>

YLD, years of life disabled; YLL, years of life lost; DALY, disability—adjusted life years.

From Murray C, Lopez A (45) and WHO (22).

DISEASE BURDEN OF MALNUTRITION

With the multitude of consequences arising from malnutrition and infection, the disease burden of malnutrition is indeed immense. The Global Burden of Disease (GBD) study, which began in 1992, has assessed the major risk factors using a time-based calculation of future potential years of life lost or lived with a disability, namely disability-adjusted life years (DALYs). In 1990, nearly 1.3 billion DALYs were reportedly lost as a result of new cases of disease and injury that year, almost 90% occurring in developing countries. Of the major risk factors evaluated, malnutrition was by far the leading contributor to DALYs worldwide, causing an estimated 16% of the global burden of disease in 1990 (18% in developing regions), with the contributions to disease burden being particularly evident in Sub-Saharan Africa (33%) and India (22%) (44).

Malnutrition (including protein-energy malnutrition, vitamin A deficiency, iodine deficiency, and anemia) is included among group I causes of death, accounting for 11.7% of total deaths, followed by poor water and sanitation as the next risk factor (Table 4) (45).

COSTS OF MALNUTRITION

The burden of childhood malnutrition and disease can lead to substantial loss of adult productivity. The ultimate cost of malnutrition in children can be divided into the well-known visible and the less well-known invisible costs. The visible part includes the cost of drugs, hospital admission, transportation, and food, plus the cost of treatment of non-nutritional diseases. The larger and invisible part is composed of loss of family income and national productivity as a result of one or both of the parents attending to the child; expenses incurred by hospital costs and the cost of pregnancy, childbirth, and lactation; the cost of food consumed by the child; clothing, education, and other related expenses; and the loss of a potential working population, lowered capacity to work, and, thus, a slower national economic growth. If this is translated
into quantifiable terms of national losses of productivity, the burden at the global level can be immense.

REDUCED COGNITION, PHYSICAL WORK CAPACITY, AND PRODUCTIVITY

Malnourished children, unlike well-nourished children, not only have lifetime disabilities and weakened immune systems, but also lack the capacity for learning of their well-nourished peers. Undernutrition could also have a direct effect on the child’s central nervous system. Stunted children reportedly have smaller heads than those who are not stunted, and head size was shown to be a stronger predictor of intelligence quotient at 7 years of age than other previous or current anthropometric measures (46). In young children, malnutrition dulls motivation and curiosity and reduces play and exploratory activities. These effects, in turn, impair mental and cognitive development. Such children grow up to be adults with fewer productive capacities.

Table 5 shows productivity losses of protein-energy malnutrition and iron deficiency in Asian countries, which are indicative of the impending burden (47).

In an expectant mother, malnutrition, especially iodine deficiency, can produce varying degrees of mental retardation in her infant. Even in populations known to be at risk of iodine deficiency disease where no evidence of cretinism is seen, a downward shift in the frequency distribution of IQ in school children has been noted, as has been documented in Italy and Spain (48). In Indonesia, 140 million IQ points were lost each year, owing to iodine deficiency, before the Ministry of Health started its current preventive campaign (49).

Of greatest concern, is that iodine deficiency in infants and children is associated with impaired physical and cognitive development. The mental and motor effects of iron deficiency or anemia have not been studied closely in infants in Asia, but studies elsewhere show that iron-deficient infants are at risk of long-term impairment in mental and motor development (50). Lower scores in IQ tests and poorer performance in school at a later age were seen to be associated with iron deficiency during infancy (51). Anemic preschool and school-aged children in India and Pakistan performed more poorly than children with normal hemoglobin levels in learning and se-

<table>
<thead>
<tr>
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<th>Current losses (manual labor) (%)</th>
<th>Losses based on childhood malnutrition (cognitive) (%)</th>
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<tbody>
<tr>
<td>Protein-energy</td>
<td>2–6 (moderate stunting)</td>
<td>10</td>
</tr>
<tr>
<td>Malnutrition</td>
<td>2–9 (severe stunting)</td>
<td></td>
</tr>
<tr>
<td>Iron deficiency</td>
<td>17 (heavy labor)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>5 (blue-collar)</td>
<td></td>
</tr>
</tbody>
</table>

From ADB-UNICEF (47).
lected cognitive function tests (52,53). Earlier studies carried out in India and Pakistan (54,53) likewise revealed impaired ability among anemic preschool children to perform physical work.

Activity levels and frequency of children’s play, which are important for long-term developmental and cognitive outcomes, have increased with zinc supplementation. Studies in India (55) and China (56) have shown positive effects of zinc supplementation on exploratory, neuromotor, and cognitive functions in children.

Deficits in cognitive performance in early life can, therefore, lead to cumulative deficits in school performance, resulting in higher school dropout rates and a high burden of illiteracy in our future populations. Reduced ability to engage in physical activity has implications in that it limits the child’s scope for exploratory activities and does not allow optimal development of motor skills in such children. Growth deficits arising out of malnutrition, thus, invariably persist into adulthood, adversely affecting work performance and productivity, and additionally, for girls, increasing the risk of bearing infants with low birthweight.

THE NEED FOR INTEGRATED APPROACHES

To fight and succeed against malnutrition and infection, a range of preventive and practical actions is necessary, using integrated approaches.

The greatest preventive measures for combating child mortality include the combined inputs of immunization, improved maternal health, and family planning. As part of improved health and nutrition interventions, they serve to prevent or provide effective treatment for common childhood infectious diseases. An integrated management of childhood illnesses and rationalization of the task of health workers are mandatory. It is gratifying to note that many infectious disease control programs now include a major section on nutritional management. Diarrheal disease, acute respiratory infection (including measles), and AIDS all have vital nutritional components to management (1).

Empowerment of women and communities is ultimately crucial for nutritional improvement and for addressing disease concerns of both the women themselves and their children. Most countries in which nutrition has improved have employed integrated community-based programs using holistic participatory approaches in reaching the vulnerable groups. Self-reliance needs to be emphasized at the community level by developing need-based programs and furnishing support to strengthen the self-help capabilities of the disadvantaged, with a special focus on mothers and children (57).

This approach is based on the principle that community nutrition projects cannot be sustained if they are planned solely from the top, focus only on individuals, and are isolated from the entire community development process. Community involvement, being fundamental to solving local nutrition and related health problems, relies heavily on the participatory approach, which eventually leads to greater coverage of the target population, namely mothers and children. Certain key community-based nutrition program components are included (Fig. 7).
For a community-based approach to have a chance of success, the objectives of each activity as well as for the program overall must be made clear to the implementing personnel in all major sectors, namely health, education, agriculture, and rural development, all of which impinge on the nutritional status of communities and, specifically, on children. This depends largely on participatory action in not only implementing the activities but also following up on recommended actions. Crucial to this is empowering facilitators and mobilizers with the knowledge and motivation to translate vital ideas into action. This is one of the reasons why it is so essential to integrate nutritional interventions both into primary healthcare activities and into overall community development initiatives that are being planned and managed at various levels. For example, between 1982 and 1991 Thailand dramatically reduced severe and moderate malnutrition, and almost eradicated it through an accelerated action program that focused on nutrition (58). Protein-energy malnutrition was identified as the most important nutritional problem, and a separate national plan for food and nutrition was included in the National Economic and Social Development Plan, with clear goals to eradicate all severe forms of protein-energy malnutrition and to reduce moderate forms by 50% and mild forms by 25%. Comprehensive nutritional surveillance was instituted through growth monitoring, and a program of nutrition education and communication was rigorously implemented throughout the country. Household and community food security was strengthened through home gardening,
fruit trees, fish ponds, and prevention of epidemic diseases in poultry. School lunch programs were instituted in poor areas, and food fortification was introduced to iodize salt. Food and nutrition was integrated in the context of the poverty alleviation plan in Thailand, which enabled virtual eradication of severe and moderate malnutrition within a decade.

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GLOBAL BURDEN OF MALNUTRITION AND INFECTION


47. ADB-UNICEF Regional study on reducing child malnutrition in Asian countries; 1998.


