

## *While poverty and socioeconomic inequity remains an important factor, in many cases, the presence of micronutrient deficiency is a factor of diet quality*

Ann Nutr Metab 2012;61(suppl 1):19–27

### **Global Nutrition Epidemiology and Trends** by Zulfiqar A. Bhutta and Rehana A. Salam

#### **Key insights**

Possible strategies to combat high morbidity (e.g. stunting and underweight) and mortality in malnourished children include promotion of breastfeeding, dietary supplementation of micronutrients, prevention of protein-energy malnutrition, and hygiene of available weaning foods. Interventions that depend on strong health systems or behavioral changes appear to be stalled and need to be re-examined to find more effective ways of delivery.

#### **Current knowledge**

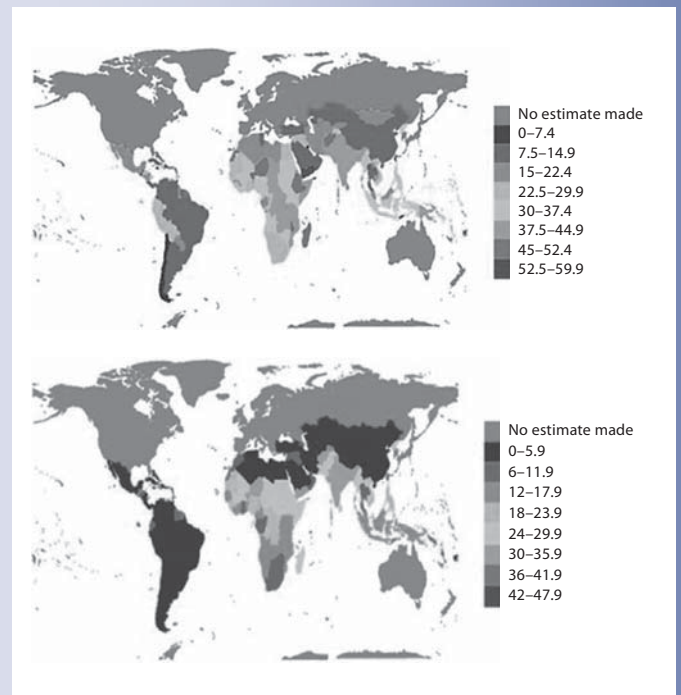
Infectious diseases including diarrhea often coexist with micronutrient deficiencies and lead to the vicious cycle of malnutrition and infections. Emerging data from community intervention trials provide evidence that implementing intervention strategies that combine appropriate infant and young child feeding with micronutrient interventions at scale are tangible and could lead to an alleviation of malnutrition.

#### **Practical implications**

Effective, packaged delivery of proven interventions and ensuring universal coverage could prevent about one quarter of child deaths under 36 months of age and reduce the prevalence of stunting at 36 months by about one third.

#### **Recommended reading**

Bhutta ZA, Chopra M, Axelson H, et al: Countdown to 2015 decade report (2000–10): taking stock of maternal, newborn, and child survival. *Lancet* 2010;375:2032–2044.



Prevalence data (2011) of stunting (upper panel) and underweight (lower panel). Reproduced with permission from Stevens et al. [31].

# Global Nutrition Epidemiology and Trends

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## Key Messages

- 6.9 million children under the age of 5 years died worldwide in 2011, one third of deaths being attributable to the underlying cause of undernutrition.
- The majority of the undernutrition burden exists in sub-Saharan Africa and South-Central Asia.
- Infectious diseases including diarrhea often coexist with micronutrient deficiencies and lead to the vicious cycle of malnutrition and infections.
- Possible strategies to combat malnutrition include promotion of breastfeeding, dietary supplementation of micronutrients, prevention of protein-energy malnutrition, and hygiene of available weaning foods.
- Packaged delivery of these proven interventions and ensuring its universal coverage could prevent about one quarter of child deaths under 36 months of age and reduce the prevalence of stunting at 36 months by about one third.
- For several interventions, including exclusive breastfeeding and case management of childhood illnesses, the median coverage rates still hover at or below 50%.
- Interventions requiring strong health systems or behavior change appear to be stalled and need to be re-examined to find more effective ways of delivery.

## Key Words

Infections · Micronutrient deficiency · Undernutrition

## Abstract

In the year 2011, 6.9 million children under the age of 5 years died worldwide, one third of them related to increased susceptibility to illnesses due to undernutrition. An estimated 178 million children under 5 years are stunted, 55 million are wasted, and 19 million of these are severely affected and are at a higher risk of premature death, the vast majority being from sub-Saharan Africa and South-Central Asia. Globally, over 2 billion people are at risk for vitamin A, iodine, and/or iron deficiency. Other micronutrient deficiencies of public health concern include zinc, folate, and the B vitamins. The risk factors for undernutrition include low birth weight, inadequate breastfeeding, improper complementary feeding, and recurrent infections. Infectious diseases often coexist with micronutrient deficiencies and exhibit complex interactions leading to the vicious cycle of malnutrition and infections. Diarrhea along with the poor selection and intake of complementary food are the major contributors to undernutrition. Possible strategies to combat malnutrition include promotion of breastfeeding, dietary supplementation of micronutrients, prevention of protein-energy malnutrition, and improvement in the standard of preparation and hygiene of available weaning foods. The universal coverage with the full package of these proven interventions at observed levels of program effectiveness could prevent about

one quarter of child deaths under 36 months of age and reduce the prevalence of stunting at 36 months by about one third. The median coverage rate of interventions along the continuum of care for Countdown countries has however been  $\geq 80\%$  for vaccination and vitamin A supplementation. However, for several interventions, including early initiation and exclusive breastfeeding below 6 months of age and case management of childhood illnesses, the median coverage rate hovers at or below 50%. This suggests that interventions requiring strong health systems or behavior change appear to be stalled and need to be re-examined to find more effective ways of delivery.

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## Introduction

Despite numerous advances and improvements in child health, malnutrition still remains one of the main public health challenges of the 21st century, particularly in developing countries [1]. In the year 2011, almost 6.9 million children under 5 years of age died worldwide, a large proportion of deaths being related to increased susceptibility to illnesses due to undernutrition [2]. Undernutrition undermines the survival, growth, and development of children and is associated with almost one third of all deaths in children under the age of 5 worldwide.

The condition of maternal and childhood undernutrition includes a wide array of effects including intra-uterine growth restriction (IUGR) resulting in low birth weight (LBW); stunting, a chronic restriction of growth in height indicated by short stature; wasting, an acute weight loss indicated by a low weight-for-height, and less visible micronutrient deficiencies due to deficiencies of essential minerals and vitamins. An estimated 178 million children under 5 suffered from stunting, the vast majority in sub-Saharan Africa and South-Central Asia [3]. Of these, 160 million (90%) lived in just 36 countries, representing almost half (46%) of the 348 million children in those countries [3]. An estimated 55 million children were wasted, 19 million of these were severely affected and at high risk of premature death [3]. Altogether, >3.5 million mothers and children under 5 died unnecessarily each year in poor countries due to the underlying cause of undernutrition [4]. Many of these conditions are associated with concomitant micronutrient deficiencies and, among these, vitamin A, iron, zinc,

and iodine deficiencies are the most prevalent in childhood.

Major risk factors for undernutrition, such as suboptimal breastfeeding and micronutrient deficiencies (vitamin A and zinc), were responsible for more than one third of all under-5 child deaths and 11% of the global total disease burden [2]. These conditions are most significant in the first 2 years of life, highlighting the importance of nutrition in pregnancy and the window of opportunity for preventing undernutrition from conception through 24 months of age. Conditions such as poor fetal growth during pregnancy, stunting during early childhood, and severe wasting in the first 2 years of life cause irreparable harm by impeding physical growth and – if followed by rapid weight gain in the 3–5 year age range – significantly increase the risk of chronic disease later in life. Children who are stunted or born with IUGR are also shown to complete fewer years of schooling and earn less income as adults, hindering their cognitive growth and economic potential. Lower income, poor health, and reduced access to proper nutrition then continue to impact the health of children born into future generations, establishing a repetitive cycle.

The median case fatality from severe malnutrition has remained unchanged over the last 5 decades and is typically 20–30%, with the highest levels (50–60%) being among those with edematous malnutrition [5].

Micronutrient deficiency is a major contributor and it affects the people of the developed and developing countries of all ages, but its effects appear more devastating in children, especially young infants. Micronutrients play a critical role in cellular and humoral immune responses, cellular signaling and function, learning and cognitive functions, work capacity, reproductive health, and even in the evolution of microbial virulence [6, 7]. The body cannot synthesize them, so they must be made available through the diet [7]. This does not in any way undermine the significance of protein-energy malnutrition for infant mortality, but emphasizes the understanding of the central role of micronutrients in the morbidity and mortality of infants. Two recent major advances in the understanding of the global importance of malnutrition are (1) the data of 53 countries that link protein-energy malnutrition (assessed by underweight; fig. 1) directly to increased child mortality rates and (2) the outcome in 6 of 8 large vitamin A supplementation trials showing decreases of 20–50% in child mortality [8].

***Altogether, >13.5 million mothers and children under 5 died unnecessarily each year in poor countries due to the underlying cause of undernutrition.***

## Undernutrition Epidemiology

Recent estimates indicate that globally, >2 billion people are at risk for vitamin A, iodine, and/or iron deficiency, in spite of recent efforts in the prevention and control of these deficiencies. The prevalence is especially high in Southeast Asia and sub-Saharan Africa. Other micronutrient deficiencies of public health concern include zinc, folate, and the B vitamins. In many settings, more than one micronutrient deficiency exists, suggesting the need for simple approaches that evaluate and address multiple micronutrient malnutrition [9].

Anemia, one of the major global nutrition concerns, is caused not only by deficiency of iron, but is also associated with other nutrient deficiencies, such as vitamin A, B6 and B12, riboflavin, and folic acid. Besides nutrient deficiencies, general infections, chronic diseases, malaria and Helminthes infestation also lead to anemia. In developed countries, iron deficiency is a major cause of anemia, while in developing countries (apart from iron), vitamin A, zinc, and folic acid are nutrient factors which are important as well [10, 11].

Iodine deficiency disorder (IDD) is a public health problem in 130 countries and affects 13% of the world's population [12]. Globally, about 740 million people are affected by goiter, and >2 billion are considered at risk of IDD. The major consequences of IDD include impaired development of the fetal brain, and it is the first cause of preventable brain damage in children [13]. It is estimated that 68% of the populations of affected countries have currently access to iodized salt.

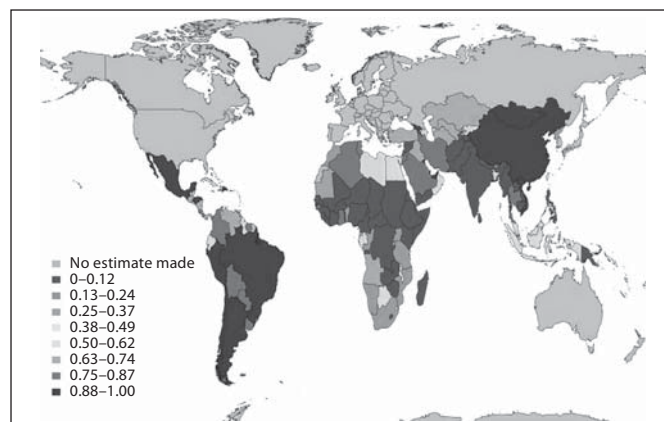
Zinc is a vital micronutrient for body function at different statuses of body physiology. It is estimated that one third of the world population lives in countries with a

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***Recent estimates indicate that globally, 12 billion people are at risk for vitamin A, iodine, and/or iron deficiency, in spite of recent efforts in the prevention and control of these deficiencies.***

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high prevalence of zinc deficiency. Deficiency of zinc, which is essential for DNA and protein synthesis and a component of several metalloenzymes, leads to growth failure. There is now increasing recognition of the importance of zinc in childhood growth and development [14] and subclinical zinc deficiency has been widely rec-



**Fig. 1.** Posterior probability of meeting Millennium Development Goal 1 target. Reproduced with permission from Stevens et al. [31].

ognized as a significant limiting factor for growth among children in both developing and developed countries [15].

Clinical vitamin A deficiency (VAD) affects at least 2.80 million preschool children in >60 countries, and subclinical VAD is considered a problem for at least 251 million, including school age children and pregnant women [8]. Severe as well as marginal VAD has been shown to lead to an increased risk of morbidity and mortality in children. Delayed growth, especially stunting, has also been reported in children with clinical signs of VAD [16].

Folic acid, known as the universal vitamin, is present in a variety of foods. The majority of the data on folate deficiencies are based on small, local surveys, but they suggest that the deficiency may be a public health problem affecting millions of people globally. Folate status is the major determinant of plasma homocysteine level, and there is a strong inverse correlation between plasma homocysteine level and serum or erythrocyte folate levels [17]. Folate and B12 deficiencies have been found to be associated with adverse pregnancy outcomes including both LBW and preterm birth [18].

## Contributing Factors

The risk factors for malnutrition include LBW, inadequate breastfeeding, improper complementary feeding, and recurrent infection. Infectious diseases cause 7 out of 10 deaths among the world's children [19]. Infectious diseases often coexist with micronutrient deficiencies and exhibit complex interactions leading to the vicious cycle



of malnutrition and infections among underprivileged populations of the developing countries.

Malnutrition and diarrhea go hand in hand; micronutrient deficiency is inherent in these conditions. The estimated deaths in the developing countries because of acute diarrhea account for 35%, dysentery for 20%, and non-dysenteric persistent diarrhea for 45% of total diarrheal deaths. Diarrhea, in turn, not only leads to further loss of micronutrients [20], especially of zinc, but also deteriorates the absorption capability of the intestine, thus putting the child at an increased risk. Factors that increase the risk of acute diarrhea becoming persistent include antecedent malnutrition, micronutrient deficiency particularly for zinc and vitamin A, transient impairment in cell-mediated immunity, sequential infection with different pathogens, and lack of exclusive breastfeeding during the initial 4 months of life, particularly in connection with use of bovine milk [20].

Although the association between diarrheal 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 diarrhea, 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 severe diarrhea has been well recognized. In addition, it is recognized that children with shigellosis can lose a significant amount of vitamin A in the urine, thus further contributing to VAD. The risk of micronutrient deficiency in infancy and early childhood can be compounded several folds by the presence of low body stores from birth as in LBW infants, as well as poor complementary feeding practices. It is therefore not surprising that micronutrient deficiencies and a high burden of diarrhea frequently coexist in susceptible populations and may lead to a vicious cycle of malnutrition.

Several micronutrients, such as vitamin A,  $\beta$ -carotene, folic acid, vitamin B12, vitamin C, riboflavin, iron, zinc, and selenium, have immune-modulating functions and thus influence the susceptibility of a host to infectious diseases and the course and outcome of such diseases. Certain of these micronutrients also possess antioxidant functions that not only regulate immune homeostasis of the host, but also alter the genome of the microbes, particularly in viruses, resulting in grave consequences

like resurgence of old infectious diseases or the emergence of new infections [21].

In addition to the role of diarrhea, the major contributory factor of micronutrient deficiency in early childhood is poor dietary intake. While poverty and socioeconomic inequity remains an important factor, in many cases the presence of micronutrient deficiency is a factor of diet quality. Thus, both poor intake of complementary foods as well as selection of foods with high phytate and fiber content may lead to the development of a 'deficient' state for both iron and zinc. It is also important to note that many of these children with relatively high intakes of staple cereal-based diets with poor iron and zinc bioavailability also belong to poor households with low intakes of meat and dairy products. The latter are also important dietary sources of carotenoids and vitamin A, and thus a malnourished child with diarrhea and poor dietary intake is already set up for multiple micronutrient deficiencies.

### Intervention Coverage Trends

Possible strategies include promotion of breastfeeding, dietary supplementation of micronutrients, prevention of protein-energy malnutrition as far as possible, and improvement in the standard of preparation and hygiene of available weaning foods [22]. Recent reviews have shown that no breastfeeding led to a 47 and 157% increase in diarrhea-related mortality in 6- to 11- and 12- to 23-month-old children, respectively [23]. Preventive zinc supplementation resulted in a 18% reduction in diarrhea-related mortality and a 9% reduction in all-cause mortality [24]. The therapeutic effect of zinc supplementation on acute and persistent diarrhea has been evaluated in a meta-analysis confirming the beneficial effect on both severity and duration of diarrhea [25]. This was also indicated by the 60% reduction in mortality among LBW infants receiving zinc supplementation in India [26].

Table 1 summarizes the median national coverage of interventions along the continuum of care in Countdown countries since 2006 [27, 28]. All four vaccines [measles, diphtheria-tetanus-pertussis (DTP3), Haemophilus influenzae type B (HiB3), and neonatal tetanus protection] and vitamin A (2 doses) have reached a median coverage level of  $\geq 80\%$  in the Countdown coun-

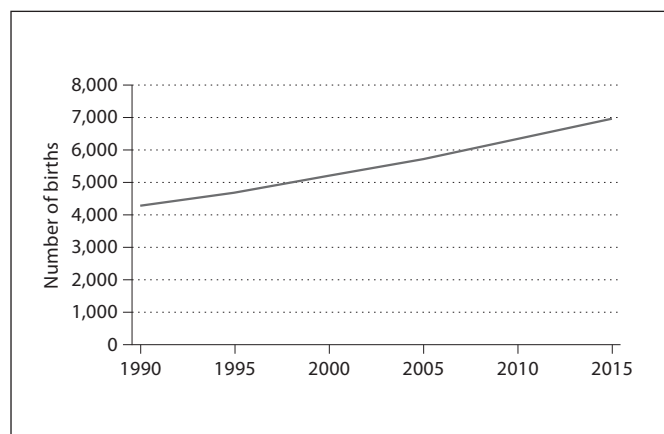
*In recent years, the association of increased micronutrient losses, such as those of zinc and copper, with severe diarrhea has been well recognized.*

**Table 1.** Median national coverage of Countdown intervention based on the most recent measurement since 2006, with number of countries reported and range [27, 28]

Countdown indicator	Countries with data n	Median coverage %	Range %
<i>Pre-pregnancy</i>			
Demand for family planning satisfied	46	56	17–97
<i>Pregnancy</i>			
Antenatal care (at least 1 visit)	69	88	26–100
Antenatal care ( $\geq 4$ visits)	49	55	6–97
IPTp*	39	13	0–69
Neonatal tetanus protection	66	85	60–94
<i>Birth</i>			
Skilled attendant at birth	67	57	10–100
<i>Postnatal period</i>			
Postnatal visit for mother	22	41	22–87
Postnatal visit for baby	4	50	8–77
Early initiation of breastfeeding	55	46	18–81
<i>Infancy</i>			
Exclusive breastfeeding	57	37	1–74
Introduction of semi-solid/solid foods	39	73	16–94
Vitamin A (2 doses)	56	92	0–100
Measles	73	84	46–99
DTP3	74	85	33–99
HiB3	58	83	45–99
<i>Childhood</i>			
ORT	53	45	7–68
ORS	57	33	10–77
Care seeking for pneumonia	57	55	13–83
Antibiotic treatment for pneumonia	45	39	3–88
ITN use*	36	34	3–70
Antimalarial treatment*	31	25	0–91
<i>Water and sanitation</i>			
Improved drinking water sources (total)	70	76	29–99
Improved sanitation facilities (total)	71	40	9–100

IPTp = Intermittent preventive therapy of malaria during pregnancy; ORT = oral rehydration therapy. \* For the malaria indicators, the number of countries is based on those countries with  $\geq 75\%$  of the population at risk of *Plasmodium falciparum* transmission with an estimate during the time period 2006–2010.

tries with available data. In most Countdown countries, vaccines and vitamin A are provided in fixed health facilities as well as during campaigns such as national Child Health Days when outreach teams are able to reach high proportions of the population. Child Health Days were introduced in response to the declining coverage of many essential child survival interventions as a result of weakening health systems. Child Health Days suggest

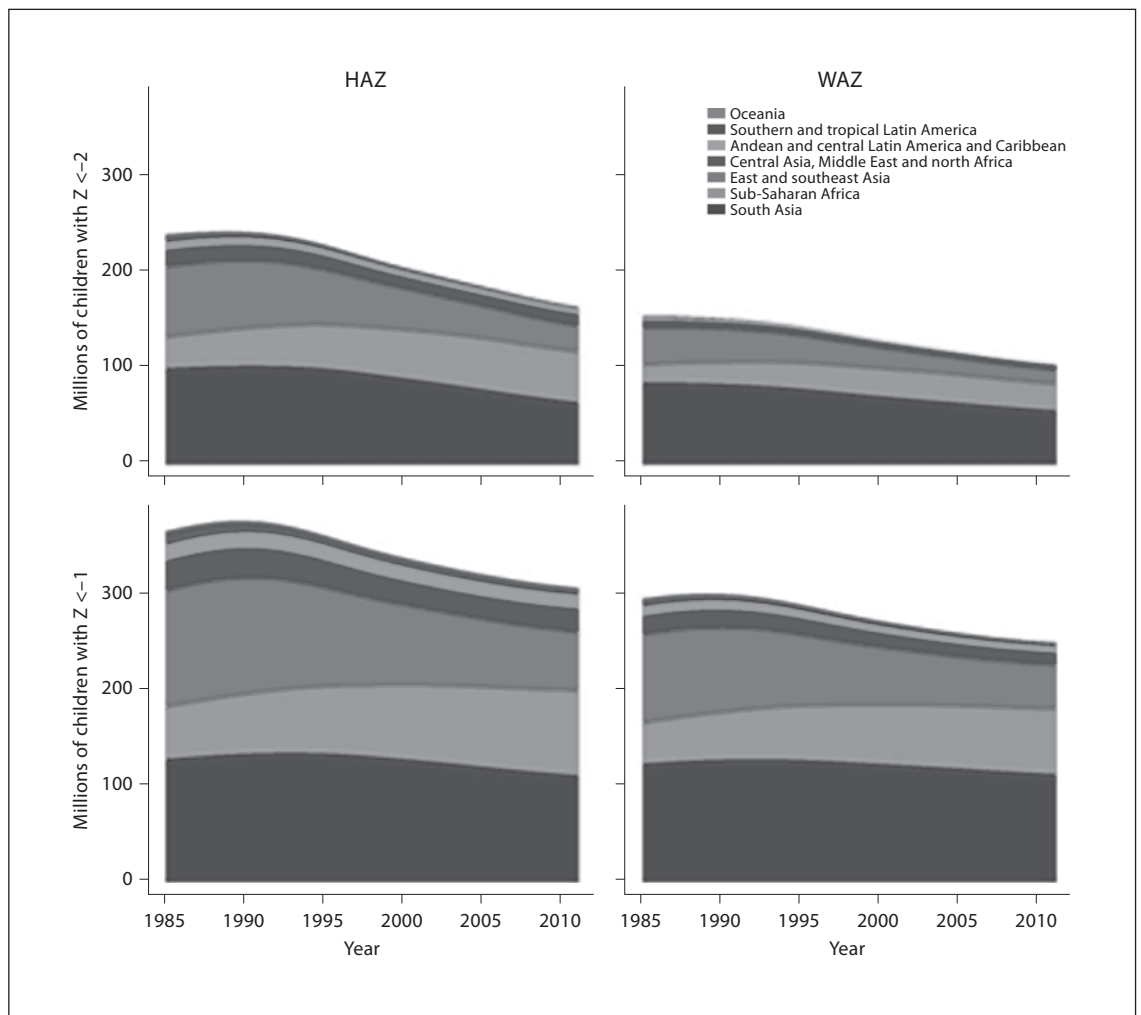


**Fig. 2.** Increased service volumes can depress coverage gains. Annual numbers of births in Nigeria. Reproduced with permission from World Population Prospects, the 2010 Revision [30].

that these achieve greater coverage than stand-alone campaigns, particularly in previously low-coverage countries. In the countries studied, Child Health Days also improved the manner in which key child survival interventions were delivered through strengthened supervision and health worker performance and motivation, and mobilization of additional resources (funds, fuels, and vehicles). In turn, these advances translated into coverage gains [29].

Coverage with  $\geq 1$  antenatal visit is also very high (median of 88%). This level drops to 55% for coverage of  $\geq 4$  antenatal visits. The results also show that at least 1 country has achieved coverage levels above 80% for 16 interventions; and at least 1 country reached a coverage level of between 70 and 80% for 4 other interventions [postnatal care for babies, exclusive breastfeeding, insecticide-treated net (ITN) use in children under 5, and oral rehydration salt (ORS)]. The results also show, however, that substantial progress is still needed. The median coverage levels for several interventions hover at or below 50% (i.e. interventions related to case management of childhood illnesses, demand for family planning satisfied, and early initiation of and exclusive breastfeeding under 6 months of age) [27, 28].

In absolute terms, the largest increase was observed for ITNs (35%), followed by exclusive breastfeeding (14%), antenatal care (at least 1 visit) and DTP3 vaccine (both with 12%). The slowest absolute gains were observed for ORS and early initiation of breastfeeding, both with 4%. Absolute gains need to be interpreted with caution because increases are harder to achieve if baseline levels are



**Fig. 3.** Trends in the number of undernourished children. Reproduced with permission from Stevens et al. [31]. HAZ = Height-for-age Z score; WAZ = weight-for-age Z score.

already high. For example, median coverage of measles and DTP3 was already relatively high at 71% during the time period 2000–2005, limiting the possible absolute increase in coverage to 29% [27, 28].

Table 2 shows progress in intervention coverage from 2000–2005 to 2006–2011 [27, 28]. This illustrates that interventions that had already achieved coverage of  $\geq 70\%$  by 2005 (1 antenatal care visit, DTP3, and measles) and had a potential for rapid growth among new interventions were backed by high levels of resources and political commitment (e.g. ITNs). Interventions requiring strong health systems (skilled attendant at birth, ORS) or those requiring behavior change (breastfeeding, care seeking for pneumonia) appear to be stalled and coverage levels remain between 30 and 50%, suggesting that what we

have been doing for these interventions over the past decade is not working and needs to be re-examined to find more effective ways of reaching the women and children who need to receive them.

However, it should be noted that focus on coverage alone is not the solution. This can mask important progress in countries with delivering services to mothers, newborns, and children. One illustrative example of this is Nigeria's slow progress in increasing coverage of skilled attendants at birth despite doubling in the number of births attended by a skilled health provider. It is also a clear indication of the considerable challenges posed by population pressure on country efforts to deliver interventions at scale (fig. 2) [30].

**Table 2.** Trends in Countdown indicators, countries with data from at least 2 surveys; 2000–2005 and 2006–2011 [27, 28]

Countdown indicator	Countries with data n	Median coverage 2000–2005 %	2000–2005 range, %	Median coverage 2006–2011 %	2006–2010 range, %	Change in percentage points	% of gap closed
Antenatal care (at least 1 visit)	61	76	27–98	88	34–100	12	50
Skilled attendant at birth	61	49	6–99	57	10–100	8	16
Early initiation of breastfeeding	21	49	32–72	53	20–81	4	8
Exclusive breastfeeding under 6 months	48	26	1–68	40	3–74	14	19
Measles*	73	71	17–98	79	27–99	8	28
DTP3*	73	71	25–99	83	19–99	12	41
ORS	46	29	10–66	33	10–77	4	6
Care seeking for pneumonia	45	44	16–93	51	23–83	7	13
ITN**	26	2	0–23	37	3–64	35	36

\* The immunization data, measles and DTP3, are based on the interagency estimates from 2002 and 2008; these were the average reference years for calculating trends for the non-vaccine indicators. \*\* For the malaria indicators, analyses are restricted to countries with  $\geq 75\%$  of the population at risk of *Plasmodium falciparum* transmission and with trend data available.

### Undernutrition, Food Security and Poverty: The Inequities

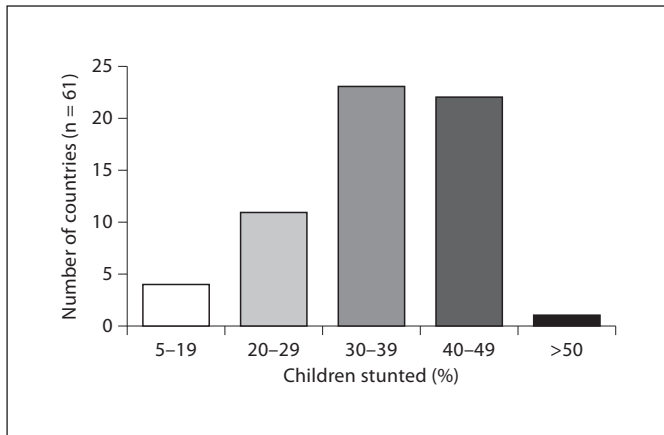
Although rates of childhood malnutrition have decreased overall, the relative improvements in trends for malnutrition indicate considerable disparity, with South Asia still showing a high burden of malnutrition (fig. 3) [31]. Of all the world's LBW infants, almost three quarter are born in South Asia alone [32, 33]. In other parts of the world, high rates of HIV threaten to reverse all the gains made by child survival programs, with increasing malnutrition.

Stunting prevalence is a critical indicator of progress in child survival, reflecting long-term exposure to poor health and nutrition, especially in the first 2 years of life [34]. Children under the age of 5 around the world have the same growth potential, and prevalence of stunting above the 3% level expected in a well-nourished population indicates the need for remedial actions. All 61 Countdown countries with data available since 2006 have levels of stunting above the 3% threshold (fig. 4). In the majority of these countries, more than 1 in 3 children is stunted, a situation requiring urgent attention. Stunting is particularly high among the poorest populations within the Countdown countries (fig. 5). In one fifth of the Countdown countries, more than half of the children in the poorest 20% of all families are stunted. Addressing childhood undernutrition through multisectoral programs must continue to be a major priority across the Countdown countries.

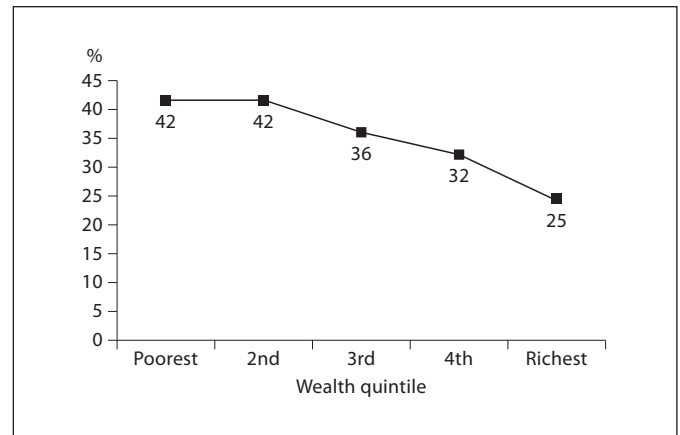
Wasting, or low weight-for-height in children under 5 years of age, is the most reliable indicator of acute food insecurity and signals an urgent need for action [1]. The short-term mortality risk for a wasted child is much higher than for a stunted child. In 60 Countdown countries with data since 2006, the median prevalence of wasting is 7.1%, ranging from 0.6% in Peru to 21% in the last survey in pre-cession Sudan. Very high rates of wasting are also observed in Niger (15.5%), Chad (15.6%), Bangladesh (17.5%), and India (20.0%).

Poor maternal nutrition contributes to at least 20% of maternal deaths and increases the probability of other poor pregnancy outcomes including newborn deaths [1]. There are fewer data available on the nutritional status of women than on the nutritional status of children. Key indicators of maternal nutrition are maternal stature, body mass index (BMI), and anemia. Prevalence of low BMI among women of reproductive age is an important risk factor for IUGR and LBW, as well as for neonatal mortality. Maternal undernutrition is particularly severe in Countdown countries in the South Asia region. National data from Pakistan, for example, indicate that  $>25\%$  of women 15–19 years of age had a BMI  $<18.5$  and 10% were shorter than 145 cm [35]. In 24 Countdown countries with a recent Demographic and Health Survey, the median prevalence of low BMI among women of reproductive age is 10.9%, with a minimum of 0.7% in Egypt. Four countries report an extremely high prevalence: Nepal (26.1%), Madagascar (28.1%), Bangladesh (32.8%), and India (39.9%). Low BMI is not the only type





**Fig. 4.** Percentage of children under 5 years who are stunted in 61 Countdown countries from 2006 to 2010. Reproduced with permission from Bhutta et al. [27] and Countdown to 2015 [28].



**Fig. 5.** Poorer children are more likely to be stunted. Median prevalence of stunting by wealth quintile in 61 Countdown countries. Reproduced with permission from Bhutta et al. [27].

of undernutrition affecting pregnant women; short maternal stature, often a result of childhood stunting, is a risk factor for obstructed labor and caesarean delivery due to a resulting disproportion between the baby's head and the maternal pelvis. A World Health Organization review of nationally representative surveys from 1993 to 2005 found that 42% of pregnant women worldwide are anemic, with over half of all cases due to iron deficiency [36]. Prenatal folic acid deficiency is also widespread and associated with an increased risk of neural tube defects.

Further research is needed to understand the relationships between maternal undernutrition and short- and long-term maternal and child health outcomes. More and better data are also needed on measures of maternal nutritional status and on coverage of evidence-based interventions, including folic acid supplementation in the periconceptional period, iron and folic acid uptake among women at risk of iron deficiency anemia, and nutritional programs to address food insecurity and low maternal BMI.

## Conclusions

Given the wide prevalence of multiple micronutrient deficiencies in developing countries, the challenge is to implement intervention strategies that combine appropriate infant and young child feeding with micronutrient interventions at scale. Emerging data from community intervention trials now provide evidence that this is both tangible and can lead to alleviation of childhood undernutrition. In other instances, strategies to address food insecurity and poverty alleviation are the key.

Current guidelines for the management of severe malnutrition are mainly based on new concepts regarding the causes of malnutrition and on advances in our knowledge of the physiological roles of micronutrients. In contrast to the early 'protein dogma', there is a growing body of evidence that severely malnourished children are unable to tolerate large amounts of dietary protein during the initial phase of treatment. A need for the mineral-vitamin mix supplementation was recognized, which could be designed for the initial treatment and the rehabilitation phase [37]. In many settings, more than one micronutrient deficiency exists, suggesting the need for simple approaches that evaluate and address multiple micronutrient malnutrition [9]. Food-based approaches are regarded as the long-term strategy for improving nutrition, which would need enormous efforts and proper planning, but for certain micronutrients, supplementation, be it to the general population, to high-risk groups or as an adjunct to treatment, must also be considered. Furthermore, any plan for the fortification would need to be piloted and get experienced before implementation. Universal coverage with the full package of proven interventions at observed levels of program effectiveness could prevent about one quarter of child deaths under 36 months of age and reduce the prevalence of stunting at 36 months by about one third.

## Disclosure Statement

We do not have any financial or non-financial competing interests for this review. The writing of this article was supported by Nestlé Nutrition Institute.

## References

- 1 Black RE, Allen LH, Bhutta ZA, et al: Maternal and child undernutrition: global and regional exposures and health consequences. *Lancet* 2008;371:243–260.
- 2 You D, Jin NR, Wardlaw T: Levels and Trends in Child Mortality: Report 2012. United Nations Children's Fund, 2012.
- 3 Bhutta ZA: Micronutrient needs of malnourished children. *Curr Opin Clin Nutr Metab Care* 2008;11:309–314.
- 4 World Health Organization: Severe Malnutrition: Report of a Consultation to Review Current Literature. Geneva, World Health Organization, 2005.
- 5 Schofield C, Ashworth A: Why have mortality rates for severe malnutrition remained so high? *Bull World Health Organ* 1996;74:223.
- 6 Guerrant RL, Lima AA, Davidson F: Micronutrients and infection: interactions and implications with enteric and other infections and future priorities. *J Infect Dis* 2000;182(suppl 1):S134–S138.
- 7 Kapil U, Bhavna A: Adverse effects of poor micronutrient status during childhood and adolescence. *Nutr Rev* 2008;60:S84–S90.
- 8 Stephenson LS, Latham MC, Ottesen EA: Global malnutrition. *Parasitology* 2000;121:5–22.
- 9 Ramakrishnan U: Prevalence of micronutrient malnutrition worldwide. *Nutr Rev* 2002;60:S46–S52.
- 10 Morais MB, Ferrari AA, Fisberg M: Effect of oral iron therapy on physical growth. *Rev Paul Med* 1993;111:439–444.
- 11 Olivares M, Walter T, Hertrampf E, Pizarro F: Anaemia and iron deficiency disease in children. *Br Med Bull* 1999;55:534–543.
- 12 Vir SC: Current status of iodine deficiency disorders (IDD) and strategy for its control in India. *Indian J Pediatr* 2002;69:589–596.
- 13 De Benoist B, Delange F: Iodine deficiency: current situation and future prospects (in French). *Sante* 2002;12:9–17.
- 14 Child Health Research Project. Zinc for Child Health. John Hopkins School of Public Health, November 17–19, 1996, June 1997.
- 15 Ploysangam A, Falciglia GA, Brehm BJ: Effect of marginal zinc deficiency on human growth and development. *J Trop Pediatr* 1997;43:192–198.
- 16 Chaudhary S, Verma M, Dhawan V, et al: Plasma vitamin A, zinc and selenium concentrations in children with acute and persistent diarrhoea. *J Diarrhoeal Dis Res* 1996;14:190–193.
- 17 Krishnaswamy K, Lakshmi AV: Role of nutritional supplementation in reducing the levels of homocysteine. *J Assoc Physicians India* 2002;50:36–42.
- 18 Vollset SE, Refsum H, Irgens LM, et al: Plasma total homocysteine, pregnancy complications, and adverse pregnancy outcomes: the Hordaland Homocysteine study. *Am J Clin Nutr* 2000;71:962–968.
- 19 Dewey KG, Mayers DR: Early child growth: how do nutrition and infection interact? *Matern Child Nutr* 2011;7:129–142.
- 20 Bhan MK, Bhandari N, Bhatnagar S, Bahl R: Epidemiology and management of persistent diarrhoea in children of developing countries. *Indian J Med Res* 1996;104:103–114.
- 21 Bhaskaram P: Micronutrient malnutrition, infection, and immunity: an overview. *Nutr Rev* 2002;60:S40–S45.
- 22 Torun B, Chew F: Recent developments in the nutritional management of diarrhoea. 3. Practical approaches towards dietary management of acute diarrhoea in developing communities. *Trans R Soc Trop Med Hyg* 1991;85:12–17.
- 23 Imdad A, Yakoob MY, Bhutta ZA: Effect of breastfeeding promotion interventions on breastfeeding rates, with special focus on developing countries. *BMC Public Health* 2011;11(suppl 3):S24.
- 24 Yakoob MY, Theodoratou E, Jabeen A, et al: Preventive zinc supplementation in developing countries: impact on mortality and morbidity due to diarrhea, pneumonia and malaria. *BMC Public Health* 2011;11(suppl 3):S23.
- 25 Walker CLF, Black RE: Zinc for the treatment of diarrhoea: effect on diarrhoea morbidity, mortality and incidence of future episodes. *Int J Epidemiol* 2010;39(suppl 1):i63–i69.
- 26 Sazawal S, Black RE, Menon VP, et al: Zinc supplementation in infants born small for gestational age reduces mortality: a prospective, randomized, controlled trial. *Pediatrics* 2001;108:1280–1286.
- 27 Bhutta ZA, Chopra M, Axelson H, et al: Countdown to 2015 decade report (2000–10): taking stock of maternal, newborn, and child survival. *Lancet* 2010;375:2032–2044.
- 28 Countdown to 2015. Building a Future for Women and Children: The 2012 Report. <http://www.countdown2015mnch.org/reports-and-articles/2012-report> (accessed October 20, 2012).
- 29 Doherty T, Chopra M, Tomlinson M, Oliphant N, Nsiband D, Mason J: Moving from vertical to integrated child health programmes: experiences from a multi-country assessment of the Child Health Days approach in Africa. *Trop Med Int Health* 2010;15:296–305.
- 30 World Population Prospects, the 2010 Revision. United Nations Department of Economic and Social Affairs, 2010.
- 31 Stevens GA, Finucane MM, Paciorek CJ, et al: Trends in mild, moderate, and severe stunting and underweight, and progress towards MDG 1 in 141 developing countries: a systematic analysis of population representative data. *Lancet* 2012;380:824–834.
- 32 Alexander GR, Kogan MD, Himes JH: 1994–1996 US singleton birth weight percentiles for gestational age by race, Hispanic origin, and gender. *Matern Child Health J* 1999;3:225–231.
- 33 Barker DJP: Mothers, Babies, and Health in Later Life. Edinburgh, Churchill Livingstone, 1998.
- 34 Victora CG, de Onis M, Hallal PC, Blössner M, Shrimpton R: Worldwide timing of growth faltering: revisiting implications for interventions. *Pediatrics* 2010;125:e473–e480.
- 35 National Nutrition Survey Pakistan 2011. <http://pakresponse.info/LinkClick.aspx?fileticket=BY8AFPcHZQo%3D&tabid=117&mid=752> (accessed October 20, 2012).
- 36 World Health Organization, Centers for Disease Control and Prevention: Worldwide Prevalence of Anaemia 1993–2005. WHO Global Database on Anaemia. Geneva, World Health Organization, 2008.
- 37 Wasantwisut E: Nutrition and development: other micronutrients' effect on growth and cognition. *Southeast Asian J Trop Med Public Health* 1997;28(suppl 2):78–82.