

Hunger and Malnutrition Sue Horton, Harold Alderman and Juan Rivera

Despite significant reductions in poverty, undernutrition remains a serious problem, with 146 million children in the developing world being underweight for their age. Poor nutritional quality is as much a problem as food quantity alone. Undernutrition leads to increased mortality and morbidity and hence reduced economic output and increased healthcare spending. The first of the Millennium Development Goals (MDGs) is to eradicate extreme poverty and hunger, and progress in many of the other goals will be restricted without this being achieved.

The Challenge

Much of the data highlights nutritional deficiencies in the under-fives, but they are of course also important for the other 88% of the developing world's population. In particular, young children's nutrition depends critically on the nutritional status of their mothers during pregnancy and lactation.

South Asia accounts for 74 million of the 178 million total of under-fives who are chronically malnourished (stunted), with sub-Saharan Africa and East Asia/Pacific also having high levels. Only in the East Asia/Pacific and Latin America/Caribbean regions is the prevalence of underweight declining fast enough to meet the MDGs. On the other hand, Eastern/Southern Africa and Middle East/North Africa have increasing levels, in part due to current conflicts.

Most micronutrient deficiencies (with a few exceptions such as iodine) are correlated with overall undernutrition, and they are very widespread. For example, 31% of developing world households do not consume iodized salt and are therefore not protected from goitre, UNICEF estimates that 100-140 million children still suffer from Vitamin A deficiency, and an estimated two billion people (more than half in south Asia) have too little iron in their diet. The combined effects on mortality, morbidity and productivity are estimated to result in economic losses of billions of dollars.

Recent intervention studies show that real and significant benefits can be achieved if diets are improved. Supplementation, food fortification, treating diseases and parasites, improved sanitation and education are all ways to address the challenge.

Solutions

We consider here two types of cost-effective intervention: those which involve or are similar to primary healthcare programs, and those which largely involve behavioral changes.

Micronutrient interventions

A considerable amount of effort in the last couple of decades has been focused on reducing micronutrient deficiencies. The costs of undernutrition are high, and inexpensive technologies are available to provide micronutrients. The introduction of iodized salt has considerably improved the situation globally, but there are parts of South Asia and some sub-Saharan African countries where many households do not have access to it. At a cost of \$0.05 per person per year and having a benefit-cost ratio of

around 70, extending access remains a key priority. Where this is not feasible, a single large dose of iodized oil for children and pregnant and lactating women is recommended.

Vitamin A deficiency is still a problem for between 17 and 25% of children under five in developing countries, and new delivery modes are now needed. Iron, the third of the "big three" micronutrients, has been harder to address effectively, since it must be consumed regularly. Zinc and folate have become concerns more recently.

As for delivery, fortification is generally preferred, as it tends to have a lower unit cost than supplementation. However, supplementation is needed where particular sub-populations are targeted and the micronutrient is more costly.

Vitamin A

Until recently, the recommended intervention has been to provide vitamin A to lactating women in the first two months of a newborn's life, followed by provision to children from 6 months to 6 years of age. Mortality among under-3s has been found to be reduced by 23%, at a cost estimated variously at from less than \$100 to \$500 per life saved. New evidence suggests that supplements given to newborns can give similar reductions in mortality, but reaching all neonates in less developed countries with large rural populations is likely to be difficult and only achievable as part of a package of neonatal care.

A package of measures – vitamin A supplements, de-worming, nutrition screening and measles vaccination – currently reaches more than 10 million children across Ethiopia, at a cost of \$1.04 per child (or \$0.56 without the vaccination). Ignoring the benefits of other components of the program, the cost per life saved by the vitamin A supplementation without vaccination is \$228. In practice, additional benefits are likely to accrue in countries with similarly high mortality rates and poor primary healthcare.

Iron

Iron supplementation or fortification can increase productivity in adults (by up to 17% for heavy manual work) and boost cognitive development in children, particularly for those who were initially iron-deficient or anemic. However, in areas with high rates of malaria, iron supplementation is associated with increased hospital admissions and mortality for non iron-deficient children, because of interactions with the malaria parasite and reduced efficacy of anti-malarial drugs. In such areas, supplementation should be targeted at pregnant women and iron-deficient children, although the testing necessary also raises the cost of the intervention.

The impact of home fortification (Sprinkles, containing iron and other micronutrients) appears very high, with a benefit-cost ratio of up to 37 assuming a four month intervention between the ages of 6 and 12 months largely protects against anemia throughout childhood.

Fortification of staple foods such as flour with iron can be done at a cost of only \$0.10-0.12 per person per year, with a benefit-cost ratio calculated to be 8.7. Alternatively, providing iron supplements to pregnant women could reduce neonatal and maternal mortality for as little as \$66-115 per DALY.

Zinc

Although there is good evidence of the efficacy of zinc in treatment of diarrhea, and some studies have shown mortality, morbidity and growth benefits, there are remaina number of information gaps as to the size of the effects and the optimal pattern of intervention. Zinc as an incremental cost in diarrhea management is very cost effective, with an average cost of \$73 per DALY gained and \$2,100 per death averted. Preventive supplementation to reduce morbidity and mortality is potentially cost-effective for infants, but there is too little evidence to estimate this at present.

Folate

The benefits of folic acid supplements in preventing birth defects such as spina bifida are well known, and fortification in the USA is highly cost effective. However, these figures are unlikely to be relevant to developing countries, where healthcare costs are far lower, and folate benefits are better expressed in terms of reduced mortality and morbidity. Although data on birth defects in developing countries is scarce, studies in rural China and India show a relatively high level of neural tube defects, possibly associated with the low folate content of polished rice.

As for iron, folic acid supplementation in areas where malaria is endemic can reduce the efficacy of anti-malarials and increase mortality. However, when further evidence has been collected, it is reasonable to suppose that folic acid would be a good candidate for fortification as part of a package of micronutrients.

Bio-fortification

The potential for bio-fortification of staple crops is considered high. Breeding programs are in place and feeding studies have been done on crops bio-fortified with iron and Vitamin A. The cost per DALY averted has been estimated at between \$10 and \$120, giving BCRs in the range of 50 to 4.

Anthelminthics

Over two billion people are estimated to be infected with one or more soil-transmitted helminthes; 1.2 billion with roundworm alone. In all cases, there is an adverse effect on nutritional status. Current interventions focus on school-age children, where parasite loads are generally highest and children often most accessible for treatment, but median coverage is still only 10% of the target population. Benefits of treatment include reduced anemia and better growth and intellectual development.

School-age de-worming programs can be very cost-effective. In Kenya, for example, treatment costing \$0.49 per child generated additional wages with a net present value of \$30. School participation was also increased by 7.5% in participating primary schools, with a benefit-cost ratio of 3 even after allowing for the cost of additional teachers.

There are no benefit-cost estimates for de-worming preschool children and pregnant women available in the literature, but studies are in progress. However, we can estimate an order of magnitude cost effectiveness for de-worming preschool children. The most significant economic effect is on anemia, with a median reduction of 13%. This would improve cognitive development and hence future wages. The target age group is 4% of the population in Southeast Asia, and 6.5% in sub-Saharan Africa. At a cost of \$0.50 per child per year, the benefit-cost ratio is approximately 7.5 in Southeast Asia and 4 in SSA.

Breastfeeding promotion – baby-friendly hospitals

Exclusive breastfeeding for the first six months of a baby's life is recommended, but only about one-third of infants in developing countries actually receive this. For babies born in hospital, promotion of breastfeeding at the time of delivery can be very cost-effective. Averting diarrhea morbidity and mortality costs only \$2-4 per DALY or \$100-200 per life saved in hospitals still using formula milk, while promoting breastfeeding costs just \$0.30-0.40 per birth. Nevertheless, the impact will be primarily on middle-income countries and urban populations.

Nutrition education at the community level

The interventions covered so far are highly cost-effective but cover only limited nutritional goals. Making broader behavioral changes in early life requires one-to-one discussion with mothers of young children, and is an order of magnitude more costly than the simple interventions above. But such interventions can be very effective when delivered as part of a package and can help reduce growth and cognitive problems associated with undernutrition prior to age two, which in many cases are irreversible.

Outreach initiatives

Where primary healthcare is most limited, outreach initiatives such as Child Health Days play an important role. More than 60 countries have at least one such day each year, generally including vitamin A supplementation, immunizations and, increasingly, de-worming. In Ethiopia, each of the two rounds per year costs \$0.56 per child, or \$1.04 with measles vaccination. Delivery of vitamin A alone is cost-effective, but this approach becomes even more attractive if other benefits are taken into account.

Community nutrition interventions

Programs incorporating growth promotion have a long history and costs can often be kept down by mobilizing community volunteers. In Thailand in the 1980s, for example, the prevalence of underweight was reduced by 3% annually, against a baseline of 0.1-1% for countries in the region without national programs.

Recurrent costs have been estimated to be in the range from \$1.60 to \$10 per person (higher if food costs are included), although it has been argued that there is insufficient impact from programs costing less than \$5 per head. There is, unfortunately, little in the way of benefit-cost analysis at present. However, it is clear that programs need to be well designed for the individual populations targeted, or there is a chance they will have little if any real impact.

Nutrition components of primary health care system

In middle-income countries or urban areas, where primary healthcare facilities tend to be better, nutrition education programs can be added to existing care packages. However, costs in staff time alone are relatively high, showing why poorer countries favor the use of volunteers where possible.

Detailed economic analysis

We have summarized the basic cost-effectiveness of a range of interventions above, but now look at the sensitivity of these to two different discount rates – 3% and 6% – and DALY values of \$1,000 and \$5,000.

Methodological issues

Various aspects of methodology affect the results of our analysis, and hence the policy implications of the different interventions. The first issue is the discount rate used, and changing this will have different effects depending on when benefits accrue: the net benefit of future productivity increases is significantly lower at higher discount rates, whereas saving lives in the short term is much less sensitive to the rate used. This means that two interventions with the same undiscounted present value can look very different with 3% and 6% discount rates. If a choice was to be made purely on net present value, interventions which saved lives would be chosen over those which increased cognitive development and improved productivity in later life.

Differences in costs and epidemiological profiles across countries also matter. Benefit-cost ratios are valid for particular studies in particular countries, but cannot be assumed to hold in different circumstances. In poor countries, higher technology interventions become relatively more costly than more people-intensive activities such as nutrition education. We can estimate the cost of community-based interventions by using the relative costs of health center visits which are, for example, about 150% higher in Latin America than South Asia and sub-Saharan Africa. This means that BCRs will be significantly different for similar interventions in the poorest countries compared to middle-income countries.

The third methodological issue is the difference between incidence- and prevalence-based estimates. Incidence is the preferred basis, comparing as it does the current cost of an intervention with its downstream benefits, but such calculations are also more difficult. Prevalence estimates, based on the current costs of the intervention with the current cost of the deficiency, should be seen as rough estimates only.

Assigning a monetary value to DALYs – effectively the cost of a human life – raises ethical issues, but is inevitable if objective choices are to be made between interventions. In practical terms, the choice of both value and discount rate make an enormous difference over a 60 year span for a life saved in infancy. For a DALY value of \$1,000 and a 6% discount rate, the life saved is worth \$17,131; for a value of \$5,000 and a 3% rate, this becomes \$142,525.

A final issue is that of the value of human life at different ages, with current practice being to assign a fixed value from infancy through to old age. Some studies, in contrast, have valued the life of a productive adult more highly. With this, as for the other issues raised, there are no right or wrong answers. We simply have to be aware of the problems and regard the results of analysis as orders of magnitude rather than precise estimates.

Policy simulations

For the sake of simplicity, we assign nutrition interventions to one of three groups: those with major health outcomes, costing either \$20 or less per DALY or \$100 or less per DALY saved, and those where the primary outcome is increased productivity. We also assume intervention costs and benefits for sub-Saharan Africa and South Asia, where the large majority of undernourished people live, costs are lower and benefits generally higher.

With these assumptions, we calculate the benefit-cost ratios for all the proposed interventions, using both discount rates and both DALY valuations (although in practice a value of \$5,000 is less relevant to these regions). On this basis, all nutrition interventions have very attractive benefit-cost ratios at both discount rates.

We can now propose five solutions with ballpark estimates of costs and benefits. A very promising solution is Micronutrient Supplementation, involving the provision of Vitamin A capsules and therapeutic zinc supplements for under two-year-olds. This would cost a total of \$60.4 million annually, with benefits worth more than \$1bn yearly (BCR of more than 17:1). A second solution is Micronutrient Fortification, which would entail the provision of iodized salt and iron. For an annual cost of \$286 million, the corresponding benefits are \$2.7bn (BCR of 9.5:1). A third solution is Biofortification (improving agricultural technology) with annual costs of \$60 million and benefits of \$1 billion (BCR of more than 16:1). The fourth proposed solution is De-worming of Preschoolers. An investment of \$26.5 million would generate benefits of \$159 million yearly (BCR of 6:1). Finally, the fifth solution is Community-based Nutrition Promotion. Annual expenditure of \$789 million would yield around \$10bn of benefit (BCR of 12.5:1).

Discussion

This paper updates estimates from the 2004 Copenhagen Consensus and finds that both micronutrient supplementation/fortification and promotion of breastfeeding remain highly cost-effective. Additionally, we find that de-worming is as attractive as micronutrient interventions. Bio-fortification remains promising but not yet with widespread results.

However, all of these interventions address only a modest proportion of the overall undernutrition problem. A more comprehensive approach requires community nutrition interventions, which can also have good benefit-cost ratios if well designed and implemented.