

Chapter 2

Economics of Nutritional Interventions

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Keywords Cost-effectiveness · Benefit:cost · Micronutrients · Stunting · Cost · DALYs (disability-adjusted life years)

Learning Objectives

- Identify the economic consequences of undernutrition
- Describe the costs of nutritional interventions
- Prioritize nutritional interventions in terms of cost-effectiveness, and benefit–cost
- Analyze the growing economic burden associated with obesity in low- and middle-income countries
- Develop insights regarding health policy in low- and middle-income countries.

Introduction

Nutrition is a basic need and a key input as well as a desired outcome of economic development. The most important reason for investing in nutrition is to allow individuals to survive and thrive and reach their full potential. Quantifying the economic benefits of nutrition interventions can be a powerful way to advocate for increased resources for nutrition. Economic analysis can also help to decide how best to allocate investments to improve nutrition among competing programs, and how to use public funding most effectively.

Undernutrition is associated with 3.1 million child deaths each year (45% of all child deaths in 2011 [1]). This includes deaths associated with stunting, wasting, suboptimal breastfeeding, fetal growth restriction, and deficiencies of micronutrients including vitamin A and zinc. Estimates of economic losses associated with individual micronutrients can be as large as 1–2% of GDP (Gross Domestic Product, a measure of national income). More recently, studies have attempted to estimate the losses associated with stunting, and these losses can be as large as 8–10% of GDP (see The Costs of Undernutrition section). Stunting is to a large extent a consequence of diets which are chronically inadequate in quantity and quality, and is a good indicator of overall nutritional status. Recent work suggests that breastfeeding has benefits on IQ and income later in life, which is separate from measured nutritional status.

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There is a whole range of interventions which aim to improve nutritional status. Programs providing a substantial part of the diet tend to be more expensive and difficult to sustain financially, and as such are restricted to vulnerable groups (school feeding programs, food distribution to refugees, and feeding programs during short-term crises for example). There are many low-cost interventions designed to improve nutrition, such as micronutrient interventions and behavior change interventions (breastfeeding promotion being a particularly key behavior change) (see The Costs of Interventions to Reduce Undernutrition section).

It is not enough for a program to be inexpensive: it also needs to be cost-effective (see Cost-Effectiveness and Benefit–Cost of Interventions to Reduce Undernutrition section). Micronutrient interventions have been ranked as either the top or second to top development priority according to three Copenhagen Consensus exercises [2]. Over the last decade, knowledge of how to successfully rehabilitate children suffering from severe-acute malnutrition (SAM) at the community level has advanced considerably. Community care for SAM is not inexpensive, but is very cost-effective.

Benefit:cost analysis can be applied to those nutrition interventions whose main outcome is not to avert deaths, but to improve cognition, which in turn is associated with increased educational attainment. Better education and higher cognitive scores are associated with higher wages, which economists take as a measure of higher productivity. The benefit:cost ratios for selected micronutrient interventions range from 6:1 to 40:1; and the benefit:cost from interventions to reduce stunting are estimated at 8:1. These are all very favorable ratios, and suggest nutrition interventions are a good investment.

Although undernutrition has been until now the primary concern in low and middle-income countries (LMICs), overweight and obesity is of growing concern also in poor countries. Indeed, there may be interactions, in that adults who were in utero or early childhood facing diets of scarcity, are more susceptible to cardiovascular disease and diabetes if faced with diets of abundance later in life (see Chap. 32). Economic studies of the costs of overweight and obesity in LMICs are growing, although fewer in number than such studies for high income countries. The literature on the effectiveness of interventions to reduce overweight and obesity in LMICs is still modest, and the literature on costs and cost-effectiveness of such interventions is more modest still. This is one priority area for future research (see Future Research section). Another priority research area is “implementation science” which is important for nutrition as well as for health to provide guidance on scaling up effective programs. Using economic methods can also be valuable here as described in the following sections.

The Costs of Undernutrition

Undernutrition has a variety of consequences, depending on its severity, and on the particular nutrient (s) which is/are deficient. Economic studies have focused on the costs of at least half-a-dozen nutritional deficiencies, including vitamin A, iron, iodine, folic acid, zinc, and chronic undernutrition as indicated by stunting. Table 2.1 lists some of the functional consequences of deficiencies of these five micronutrients, as well as those associated with stunting, focusing on effects in early life (including effects during pregnancy). While undernutrition in the elderly is also an important topic, it is not covered here. The table also lists consequences of suboptimal breastfeeding. Breastfeeding has impacts on mortality and cognition which are independent of the effects of stunting. According to a review by Horta and Victora [3] there are plausible biological mechanisms for this effect due to the presence of long-chain unsaturated fatty acids in breastmilk, not present to the same degree in breastmilk substitutes, which are associated with cortical development.

Table 2.1 Summary of effects of selected nutritional deficiencies

Nutritional deficiency	Selected functional consequences for which economic effects have been estimated
Folic acid (in women periconception)	Neural tube defects [4] Lower mean birthweight [5]
Iodine	Cognitive impairments for children, if mother was deficient in pregnancy [6] Cognitive impairments in school-age children [7]
Iron	Increased anemia Cognitive impairments (significant in children ≥ 8 year) [8] Lower maximal physical work capacity (adults), lower endurance for physical work [9]
Vitamin A	Increased mortality (all-cause and diarrhea) in children [10]
Zinc	Stunting; increased diarrhea; increased pneumonia [11, 12]
Multiple (stunting)	Lower cognitive scores; Lower educational attainment; Lower earnings in adulthood [13]; increased risk of obesity/diabetes/NCDs in later life
Suboptimal breastfeeding	Higher mortality [14, 15]; lower cognitive scores and education [16]

The evidence for micronutrients is from several systematic reviews [4–12] of randomized controlled trials (RCT) involving supplementation, all recently cited by Bhutta et al. in the *Lancet* series [17]. For stunting the evidence cited is from the only major longitudinal follow-up from an RCT in childhood where children in the intervention group received supplements containing both micronutrients and protein/calories [13]. There are also supporting studies including numerous cross-sectional economic studies examining the effect of height on earnings. One study summarized eight studies for industrialized countries [18] and another eight studies for LMICs [19]; they conclude that the median increase in male wages per additional centimeter of height is 0.4% in industrialized countries, and 4% in LMICs. There are studies of natural experiments following droughts, for example, a study examining the effect on height and educational attainment in Zimbabwe [20], as well as studies following famines. A recent literature uses econometric methods to examine the interrelationships among height, cognitive attainment, schooling and earnings, for example a study of Mexico [21], which also contains references to other countries. Together, these studies also support the impact of stunting on cognition, educational attainment, and earnings. For breastfeeding, the evidence comes from systematic reviews of a mix of studies including prospective cohort and case-control studies.

There are two different techniques for incorporating an economic perspective on health and the functional impairments associated with ill health. The first approach is to use cost-effectiveness analysis, and the second is to use cost-benefit analysis (see Drummond et al. [22] for a standard reference which describes these methods in detail). In both approaches, a common outcome measure is used for various health interventions.

For cost-effectiveness analysis the common outcome is a health measure, such as deaths averted, life years saved (LYS), Quality-Adjusted Life Years (QALYs) saved, or Disability-Adjusted Life Years (DALYs) averted. LYS are typically not discounted, whereas for QALYs, and the DALY measure used here, life years saved in the future are discounted by the usual social discount rate of 3% per annum. The significance of discounting is that it makes investments with benefits far in the future (such as improved nutrition for children) less attractive. The higher the discount rate, the less attractive the investment.

For cost-benefit analysis the common outcome is a monetary unit. One frequent benefit of a health intervention is decreased treatment costs, both those incurred by the health sector as well as drug costs incurred by the patient (these two are sometimes referred to as direct costs), and those nontreatment costs borne by households (sometimes referred to as indirect costs) such as cost of caregiver's time, transportation costs to seek treatment, etc. Another benefit is associated with improved human capital.

Better health affects cognitive development, educational attainment and work participation, and hence economic productivity. Thus, the cost–benefit analysis compares the costs of providing an intervention to prevent a certain condition to the benefit in terms of higher earnings and other ‘income benefits’ resulting from the intervention, as well as future healthcare cost savings.

Some authors attach a monetary value to health outcomes (i.e., deaths and morbidity/disability), in order to combine health and economic costs into a single metric. There are a variety of techniques for doing this, such as using the Value of a Statistical Life or using a human capital approach, e.g., evaluating life by summing up future lost productivity [22]. These calculations involve many assumptions and ethical issues, such that many authors prefer to measure benefits such as mortality reductions separately from economic benefits, and to use cost-effectiveness rather than cost–benefit when examining interventions whose main benefit is saving lives.

When applying cost-effectiveness and cost–benefit methods to micronutrient deficiencies, there is a difficulty of comparing the costs of those deficiencies (vitamin A and zinc, for example) where the outcomes are primarily mortality and morbidity, with those deficiencies (iron and iodine, for example) where cognitive losses and hence economic productivity losses are more significant. Hence we may not be able to readily compare the economic gains associated with improved vitamin A and zinc status, with those of improved iron and iodine status. Similarly, improvements in folate status and reduced stunting have various outcomes both in terms of reduced morbidity/mortality as well as in terms of productivity and reduced treatment costs.

In Table 2.2 we summarize some estimates for costs associated with undernutrition, both in terms of health and economic costs. Later in this chapter we combine these with costs of nutrition interventions (The Costs of Interventions to Reduce Undernutrition section) to present cost-effectiveness and benefit:cost estimates for undernutrition (Cost-Effectiveness and Benefit–Cost of Interventions to Reduce Undernutrition section).

The costs of undernutrition are significant, whether in terms of increased mortality (particularly for vitamin A and zinc), lost cognition and productivity (iodine, iron), or a combination of effects (both mortality/morbidity and large treatment costs for folic acid; both mortality and losses in cognition, educational attainment, and productivity for stunting as well as suboptimal breastfeeding).

Costs measured in terms of losses at the individual level are useful, but not always easy to interpret. Various studies have been done to estimate the losses associated with certain nutritional deficiencies, at the level of a country (Table 2.3). These are obtained from models which rely on coefficients from individual-level studies such as those in Table 2.2.

The losses associated with individual micronutrient deficiencies are up to a couple of percent of GDP in the most severely affected countries. As presented in the next section, the losses are large in relation to the cost of interventions which can successfully reduce these deficiencies.

One problem with the estimates of losses attributable to individual micronutrients is that it is not easy to add up these losses in cases where there are multiple micronutrient deficiencies. For example, countries where iodine deficiency is a public health problem often have other micronutrient deficiencies as well. We would also expect interaction among the outcomes of micronutrient interventions, both in their uptake and in their impact. Some micronutrients interact in a positive way in uptake, for example, improved intake of vitamin C enhances the bioavailability of iron. Some interact in a negative way, for example, depending on amounts provided, supplementation with iron can impede uptake of zinc and vice versa, and similarly iron and calcium interact.

Micronutrients are also likely to interact in their impact on health and on productivity. For example, the effect on mortality or productivity for iron is likely to differ according to whether the individual is deficient or replete in other micronutrients. Effects may also vary according to other differences in the environment. For example, the impact of vitamin A supplementation on mortality also depends on the causes of child mortality and other measures to prevent these, such as immunization.

Table 2.2 Examples of health and economic costs associated with selected nutritional deficiencies

Nutritional deficiency	Examples of cost
Folic acid (in women periconception)	RR = 0.28 of NTDs ^a for supplementation of women of reproductive age [5]; Annual treatment costs per case: US\$51,574 (NTD); \$11,061–65,177 (spina bifida) \$ of 2003; Spain \$2734 (spina bifida), \$ of 1988; South Africa \$12,609 (NTD) \$ of 2008 [23]
Iodine	Productivity loss per child born to a mother with goiter estimated as 10% [24]
Iron	17% productivity loss estimated in heavy manual labor; 5% in light manual, 4% in other work, for anemic adults [25]; Standardized mean difference in IQ score >8 years of age: 0.41 [8]
Vitamin A	Reduction of all-cause mortality (RR 0.76); diarrhea-related mortality (RR 0.72), reduced incidence of diarrhea (RR 0.85) and measles mortality (0.50) [10]
Zinc	Preschool children in 24-week preventive supplementation study had greater height gain (0.37 cm), 13% reduction in diarrhea and 19% in pneumonia compared to control [11, 12]
Multiple (stunting)	Children who were not stunted at 36 months, compared to those who were, in adulthood had [13]: <ul style="list-style-type: none"> – 20% higher hourly earnings (men); 7.2% higher (women) – Almost 20% higher per capita household income – 3.6 more grades completed schooling – 1 standard deviation higher in cognitive scores – 1.86 fewer children (women) 1 cm additional height is associated with 0.55% higher earnings for men in high income countries (median, 8 cross-sectional studies) [18] 1 cm additional height is associated with 4.5% greater earnings for men in low and middle-income countries (median, 8 cross-sectional studies) [19] Stunting in children is associated with increased relative risk of mortality: relative risk is 5.5 for severe stunting and 2.3 for moderate stunting, compared to children who are mildly stunted/not stunted [26]
Suboptimal breastfeeding	In 2011, 804,000 child deaths (11.6% of all child deaths) attributable to suboptimal breastfeeding [1]; breastfeeding associated with an increase in IQ of about 3 points [16]

^aNTD neural tube defects; RR relative risk

More recently, several studies have used a broader indicator of nutritional status to model the loss of GDP. The first such studies in Latin America [28, 29] used underweight (weight-for-age) as the measure, which is not ideal, since stunted obese individuals are not classified as underweight. In Latin America considerable progress has been made against undernutrition so in some countries the losses were as low as 1.7% of GDP, while in others as great as 11.4%. A study for sub-Saharan Africa [30], using a similar methodology (but conflating a mixture of indicators including underweight, stunting and low birthweight) found somewhat greater losses than in Latin America, as Sub-Saharan African countries in general have greater levels of undernutrition. Two other studies [19, 31] used stunting alone (a cleaner indicator) and estimated the loss as 11.2% of GDP, with effects via education and cognition underlying a large component of this. One of these studies [19] estimated that between a quarter and a third of the nutrition effect occurs indirectly (through cognition and education); and the other estimated that 73% is due to productivity effects, 11% due to reduced mortality, with the balance due to intergenerational benefits; taller mothers have taller children, but the full benefit of nutritional improvements may take 3–4 generations to fully manifest themselves. This study is conservative since it did not include the long-term effects of stunting on noncommunicable diseases.

Suboptimal breastfeeding imposes significant costs globally. Estimates for the US suggest that the annual benefit for moving from current rates of 12.3% of exclusive breastfeeding at 6 months to 90% would be a savings of US\$13 bn and 911 fewer child deaths per annum [32]. For the UK a modest

Table 2.3 Examples of economic cost of undernutrition at a country or regional level

Magnitude of effect ^a	What was modeled?
<i>Iron deficiency</i>	
0.81% GDP ^b ; median for 10 LMICs [25]	Used anemia
<i>Iodine deficiency</i>	
0.48% of global GDP [27]	Rough estimate based on 12% prevalence of goiter prior to universal salt iodization
<i>Stunting/underweight^c</i>	
1.7–11.4% of GDP: range for 7 Latin American/Caribbean countries [28, 29]	Used underweight
1.9–16.5% of GDP: range for 5 African countries [30]	Used a mixture of underweight, stunting and low birthweight
11.2% of GDP: estimate modeled for LMICs using 12 LMICs with good time series data on height to reflect different regions 1900–2000 [19]	Used adult male height
11.2% of GDP: average for 66 LMICs [31]	Used stunting

Notes

^aMagnitude of effect depends on severity of condition

^bGDP gross domestic product (similar to GNI or gross national income)

^cNote that impact on NCDs later in life are not included in the cost estimates

improvement in rates (such that 45% of women were to breastfeed exclusively for 4 months as opposed to 7% currently, and 75% of babies in neonatal units were to be breastfed at discharge) would save £17 m annually in costs of treating childhood illnesses (2009–10 prices; US\$27 m). For the UK effects on mothers were also modeled, and there were £21 m annually (US\$34 m) in cost savings for breast cancer as well as 512 QALYs saved per year [33]. A global study estimates the cost of cognitive losses associated with inadequate breastfeeding (defined as the gap between 100% exclusive breastfeeding to 6 months, compared to current levels) as \$302 billion US (2012 \$), or 0.49% of world GNI. This is comprised of losses of \$230 bn (0.53% of GNI) in high income countries, and \$71 bn (0.39% of GNI) in LMICs [34].

The Costs of Interventions to Reduce Undernutrition

If the benefits from improved nutrition are so large, why do parents not invest more in improved nutrition for their children, assuming that they know the benefits? Understanding this can help with evaluating possible interventions. First and foremost, undernutrition is linked to poverty. The poorest households in low-income countries already spend 80% or more of their income on food, and are still unable to purchase sufficient food (and food of appropriate diversity and nutritional quality) to obtain a diet which meets the needs of all household members. Second, households may lack nutritional knowledge, particularly of the specific needs of small children who need to eat more frequently than adults, and who (because of fast growth and metabolic requirements) are especially vulnerable to micronutrient deficiencies. Households can perhaps be educated or incentivized to adopt better behaviors. Furthermore, households may not have access to convenient and nutrient-dense foods appropriate for small children, or may be constrained in their ability to feed children optimally, for example exclusive breastfeeding may not be compatible with the mother's work situation. Poor households also often have poorer living conditions and worse access to clean water and sanitation, such that infections and parasites may impede good nutritional status. Breaking these constraints can vary considerably in cost, as well as in effectiveness: it is more costly to alleviate poverty or provide

additional food to a family than to provide nutritional education, but effectiveness may also differ. We will turn to costs of interventions now.

Table 2.4 summarizes estimates of the unit costs of selected nutritional interventions, using two different methodologies. The table presents costs for the two low-income regions of the world with the highest burden of undernutrition, namely sub-Saharan Africa and South and Southeast Asia. (See the original sources for these costs, also for costs for the other LMIC regions). The ingredients method costs utilize the OneHealth [35] tool, a tool which utilizes World Health organization databases for cost of health inputs. Where OneHealth did not already have a cost estimate, lists of “ingredients” were constructed for nutrition interventions (health worker time, drug and other input costs, and an assumed percentage for administration, storage, transport, distribution, and other overhead costs). The SUN estimates were constructed by the author from available country program data both from published studies and gray literature.

Cost of nutrition interventions varies. Interventions that do not involve food (micronutrient interventions, nutrition education) are modest in cost, typically less than \$6 per child/pregnant woman per year and in the case of fortification, less than \$1 per person per year. The exception is calcium supplementation which costs almost \$19 per pregnancy. Programs involving distribution of food are an order of magnitude (ten times) more expensive than micronutrient interventions excluding calcium. Finally, the specialized food involved in community management of severe-acute malnutrition, along with the supervision required, makes these the most costly programs discussed here. Note that the \$140 per child estimate for a 4-month treatment is probably more likely than the higher Scaling Up Nutrition (SUN) estimate, which was made earlier when SAM interventions were less well

Table 2.4 Unit costs (cost per child/per mother in US \$) of interventions to reduce undernutrition

Intervention	Cost in AFR-E, ingredients method 2010 \$ [17]	Cost in SEAR-D, ingredients method 2010 \$ [17]	Cost used in SUN estimates for sub-Saharan Africa and South Asia [36]
Salt iodization (per person per year)	0.06 ^a	0.06 ^a	0.06
Multiple micronutrient supp (per pregnancy) ^b	6.13	5.84	N/a
Calcium supplements (per pregnancy)	18.87	18.59	N/a
Energy/protein supp (per pregnancy)	25.00 ^b	25.00 ²	N/a
Vitamin A supplements (per child)	2.82	1.58	1.33
Preventive zinc supplements (per child): SUN estimate is for multiple micronutrient powders	5.88	4.63	7.98
Breastfeeding promotion (per birth)	14.18	11.69	5.82
Complementary feeding education (per child)	5.22	3.54	1.83
Complementary food supplement for 6–23 months olds (per child)	50.00 ^b	50.00 ^b	40.00–80.00 ^b
SAM management (per case—duration 4 months)	146.19	138.72	221.60
Fortification of wheat/similar with iron (per person per year); cost to also include folic acid is negligible	—	—	0.20

N/a means not available; AFR-E refers to those countries in the World Health Organization subregion in sub-Saharan Africa with the poorest demographic profile; and SEAR-D to the corresponding region in Southeast Asia. South Asia estimates are for the region as described by the World Bank. SUN refers to the Scaling Up Nutrition movement

^aUses SUN estimates

^bAuthor’s estimates, since an exact protocol for the amount, duration and composition of such supplements has not been developed

established. We will discuss relative cost-effectiveness of these various programs shortly; however for LMIC governments, affordability of interventions is very important as it requires having access to financial and nonfinancial resources. Any program costing \$140 per child in a low-income country is difficult to afford if a significant number of children are involved.

Two sets of unit cost estimates have been used in global costing exercises. The SUN estimates were used for a set of interventions similar (but not identical) to those from a previous *Lancet* nutrition series [37], and the ingredients method estimates for the 2013 *Lancet* nutrition series [17]. In each case, priority countries were picked comprising 90% of world stunting. For the SUN estimates there were 36; for the 2013 *Lancet* series there were 34 (with considerable overlap). In each case, the cost of increasing existing coverage to reach 90% of the population was estimated. The 2013 *Lancet* estimates were that scaling up ten key direct nutrition interventions would cost \$9.6 bn annually. While this is a large number, the cost would be likely split between international assistance (in particular for the poorest countries) and domestic resource mobilization. If approximately one-third of the cost was covered by international assistance (i.e., \$3 bn) this can be put in context of constituting about 11% of the annual global assistance for health, which was almost \$27 bn in 2010 [38].

The total \$9.6 bn total was divided up by intervention as shown in Fig. 2.1. Micronutrient interventions (other than calcium) account for around a third of the total (one sixth for calcium alone, and the other sixth for vitamin A, multiple micronutrients in pregnancy, and zinc). Nutrition education programs (around breastfeeding and complementary feeding) account for another \$1 bn. Finally, programs involving food account for over half of the total, fairly equally split between targeted food supplements for pregnant women and young children in food-insecure households, and community management of severe-acute malnutrition.

The *Lancet* estimates [17] only cover the costs of “nutrition-specific” interventions—interventions known to directly affect nutrition. In the long run, however, nutrition-sensitive investments are needed to sustain improved nutritional status. These investments in agriculture, women’s empowerment, water and sanitation, poverty alleviation, etc., are essential. These will promote human development in the long run, including a diet that is appropriate in quality and quantity to promote human health. Costing for these nutrition-sensitive investments has not yet been undertaken. If sufficient

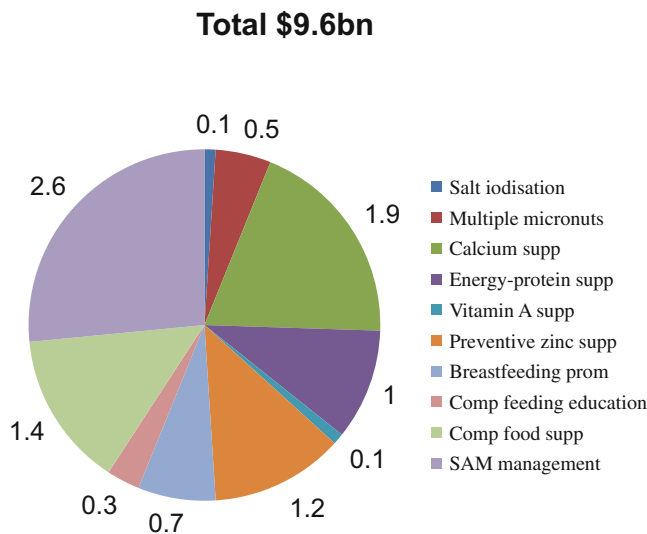


Fig. 2.1 Annual cost of increasing coverage of nutrition interventions identified as effective and cost-effective in US \$ billion [1]. Coverage increases from current levels to 90% in 34 priority countries. *Source* Uses data in web appendix for [17]

nutrition-sensitive investments can be made, then some of the shorter term nutrition-specific interventions can be discontinued. High-income countries do not need to provide food supplements except to particular vulnerable populations, and rarely have to treat severe-acute malnutrition.

Cost-Effectiveness and Benefit–Cost of Interventions to Reduce Undernutrition

Just because an intervention is inexpensive, does not make it worth implementing. Similarly, some programs which have significant cost can be worth implementing. This is where cost-effectiveness (and benefit:cost) analysis can assist.

A summary of studies undertaken between 2000 and 2008 [23, 37] suggested the following:

- Cost-effectiveness figures (cost per DALY averted)
 - \$5–15 for vitamin A supplements and periodic zinc supplements (in multiple micronutrient powders)
 - \$40 for community-based management of SAM
 - \$50–150 for behavior change interventions (at scale)
 - \$73 for therapeutic zinc
 - \$66–115 for iron fortification
 - \$90 for folic acid fortification
 - \$500–1000 for food supplements for young children
- Benefit:cost ratios were as follows:
 - 6:1 for deworming
 - 8:1 for iron fortification of staples
 - 30:1 for salt iodization
 - 46:1 for folic acid fortification

The highest priorities using the cost-effectiveness metric are the interventions with the lowest cost per DALY averted. For the benefit:cost metric, all four interventions examined are well worthwhile as their benefits (higher future wages or healthcare savings) are considerably higher than their costs. One problem is that it is not simple to compare interventions whose outcomes are DALYs, with those whose outcomes are expressed in benefit:cost terms. Thus iron fortification (where outcomes are primarily cognitive, with some modest lives saved) does not rank high on the cost-effectiveness metric, but ranks high on a benefit:cost metric.

These figures put several micronutrient initiatives at the top amongst the nutritional interventions, because they are effective but inexpensive. Community management of SAM—although costly per child—ranks next, simply because it saves the lives of children who otherwise have a high probability of dying. Effective behavior change interventions come next. Although frequently inexpensive (especially those using radio or other media, rather than one-on-one counseling), these programs vary wildly in their effectiveness often due to differences in the populations being served, including their ability to change their behavior which is linked to their circumstances and to what they can afford, and the intensity of the implementation and oversight that is being built into the programs. Finally, programs involving food supplements are the least cost-effective because providing food is costly.

These cost-effectiveness data for nutritional interventions are comparable to other high-priority health interventions for children in LMICs [39]. Other health interventions costing approximately \$10 per DALY saved include, for example: vaccination against TB, DPT, polio, and measles (the traditional “Expanded Program of Immunization” for children); use of insecticide-treated nets against malaria; and residual household spraying against malaria. Health interventions costing around \$40 per

DALY include a couple of different counseling programs against HIV/AIDS, plus condom promotion and distribution. Interventions costing \$1000 per DALY include antiretroviral treatment for HIV/AIDS, and use of aspirin and beta-blockers to prevent ischemic heart disease. These values indicate that nutrition interventions are of comparable cost-effectiveness as other high-priority public health interventions (and selected medical interventions) in LMICs.

Updated cost-effectiveness estimates are available not for individual interventions, but for components of a recommended nutrition package in the 2013 *Lancet* series, summarized in Table 2.5. In this study, a full epidemiological model was used (LiST: the Lives Saved Tool to examine the combined impact of a variety of recommended nutritional interventions delivered together [40]).

When several interventions are implemented together, or at the same time, we expect the combined impact on averting deaths and illness will be less than the sum of all the individual effects. For example, both measles vaccination and vitamin A reduce measles mortality and morbidity, but the combined effect is smaller (lives can be saved by one or other intervention, but the same life cannot be saved twice). Using a comprehensive model such as LiST avoids the double counting involved when several interventions are used simultaneously.

Note that some of the interventions in Table 2.5 have stronger effects on cognitive development but limited impacts on mortality, for example, salt iodization, iron supplements, and the food supplements both for pregnant women and young children. However, the LiST model does not take account of cognitive benefits.

Although the cost-effectiveness numbers in Table 2.5 are not quite as low as those from earlier studies, the interventions modeled remain attractive as high-priority interventions. Note that the data in Table 2.5 will be somewhat closer to those from SUN [37] once adjusted for inflation. The use of a single tool to model all the interventions when combined is more methodologically sound than separate estimates for individual interventions.

One recent study [41] used the same unit cost data as in the *Lancet* series (presented in Table 2.5) [17] to estimate the benefit:cost of interventions to reduce stunting. This is a different metric than cost-effectiveness shown in Table 2.5, since stunting can be related to improved cognition, hence education and productivity, which the LiST model does not incorporate. This study consisting of 17 LMICs estimated the cost of stunting as presented in Table 2.3, but rather than presenting the losses as a percentage of GDP, it compared the anticipated benefits from reduced stunting, to the costs of

Table 2.5 Cost-effectiveness of a package of nutritional interventions in 34 priority countries^a

Intervention	Annual cost (\$ bn)	Lives saved per year	Cost per life-year saved (DALY saved)
Optimum maternal nutrition in pregnancy ^b	\$3.4 bn	102,000	\$571 (\$1051)
Infant and young child feeding ^c	\$2.3 bn	221,000	\$175 (\$322)
Micronutrient supplementation for children ^d	\$1.3 bn	145,000	\$159 (\$293)
Management of severe-acute malnutrition ^e	\$2.6 bn	435,000	\$125 (\$230)
Total	\$9.6 bn	903,000	\$179 (\$329)

^aResults are for when entire package of all interventions is scaled up at once to 90% coverage in the 34 priority countries in [17]

^bConsists of multiple micronutrient supplements to all; calcium supplements to mothers at risk of low intake; maternal balanced energy protein supplements to mothers at risk of low intake and universal salt iodization

^cConsists of promotion of early and exclusive breastfeeding to 6 months, and continued breastfeeding to 24 months; appropriate complementary feeding education in food-secure environments, and education plus supplements in food-insecure environments

^dConsists of vitamin A supplementation between 6 and 59 months of age and preventive zinc supplements between 12 and 59 months of age

^eCommunity-based management

reducing stunting using SUN and the Lancet series methods [17, 37]. The results suggest that the benefit:cost of reducing stunting in the median country is 18:1, and that the economic benefits (as well as the benefits of saving 900,000 lives) make this a very worthwhile investment.

Future Research

In the preceding sections we have focused on undernutrition, however, it is clear that overweight and obesity in LMICs are also becoming a large issue both for well-being and the associated economic costs. One early study [42] estimated that in 1995, the costs of undernutrition and those of overweight/obesity were about the same for China, while the undernutrition costs still exceeded costs of overweight/obesity in India. However it was also estimated that by 2025, costs of overweight/obesity would exceed those of underweight for China, and the two sets of costs would be similar in magnitude for India. In this study, the economic costs of overweight/obesity were based on mortality from, and treatment costs of, diet-related noncommunicable diseases.

A more recent study for China [43] provides more detailed estimates of the costs of overweight and obesity. It separates direct costs (for medical treatment) from indirect (lost productivity due to premature mortality, morbidity, and absenteeism from work). Direct costs were estimated to account for 0.48% of GDP in 2000, and were predicted to increase to 0.50% in 2025. Estimates of indirect losses were considerably larger, amounting to 3.58% of GDP in 2000 but predicted to substantially increase to 8.73% by 2025.

A study for Brazil [44] focused only on the direct costs, which were estimated as 0.09% of GDP annually for the 2008–10 period. The authors compared these to similar estimates for Western Europe (ranging from 0.09 to 0.61% of GDP, depending on the country), and Korea (0.22% of GDP). The lower impact in the Brazil study may also have been due to including a narrower range of disease conditions than the study for China, as well as excluding indirect costs.

Even for industrialized countries where there has been intense interest in overweight and obesity, we are still at an early stage in identifying the cost-effectiveness of interventions to prevent or reduce these conditions. There is a broad array of interventions, ranging from individual actions to public health measures, and encompassing behavioral measures, price and regulatory policy, curative measures, etc.

Furthermore, obesity and overweight outcomes are harder to model than those of underweight or stunting. While stunting is largely determined early in life (within the first three years, although some catch-up is possible later), overweight and obesity can change over the life course. Hence it is harder to predict the impact on chronic diseases whose adverse consequences manifest in later life. At the same time, we are aware that dietary and possibly physical activity habits are set early in life, such that it is important to begin policies now to protect against, and reverse, the growing trends in overweight and obesity. This is an area of growing research need, also for LMICs.

Another area where research is needed for LMICs is in “implementation science” for nutritional interventions. As the SUN movement (<http://www.scalingupnutrition.org>) and related initiatives succeed in drawing attention and resources, it is important that programs are effective and cost-effective. Economics research can assist here too.

Discussion Points

- When can/should we use benefit:cost methods to evaluate nutrition interventions, and when can/should we use cost-effectiveness methods?
- How can economics methods be useful for practitioners and policymakers interested in nutrition?

- Are nutrition interventions good “value for money” for governments in LMICs and why?
- Nutrition education programs cost pennies per child, whereas treatment of severe-acute malnutrition can cost upwards of \$200 per child. Does this mean we should give higher priority to nutrition education?
- How do public health policy priorities need to change in response to the “nutritional transition” underway in LMICs?
- How do interactions among nutrition interventions affect their cost-effectiveness/benefit:cost?

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