

## Achieving the millennium development goals for health

# Cost effectiveness analysis of strategies for child health in developing countries

Tessa Tan-Torres Edejer, Moses Aikins, Robert Black, Lara Wolfson, Raymond Hutubessy, David B Evans

### Abstract

**Objective** To determine the costs and effectiveness of selected child health interventions—namely, case management of pneumonia, oral rehydration therapy, supplementation and fortification of staple foods with vitamin A and zinc, provision of supplementary food with counselling on nutrition, and immunisation against measles.

**Design** Cost effectiveness analysis.

**Data sources** Efficacy data came from published systematic reviews and before and after evaluations of programmes. For resource inputs, quantities came from literature and expert opinion, and prices from the World Health Organization Choosing Interventions that are Cost Effective (WHO-CHOICE) database.

**Results** Cost effectiveness ratios clustered in three groups, with fortification with zinc and vitamin A as the most cost effective intervention, and provision of supplementary food and counselling on nutrition as the least cost effective. Between these were oral rehydration therapy, case management of pneumonia, vitamin A and zinc supplementation, and measles immunisation.

**Conclusions** On the grounds of cost effectiveness, micronutrients and measles immunisation should be provided routinely to all children, in addition to oral rehydration therapy and case management of pneumonia for those who are sick. The challenge of malnutrition is not well addressed by existing interventions.

### Introduction

Despite pledges at the 1990 United Nations children's summit, by 2000 10.6 million children were still dying yearly, most due to pneumonia and diarrhoea and neonatal causes and, in sub-Saharan Africa, malaria.<sup>1,2</sup> Malnutrition was an underlying cause in over 50%,<sup>1</sup> with zinc and vitamin A deficiencies contributing.<sup>1,3</sup>

In September 2000, 189 countries endorsed the UN millennium declaration, which set goals for human development by 2015 ([www.who.int/mdg/en/](http://www.who.int/mdg/en/)). Millennium development goal 4 was specific to child health, aiming to have reduced mortality in children aged less than 5 by two thirds between 1990 and 2015.

Five years on, if practice continues as usual until 2015, then many countries, particularly in sub-Saharan Africa and south Asia, will miss this goal.<sup>4</sup> It is now incumbent on the international community to reconsider if the resources currently used to improve child health are being used as effectively as they could, and what strategies would ensure that any new resources achieve the maximum benefit.

In these new cost effectiveness analyses, we use the WHO Choosing Interventions that are Cost Effective (CHOICE) Millennium Development Goals Team standardised framework, methods, and tools for selected interventions for major causes of childhood morbidity and mortality. They allow combinations of interventions to be analysed at the same time and the impact of increasing coverage to be incorporated explicitly. Full details of the methods are published by Evans et al.<sup>5–7</sup>

### Methods

We evaluated nine single interventions, each at three levels of coverage (50%, 80%, and 95%) and various combinations thereof. The single interventions evaluated are oral rehydration therapy; case management of pneumonia; supplementation or fortification with vitamin A and zinc; provision of supplementary food during weaning, with counselling on nutrition (with and without growth monitoring and targeting); and measles immunisation (see [bmj.com](http://bmj.com)).

We analysed the prevented cases and deaths due to pneumonia, diarrhoea, and measles in the under 5s age group. These are converted to the number of disability adjusted life years (DALYs) averted. We obtained data on epidemiological rates by region and health state valuations primarily from the year 2000 update on burden of disease, supplemented by other published literature.<sup>8,9</sup> We obtained relative risks from systematic reviews<sup>10–12</sup> and applied these to the relevant epidemiological rates for the specific subpopulations (see [bmj.com](http://bmj.com)). For sources of information used to estimate effectiveness for each of the single interventions see [bmj.com](http://bmj.com).

We adopted the standardised WHO ingredients approach, with separate specification of units of utilisation and costs.<sup>6</sup> Utilisation rates and unit costs were derived from the literature, unpublished data, and expert opinion (see [bmj.com](http://bmj.com) and paper by Evans et al).<sup>13</sup> All costs are summarised in international dollars (\$Int; derived by dividing local currency units by an estimate of their purchasing power parity compared with a US dollar) with 2000 as the base year and future costs discounted at 3%. Purchasing power parities are the rates of currency conversion that equalise the purchasing power of different currencies by eliminating the differences in price levels between countries.

**This article is part of a series examining the cost effectiveness of strategies to achieve the millennium development goals for health**

Costs, Effectiveness, Expenditure and Priority Setting, Health Systems Financing, World Health Organization, Geneva, Switzerland

Tessa Tan-Torres Edejer  
*coordinator*

JSA Consultants, Accra, Ghana  
Moses Aikins  
*consultant*

Department of International Health, Bloomberg School of Public Health, Johns Hopkins University, Baltimore, MD, USA

Robert Black  
*professor*

Initiative for Vaccine Research, World Health Organization

Lara Wolfson  
*scientist*

Raymond Hutubessy  
*health economist*

Health Systems Financing, Evidence and Information for Policy, World Health Organization  
David B Evans  
*director*

Correspondence to: T Tan-Torres Edejer  
[tantorrest@who.int](mailto:tantorrest@who.int)

BMJ 2005;331:1177–80



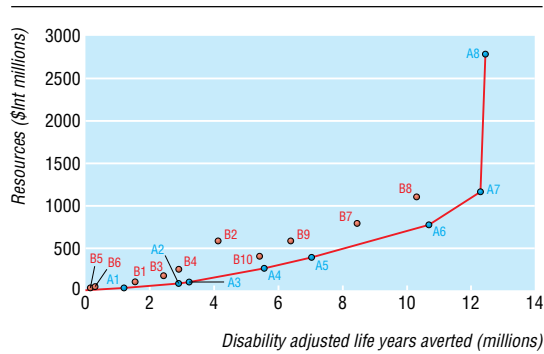
Additional tables and descriptions of the interventions are on [bmj.com](http://bmj.com)



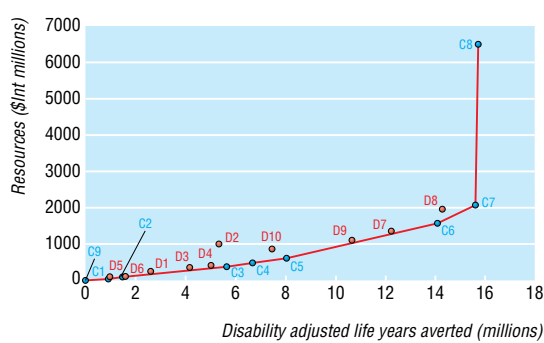
This is the abridged version of an article that was posted on [bmj.com](http://bmj.com) on 10 November 2005: <http://bmj.com/cgi/doi/10.1136/bmj.38652.550278.7C>

Association for Scientific Research in Multiple Births, B-9070 Destelbergen, Belgium  
 Robert Derom  
*professor*

Correspondence to: H Verstraelen  
 hans.verstraelen@UGent.be



**Fig 1** Expansion path for most cost effective set of interventions to improve child health in Afr-E (WHO defined region comprising countries in sub-Saharan Africa with high child mortality)



**Fig 2** Expansion path for most cost effective set of interventions to improve child health in Sear-D (WHO defined region comprising countries in South East Asia with high child mortality)

For our analysis we assumed that interventions run for 10 years, after which time managers re-evaluate their strategies, so costs are incurred for only 10 years. Improvements in health that accrue because of the activities in those 10 years are included.

To be able to assess the cost effectiveness of the current mix of interventions, we first compared interventions with a scenario of doing nothing to improve child health from today.<sup>7</sup> If more resources are available, the decision whether to add a new intervention or to expand the first intervention is made on the basis of the incremental cost effectiveness ratio compared with the first intervention, and this sequential comparison is continued until there are no more

additional health gains. This maps out the expansion path.

We carried out a sensitivity analysis with or without 3% discounting for DALYs and with or without age weighting.

## Results

Results for the full set of interventions by region are available at [www.who.int/choice](http://www.who.int/choice). We present the results for two regions, both with high rates of child mortality.<sup>7</sup> Sear-D is in South East Asia and Afr-E in sub-Saharan Africa.

The highest costs at the population level are those for the provision of supplementary food and nutrition counselling, but targeting food supplementation through growth monitoring and promotion cuts costs by 40% in Sear-D and about 52% in Afr-E. Fortification programmes are the least costly, and fortification with zinc and vitamin A costs between 5% and 30% of the costs of supplementation. The total population costs for case management of pneumonia are lower than that for oral rehydration therapy because there are fewer episodes of pneumonia than there are of diarrhoea.

The proportion of patient level costs for interventions aimed at the individual range from about 80% to 99% of the total costs. These costs increase almost linearly with increasing coverage. Because of the relatively small proportion of programme to total costs for almost all interventions except for fortification, there is limited potential to spread them across a larger number of recipients, so the unit cost of interventions is not observed to fall with increases in coverage.

In general, higher population health gains are obtained from case management of pneumonia, oral rehydration therapy, and measles immunisation, followed by the nutritional interventions. Supplementation averts more DALYs than does fortification, primarily because of the limited access in some areas to processed food. Combinations of interventions produce additive or near additive gains, with the highest health gains achieved with a bundle of interventions that includes oral rehydration therapy, case management of pneumonia and diarrhoea, measles immunisation, vitamin A and zinc supplementation, the provision of supplementary feeding, and nutrition counselling.

**Table 1** Costs, effects, and cost effectiveness ratios for most cost effective interventions in Afr-E in 2000

Intervention package	Description (coverage) of package	Additional interventions*	Yearly cost (\$Int millions)	DALYs averted per year (millions)	ACER (\$Int per DALY averted)	ICER (\$Int per DALY averted)
A1	Vitamin A and zinc fortification (95%)	Vitamin A and zinc fortification of food staple (95%)	23	1	19	19
A2	A1+measles immunisation (80%)	Measles immunisation	72	3	25	29
A3	A2+measles immunisation (95%)	Measles immunisation	91	3	28	58
A4	A3+case management of pneumonia (80%)	Case management of pneumonia	261	6	47	73
A5	Vitamin A and zinc supplementation+case management of pneumonia (80%)+measles immunisation (95%)	Fortification replaced by supplementation	386	7	55	85
A6	A5+oral rehydration therapy (80%)	Oral rehydration therapy for diarrhoea	772	11	72	106
A7	A6 (95%)	Coverage expanded to 95%	1167	12	95	243
A8	A7+provision of supplementary food and nutrition counselling, and growth monitoring and promotion (95%)	Provision of supplementary food and nutritional counselling, growth monitoring and promotion	2 797	12	225	12 791

DALY=disability adjusted life year; ICER=incremental cost effectiveness ratio; ACER=average cost effectiveness ratio; Afr-E=WHO defined region comprising countries in sub-Saharan Africa with high child mortality.

\*In order of cost effectiveness.

**Table 2** Costs, effects, and cost effectiveness ratios for most cost effective interventions in Sear-D in 2000

Intervention package	Description (coverage) of package	Additional interventions*	Yearly cost (\$Int millions)	DALYs averted per year (millions)	ACER (\$Int per DALY averted)	ICER (\$Int per DALY averted)
C1	Zinc fortification (95%)	Zinc fortification of food staple	12	1	14	14
C2	C1+vitamin A fortification (95%)	Vitamin A fortification of food staple	49	1	35	70
C3	C2+case management of pneumonia (80%)	Case management of pneumonia	365	6	64	74
C4	C3 (95%)	Case management of pneumonia expanded to 95%	470	7	70	99
C5	C4+measles immunisation (95%)	Measles immunisation	609	8	75	102
C6	Zinc supplementation+oral rehydration therapy+case management of pneumonia+measles immunisation (95%)	Zinc fortification replaced by supplementation, oral rehydration therapy for diarrhoea	1560	14	111	158
C7	C6+vitamin A supplementation (95%)	Vitamin A fortification replaced by supplementation	2094	16	134	250
C8	C7+provision of supplementary food and nutrition counselling, and growth monitoring and promotion (95%)	Provision of supplementary food and nutritional counselling, growth monitoring and promotion	6546	16	416	44 384

DALY=disability adjusted life year; ICER=incremental cost effectiveness ratio; ACER=average cost effectiveness ratio; Sear-D=WHO defined region comprising countries in South East Asia with high child mortality.

\*In order of cost effectiveness.

For both Sear-D and Afr-E, the expansion path starts with some form of micronutrient fortification—that is, using vitamin A or zinc, followed by measles immunisation in Afr-E and then by case management of pneumonia and oral rehydration therapy (tables 1 and 2 and figures 1 and 2). In Sear-D, oral rehydration therapy and measles immunisation follows closely after the case management of pneumonia. A shift occurs from fortification to supplementation at higher resource levels because even if supplementation is more costly than fortification, a greater potential exists for health gain. The cost effectiveness of the interventions included in this set is either one or two orders of magnitude lower than those of the provision of supplementary food and nutrition counselling.

Removal of age weighting and discounting for DALYs increases the health gains and makes the interventions more cost effective. It does not change the ordering in either region.

## Discussion

Cost effectiveness ratios vary across regions depending on the local epidemiology and existing cost structures. Despite this, there are enough similarities in expansion paths in Sear-D and Afr-E (WHO defined regions comprising countries in, respectively, South East Asia and sub-Saharan Africa with high child mortality) to allow for some generalisations. At one extreme, fortification with vitamin A or zinc are very cost effective, provision of supplementary feeding with nutrition counselling is at the high end, and vitamin A or zinc supplementation, oral rehydration therapy, case management of pneumonia, and measles immunisation in between.

Fortification seems to be a particularly cost effective option because it allows the possibility of fortifying a food staple with multiple micronutrients, not just those in this paper. In this analysis, the cost of fortification was based on adding the micronutrient to different food staples that would reach the entire population. However we included only the benefits obtained in the under 5s age group. Furthermore, for both supplementation and fortification, we included only the impact on childhood pneumonia and diarrhoea even though provision of these micronutrients may also have a beneficial effect on malaria in children in sub-Saharan Africa and other causes of

mortality in the under 5s age group.<sup>11 12</sup> This suggests that our estimates of the cost effectiveness of micronutrient interventions are conservative. However, it might not be feasible to find suitable processed food that young children will eat or there may be constrained access to processed food by people living in remote areas or by the poor, which would bias the results in the opposite direction.

In terms of costing, all interventions except micronutrient supplementation were assumed to be delivered in health facilities. When some types of treatment could be provided in the community by trained non-health professionals, costs would be lower as would the cost effectiveness ratios, making our estimates conservative. Alternatively, measles immunisation can be delivered in national outreach activities, but these delivery strategies are in general more costly than facility based interventions and will decrease the cost effectiveness of this intervention, unless other types of health interventions are piggy backed on immunisation campaigns.<sup>14</sup>

Progress in the other millennium development goals, such as the reduction of poverty and

### What is already known on this topic

Many countries are not on track to meet the millennium development goal for child health of reducing child mortality by two thirds

Malnutrition remains an underlying cause in half of the deaths in children

Interventions of proved effectiveness exist

### What this study adds

Child health interventions to reduce mortality are not only effective but cost effective

More resources could be allocated to interventions tackling underlying causes; specifically to scale up micronutrient provision and to find intersectoral solutions for malnutrition

Failure to tackle malnutrition in a sustainable way is a potential weakness in the child survival strategy

improvements in safe water, sanitation, and indoor air quality, will also impact on child health. A major challenge in the achievement of millennium development goal 4 will be to find a sustainable intersectoral solution to reducing malnutrition in children and to tackle the root causes of poverty, lack of education, and sex inequality.

Contributors: See [bmj.com](http://bmj.com).

Funding: None.

Competing interests: None declared.

Ethical approval: Not required.

- 1 Bryce J, Boschi-Pinto C, Shibuya K, Black RE. WHO estimates of the causes of death in children. *Lancet* 2005;365:1147-52.
- 2 Black RE, Morris SS, Bryce J. Where and why are 10 million children dying every year? *Lancet* 2003;361:2226-34.
- 3 World Health Organization. *The world health report 2002: reducing risks, promoting healthy life*. Geneva: WHO, 2002.
- 4 Evans DB, Adam T, Tan-Torres Edejer T, Lim SS, Cassels A, Evans TG, et al. Achieving the millennium development goals for health: Time to reassess strategies for improving health in developing countries? *BMJ* 2005;331:1133-6.
- 5 Murray CJ, Evans DB, Acharya A, Baltussen RM. Development of WHO guidelines on generalized cost-effectiveness analysis. *Health Econ* 2000;9:235-51.
- 6 World Health Organization. *Making choices in health: WHO guide to cost-effectiveness analysis*. Geneva: WHO, 2003.

- 7 Evans DB, Tan-Torres Edejer T, Adam T, Lim SS, for the WHO-CHOICE Millennium Development Goals Team. Achieving the millennium development goals for health: Methods to assess the costs and health effects of interventions for improving health in developing countries. *BMJ* 2005;331:1137-40.
- 8 Murray CJL, Lopez AD. *Global health statistics: a compendium of incidence, prevalence and mortality estimates for over 200 conditions*. Cambridge, MA: Harvard University Press, 1996.
- 9 Perry R, Halsey N. The clinical significance of measles: a review. *J Infect Dis* 2004;189:S4-16.
- 10 Fishman S, Caulfield L, de Onis M, Blossner M, Hyder A, Mullany L, et al. Chapter 2. Childhood and maternal undernutrition. In: Ezzati M, Lopez AD, Rodgers A, Murray CJL, eds. *Comparative quantification of health risks: global and regional burden of disease attributable to selected major risk factors, Vol 1*. Geneva: WHO, 2004.
- 11 Rice A, West K, Fishman S, Black R. Chapter 4. Vitamin A deficiency. In: Ezzati M, Lopez AD, Rodgers A, Murray CJL, eds. *Comparative quantification of health risks: global and regional burden of disease attributable to selected major risk factors, Vol 1*. Geneva: WHO, 2004.
- 12 Caulfield L, Black R. Chapter 5. Zinc deficiency. In: Ezzati M, Lopez AD, Rodgers A, Murray CJL, eds. *Comparative quantification of health risks: global and regional burden of disease attributable to selected major risk factors*. Geneva: WHO, 2004.
- 13 Horton S. *Unit costs, cost-effectiveness, and financing of nutrition interventions*. Population and Human Resources Department, Washington, DC: World Bank, 1992. WPS-952.
- 14 Pegurri E, Fox-Rushby JA, Damian W. The effects and costs of expanding the coverage of immunisation services in developing countries: a systematic literature review. *Vaccine* 2005;23:1624-35.

(Accepted 12 October 2005)

doi 10.1136/bmj.38652.550278.7C

## How does progress towards the child mortality millennium development goal affect inequalities between the poorest and least poor? Analysis of Demographic and Health Survey data

Kath A Moser, David A Leon, Davidson R Gwatkin

Department of  
Epidemiology and  
Population Health,  
London School of  
Hygiene and  
Tropical Medicine,  
London  
WC1E 7HT

Kath A Moser  
lecturer

David A Leon  
professor

6483 Wishbone  
Terrace, Cabin John,  
Maryland 20818,  
USA

Davidson R  
Gwatkin  
consultant on health  
and poverty

Correspondence to:  
K A Moser  
kath.moser@  
ons.gov.uk

*BMJ* 2005;331:1180-3

The millennium development goals (MDGs) have been widely accepted as a framework for improving health and welfare worldwide. Child mortality is one of the most crucial and avoidable global health concerns. In many low income countries, 10-20% of children die before reaching 5 years (compared with, for example, 0.7% in England and Wales). The child mortality MDG (to reduce the under 5 mortality rate by two thirds between 1990 and 2015) is formulated as a national average. The *World Health Report 2003* posed an important question: how does progress towards the MDGs affect equity? We investigated this by examining, across a range of settings, how inequality in the under 5 mortality of the poorest and least poor changes as progress is made towards the MDG.

### Participants, methods, and results

Using published data<sup>1</sup> we examined changes in inequalities in under 5 mortality within 22 low and lower middle income countries (11 in Africa, five in Latin America or the Caribbean, and six in Asia) each with two Demographic and Health Surveys between 1991 and 2001 ([www.measuredhs.com](http://www.measuredhs.com)). These countries encompass high and lower mortality situations, varied sociodemographic conditions, and in 2000 they accounted for 27% of the world's population. Under 5 mortality was estimated, using standard methods, from

information on births in the 10 years preceding the survey derived from birth histories collected from women of reproductive ages. Socioeconomic position was described using an index of household wealth calculated from information on ownership of household assets (for example, a radio), housing characteristics (for example, floor materials), drinking water source, toilet facilities, and availability of electricity. The method is described elsewhere.<sup>2</sup> Households, ranked by wealth index, were split into five groups each containing 20% of individuals and representing the poorest up to the least poor quintiles of the population. Under 5 mortality rates (deaths under age 5 per 1000 live births) were calculated for each quintile and the rate ratio (ratio of mortality in poorest and least poor quintiles) used to describe relative inequality. Inequality was considered to have increased or decreased over time if the rate ratio changed by at least  $\pm 10\%$ .

National under 5 mortality rates vary between 30 and 250 deaths per 1000 live births (table). In all surveys mortality is higher in the poorest as compared with the least poor quintile. Most rate ratios lie within the range 1.5 to 3.0 and almost all the 95% confidence intervals exclude 1.0. Thirteen countries had statisti-

This article was posted on [bmj.com](http://bmj.com) on 11 November 2005: <http://bmj.com/cgi/doi/10.1136/bmj.38659.588125.79>