

Measles Mortality Reduction Contributes Substantially to Reduction of All Cause Mortality Among Children Less Than Five Years of Age, 1990–2008

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Background. The Millennium Development Goal 4 (MDG4) to reduce mortality in children aged <5 years by two-thirds from 1990 to 2015 has made substantial progress. We describe the contribution of measles mortality reduction efforts, including those spearheaded by the Measles Initiative (launched in 2001, the Measles Initiative is an international partnership committed to reducing measles deaths worldwide and is led by the American Red Cross, the Centers for Disease Control and Prevention, UNICEF, the United Nations Foundation, and the World Health Organization).

Methods. We used published data to assess the effect of measles mortality reduction on overall and disease-specific global mortality rates among children aged <5 years by reviewing the results from studies with the best estimates on causes of deaths in children aged 0–59 months.

Results. The estimated measles-related mortality among children aged <5 years worldwide decreased from 872,000 deaths in 1990 to 556,000 in 2001 (36% reduction) and to 118,000 in 2008 (86% reduction). All-cause mortality in this age group decreased from >12 million in 1990 to 10.6 million in 2001 (13% reduction) and to 8.8 million in 2008 (28% reduction). Measles accounted for about 7% of deaths in this age group in 1990 and 1% in 2008, equal to 23% of the global reduction in all-cause mortality in this age group from 1990 to 2008.

Conclusions. Aggressive efforts to prevent measles have led to this remarkable reduction in measles deaths. The current funding gap and insufficient political commitment for measles control jeopardizes these achievements and presents a substantial risk to achieving MDG4.

Mortality among children aged <5 years has been declining globally in recent decades as a result of

socioeconomic development and implementation of child survival interventions. Yet, in 2008, an estimated 8.8 million children [1, 2] still died each year before their fifth birthday, down from >12 million deaths in 1990 [1, 3]. The United Nations Millennium Development Goal 4 (MDG4) aims for a two-thirds reduction in mortality among children aged <5 years from 1990 to 2015. Many countries are not on track to meet this target [1].

Updates on the total all-cause mortality for children aged <5 years are published annually, and the most recent estimates are for 2008 [1]. The latest comprehensive review of the causes of mortality for children in this age group globally was undertaken by the Child Health Epidemiology Reference Group (CHERG) and the World Health Organization (WHO) for the year 2008 [2].

The 3 indicators for MDG4 are the mortality rate among children aged <5 years, the infant mortality rate, and the proportion of 1-year-old children immunized

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Table 1. Estimated Number of Deaths From All Causes Worldwide Among Children <5 Years of Age and Proportionate Cause-Specific Mortality

Year	All causes							Source unless otherwise indicated
	You et al 2010 [1]	Other sources ^a	ARI (pneumonia)	Diarrhea	Measles ^b	Malaria	HIV	
c. 1990	12,657,000(100)	2,372,000(18.7)	2,478,000(19.6)	863,000(6.8)	632,000(5.0)	58,000(0.5)	Murray and Lopez 1994 [5]	
1990	12,500,000	2,533,000(20.9)	2,374,000(19.6)	872,000(7.2)	588,000(4.8)	62,000(0.5)	Lopez et al 2006 [3]	
2000	10,400,000							
c. 2001	10,605,000(100)	1,944,000(18.3)	1,600,000(15.1)	556,000(5.2)	1,086,000(10.2)	340,000(3.2)	Lopez et al 2006 [3] Mathers et al 2006 [6]	
c. 2004	10,600,000(100)	2,014,000(19)	1,802,000(17)	424,000(4)	848,000(8)	318,000(3)	Bryce et al 2005 [7]	
2004	10,400,000(100)	1,768,000(17)	1,768,000(17)	416,000(4)	771,000(7)	208,000(2)	WHO 2008 [8]	
2005	9,300,000							
c. 2008	8,800,000	8,795,000(100)	1,575,000(18)	1,336,000(15)	118,000(1)	732,000(8)	201,000(2)	Black et al 2010 [2]

NOTE. Data are no. (%) of deaths unless otherwise specified. Nontalicized numbers are shown as reported in the source document (rounded to nearest thousand); italicized numbers are computed (rounded to nearest thousand). ARI, acute respiratory infection; HIV, human immunodeficiency virus; WHO, World Health Organization.

^a Source is specified in last column, unless otherwise indicated.

^b Wolfson et al [9] estimate that measles mortality among children aged <5 years decreased from 791,000 (uncertainty bounds, 573,000–1,032,000) in 1999 to 311,000 (uncertainty bounds, 222,000–415,000) in 2005.

against measles. The global rate of mortality for children aged <5 years has decreased from 90 deaths per 1000 live births in 1990 to 65 in 2008 [1], a decline of 28%. Although substantial progress has been made in reducing deaths among children aged <5 years, the rate of decline for deaths in this age group is still insufficient to reach the MDG4 goal by 2015, particularly in sub-Saharan Africa and South Asia [1, 4].

In addition, children from poorer households remain disproportionately vulnerable across all regions of the developing world. Mortality rates in children aged <5 years are, on average, twice as high for the poorest 20% of households as for the richest 20%. Similarly, children in rural areas are more likely to die before their fifth birthday than those in urban areas. The highest rates of mortality in children <5 years of age continue to be found in sub-Saharan Africa, which accounted for nearly half the deaths among children aged <5 years worldwide in 2008: 1 in 7 children died before their fifth birthday. Most of these deaths of children in developing countries continue to result from preventable or treatable causes, with pneumonia (18%) and diarrhea (15%) the 2 main killers and undernutrition contributing to more than one-third of all under-five deaths (Table 1) [1–3, 5–9].

Measles is one of the leading causes of under-five mortality among vaccine-preventable diseases and accounted for approximately 7% of all-cause mortality among children aged <5 years in 1990 (Table 1) [3, 5]. Routine childhood immunization with measles vaccine is recommended as an effective intervention to reduce mortality due to measles. Measles routine immunization coverage (MCV1) can also serve as a proxy indicator for access to basic health services for children aged <5 years.

Immunization programs have made an impressive contribution to reducing deaths of children aged <5 years, although disparities in coverage continue to be evident. Since 1990, global MCV1 coverage has increased from 73% to 82%; that is, >15 million additional children are reached each year. Improved MCV1 coverage has been achieved in all types of countries—in the developed world (from 82% to 93%), in the countries of the Commonwealth of Independent States (from 85% to 96%), and in sub-Saharan Africa (from 56% to 67%) [10]. Specific delivery modes, such as Supplementary Immunization Activities (SIAs) to vaccinate (or revaccinate) children against measles, have often served to protect children unreached by routine immunization. Those additional vaccinated children are not reflected in the routine coverage estimates. Worldwide, nearly 700 million children have benefited from a second opportunity to receive a dose of measles vaccine through SIAs supported by the Measles Initiative since 2001 [11, 12].

The Measles Initiative, launched in 2001, is led by the American Red Cross, the United Nations Foundation, the US Centers for Disease Control and Prevention (CDC), the United

Nations Children's Fund (UNICEF), and the World Health Organization and provides technical and financial support to governments and communities for mass vaccination campaigns and disease surveillance around the world (www.measlesinitiative.org, accessed 1 July 2010).

The Global Strategy for Measles Control is a comprehensive strategy for accelerated and sustained reduction in mortality due to measles that was developed by the WHO, UNICEF, and the CDC [13]. The strategy was based on the success of the Pan American Health Organization's measles elimination program and the dramatic reduction in measles mortality and morbidity in 7 southern African countries in the 1990s [14, 15]. The Measles Initiative has supported the implementation of this comprehensive strategy in 46 of 47 priority countries (mainly located in sub-Saharan Africa and Asia) that accounted for 94% of estimated global measles deaths in 2000. This paper compares global measles mortality reduction with all-cause mortality reduction for children aged <5 years during the period 1990–2008 and describes the contribution of measles mortality reduction toward achievement of the 2015 MDG4 goal.

METHODS

Our description of the contribution of measles mortality reduction toward MDG4 is based on published literature that used results from multicausal proportionate mortality models to estimate deaths in children aged 0–59 months. These studies also used selected single-cause disease models and analysis of vital registration data when available to estimate causes of death among children aged <5 years. We focused on several specific papers that published cause of death data for children aged <5 years at specific points in time: 1990, 2001, 2004, and 2008 (Table 1). [1–3, 5–8] We compared the gold standard for all-cause mortality in this age group published by You et al [1] with the data on estimates that include cause-specific mortality estimates for 1990 [3, 5], 2001 [3, 6], 2004 [7,8], and 2008 [2] (see Table 1). The data for 1990 and 2001 were published by the same

group, and the methodologies used to derive estimates are comparable. However, the studies for the 2004 and 2008 estimates used a different methodology for the cause-specific estimates. Despite those methodological differences, we chose to compare the studies that provided the best estimates for 1990, 2001, 2004, and 2008 and analyzed whether trends could be identified.

The data on global burden of disease estimates for 1990 were first published by Murray and Lopez in 1994 [5] and revised by Lopez and colleagues in 2006 [3]. We used the revised figures in our final analysis. The methods for estimating country-specific mortality rates among children aged <5 years and cause-specific mortality are described elsewhere [2, 3, 5–9].

RESULTS

Deaths due to all causes among children aged <5 years decreased from >12 million deaths in 1990 to 10.6 million in 2001 according to Lopez et al [3], with an annual reduction rate of about 1% per year, and to 8.8 million in 2008 [2], with an annual reduction rate of about 2% (Figure 1). The total decrease for 1990–2008 according to those time series is 28%. You et al [1] reported a decrease in overall mortality in children aged <5 years from 12.5 million deaths in 1990 to 10.4 million in 2004 and 8.8 million in 2008, ie, a 30% decrease between 1990 and 2008.

In 1990, diarrhea, pneumonia, malaria, and measles accounted for an estimated 20%, 21%, 5%, and 7% of deaths in children aged <5 years, respectively, according to Lopez et al [3] (Figure 2). As noted by Black et al [2], infectious diseases caused 68% of all deaths in 2008, with the largest percentages due to pneumonia (18%), diarrhea (15%), and malaria (8%) (Table 1) [2]. The cause-specific contribution of measles to the overall global death burden decreased markedly from 7% in 1990 to 1% in 2008 (Table 1) [2, 3]. Estimated measles deaths in children younger than 5 years of age worldwide decreased from 872,000 deaths in 1990 [3] to 556,000 in 2001 [3], about 3% per year, and to 118,000 in 2008 [2], with an annual reduction rate of

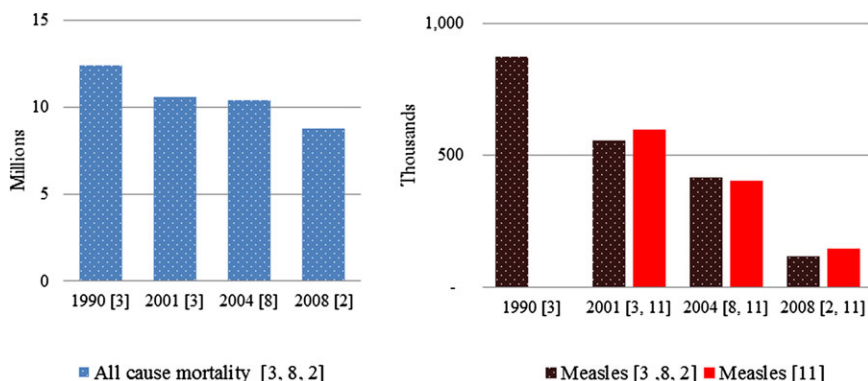


Figure 1. Declines in estimated all-cause mortality and measles-specific mortality among children <5 years of age from all causes (*left*) and measles specific (*right*), 1990–2008.

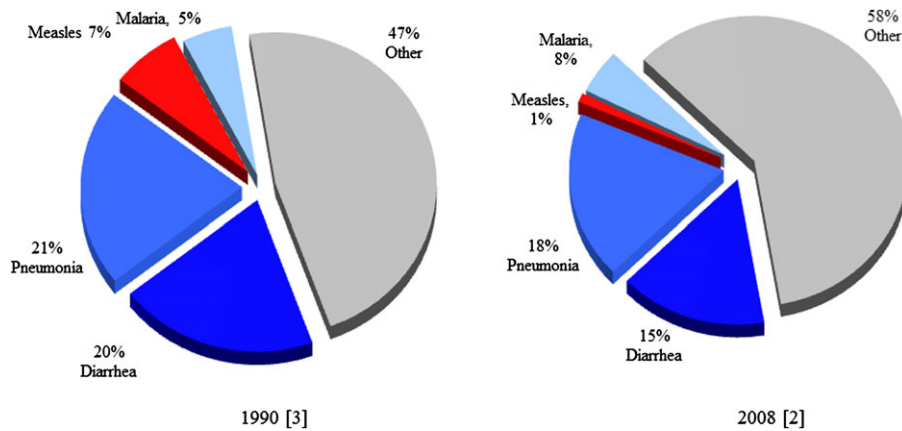


Figure 2. Cause-specific proportionate mortality worldwide among children <5 years of age in 1990 [3] and 2008 [2].

about 10% per year (Figure 1). Using those estimates, measles-specific mortality decreased by 36% between 1990 and 2001 [3] and by 86% between 1990 [3] and 2008 [2].

Approximately 23% of averted deaths in children aged <5 years between 1990 and 2008 were due to a decrease in measles deaths (Figure 3). Reductions in measles-related mortality accounted for 21% of the averted deaths due to all causes during 1990–2001 and for 24% during 2001–2008 [2, 3].

Globally, the rate of coverage for the first dose of measles vaccination increased from 73% in 1990 to 82% in 2008. Since 1990, all countries, except India, have introduced a 2-dose measles vaccination schedule by 2009. Specifically, South America and southern Africa have conducted large-scale catch-up campaigns during the first period, 1990–2001. The latter period, 2001–2008, coincides with the scale-up, through the Measles Initiative, of catch-up and follow-up measles SIAs in 46 of the 47 priority countries. These countries introduced a second dose of measles vaccine through SIAs in their immunization

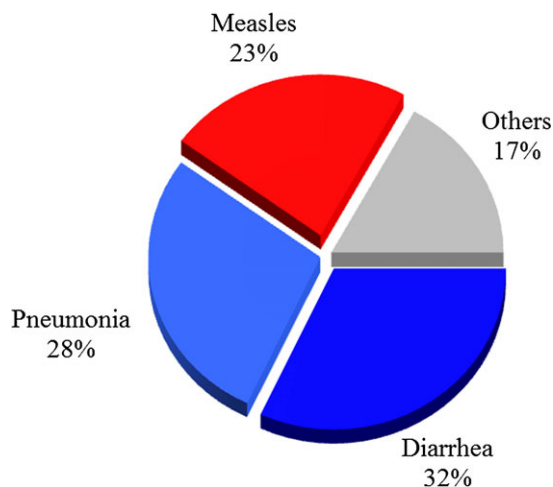


Figure 3. Progress toward Millennium Development Goal 4: Cause-specific mortality reduction in children <5 years of age, 1990–2008.

programs and improved their first-dose routine measles vaccine coverage (MCV1).

DISCUSSION

Using estimates from studies that included cause-specific mortality, the overall mortality rate among children aged <5 years decreased from >12 million in 1990 [3] to approximately 8.8 million in 2008 [2], according to Lopez et al [3] and Black et al [2], resulting in a 28% reduction in the overall number of deaths among children aged <5 years during this time period. According to You and colleagues, those figures are slightly different: mortality among children aged <5 years decreased from 12.5 million to 8.8 million, resulting in a 30% reduction between 1990 and 2008 [1]. Taking into account uncertainties in the data estimates, we conclude that very similar trends are observed.

By comparison, an 86% reduction in measles deaths occurred between 1990 and 2008, from 872,000 deaths [3] to 118,000 deaths [2]. Thus, measles mortality reduction efforts substantially contributed to the decrease in overall under-five mortality—approximately 23% of the decrease in all-cause mortality among children aged <5 years between 1990 and 2008 was due to a reduction in measles-related deaths. The relative importance of measles deaths decreased from about 7% (1990) to 1% (2008) of all deaths among children in this age group.

Alternatively, using Murray and Lopez data published in 1994 [5], all-cause mortality among children aged <5 years decreased from 12.657 million [5] to 8.795 million deaths yearly [2], ie, a 31% decline. According to Murray and Lopez data, measles-related deaths declined from 863,000 [5] to 118,000 yearly [2], and measles contributed 19% to the decline in under-five deaths between 1990 and 2008. However, the earlier estimates for the 1990 global burden of disease, published by Murray and Lopez in 1994, were revised by Lopez and associates in 2006. Regardless of which data source is used [3, 5], measles mortality reduction

efforts have markedly contributed to reductions in overall global under-five mortality between 1990 and 2008.

You and colleagues' estimates for all-cause mortality among children aged <5 years are considered the gold standard; however, they do not specify causes of deaths. Therefore, we chose to use the most recent and complete available data for the 4 time points to conduct the analysis. Although we realized that different methods of estimation were used for the time series 1990–2001 [3] and the data points 2004 [8] and 2008 [2], we considered the estimates to produce a similar trend and believe them to be the best available estimates.

There are a number of challenges related to estimating total and cause-specific mortality among children aged <5 years. First, vital registry, record keeping, and medical infrastructure are weakest in places with the highest mortality rates among children aged <5 years; in these settings, models are required. There are 2 basic approaches to modeling deaths of children in this age group: (1) proportional mortality models that are based on cross-sectional studies using verbal autopsies that aim to record a single underlying cause of death, and (2) natural history models that reconstruct each birth cohort in the population and follow them from birth to a fate of susceptible, exposed, diseased, and/or dead on the basis of probabilities observed in field studies; these studies estimate the number of deaths attributable to a specific etiology (eg, diarrhea due to rotavirus infection) even if that cause is not the single underlying cause but may also be part of a chain of events that results in death. Hence, the estimates from natural history methods are usually higher than estimates derived from proportional mortality models. The Global Burden of Disease project approach and methodology used by the CHERG to estimate global measles deaths is a composite of both approaches mentioned above, and as a result, the numbers for any given year are either the same or somewhat lower than published results from the WHO Department of Immunization, Vaccines, and Biologicals natural history method [2, 3, 5, 9]. Hence, lack of vital registration records in the countries with the highest mortality rates introduces uncertainty in the number of deaths among children aged <5 years and in cause-specific proportionate mortality. In addition, the methods used to estimate under-five mortality may have changed over time without any revision of the whole time series based on the latest method.

Wolfson et al [9], using the natural history model, estimated about 1.2 million measles deaths in 1990, 732,000 in 2000, and 347,000 in 2005 occurring among all age groups. Dabbagh and colleagues, using the same model, recently estimated that 164,000 measles deaths in all age groups occurred in 2008 [11, 12] (Figure 1). Although differences in the numbers of deaths exist between the different estimates, the rate of the decline in measles deaths is consistent between the methods.

As noted by Black et al [2], caution is essential when comparing data produced using different methodologies at different

time points. Because modern estimation processes might provide enhanced precision using additional data and improved analytical methods, changes in estimates over time might indicate trends that deviate from the true trend. However, the trend in decreased measles mortality is evident from any of the data included in this analysis and is consistent with the results produced using the natural history model [9].

The success of measles mortality reduction is mainly due to increased vaccination coverage. MCV1 coverage increased from 73% in 1990 to 82% in 2008 worldwide [10]. Although global measles coverage of the first dose of vaccine leveled off in the 1990s, large-scale measles vaccination campaigns in South America and southern Africa and the introduction of a second dose in the routine delivery system in some countries contributed to the decrease in mortality between 1990 and 2000. The gains that occurred since 2000 were due to an increase in global vaccination coverage from 72% to 82% in 2008 and to the full implementation of the measles mortality reduction strategy in all countries except India. Worldwide, nearly 700 million children received a measles vaccination during supplementary immunization activities between 2001 and 2008.

An estimated 12.7 million measles deaths were averted during 2000–2008; of these, 8.4 million measles deaths were averted by maintaining routine immunization coverage at the 2000 level and 4.3 million deaths were averted as a result of measles SIAs and improved routine measles coverage [11, 12].

Yet, routine immunization systems continue to miss the most marginalized children in the poorest countries. In 2008, the WHO and UNICEF estimated that 23.8 million infants and young children did not receive the first measles dose through the routine immunization program. Approximately 60% of the children who were missed lived in 6 large countries: India, Nigeria, China, Pakistan, Indonesia, and Ethiopia (unpublished data based on UNICEF Immunization Summary [10]). According to Demographic Health Survey and Multiple Indicator Cluster Survey data from 242 surveys in 95 countries conducted between 1986 and 2007, children who belong to the poorest wealth quintiles or whose caregivers have lower education levels are less likely to have received routine vaccinations [16]. Yet, poor children, living in unhygienic conditions in periurban and rural areas, are most vulnerable to any disease, including measles and its consequences. Measles SIAs have been shown to be effective in reaching the poorest children and those missed by routine health services [17]. A study in Kenya performed after the measles SIA in 2002 showed that SIA coverage was similar across all wealth quintiles. In addition, 10% of children aged 9–23 months who were vaccinated during the SIA had not previously received a dose of measles vaccine through the routine health system. This percentage increased to 17% among the poorest wealth quintile.

Surprisingly, as a victim of its own success, the Measles Initiative currently receives substantially less political and financial

commitment than it did before 2007. Funding for global measles control has declined sharply since 2007, raising concerns of possible loss of the impact on measles mortality and MDG4. In Africa, where measles outbreaks became rare as the measles control program was rolled out, >80,000 measles cases have been reported during the period from June 2009 through July 2010 (WHO, unpublished data based on surveillance data from ministries of health in African countries). Without sufficient financial resources and political commitment for routine immunization and periodic measles SIAs, the achievements in measles mortality reduction risk being lost.

The WHO used the natural history model to project multiple scenarios for 2010–2013 measles mortality estimates [9, 11, 12]. In the “worst-case” scenario, it was assumed that routine measles vaccination coverage would remain at current levels and that no SIAs would be conducted in the 47 priority countries. Measles deaths would rebound, resulting in an estimated 1.7 million deaths between 2010 and 2013 [11, 12]. Without implementation of timely measles SIAs reaching the unimmunized, there would be the potential to lose an important part of the gains in reduction of mortality among children younger than 5 years of age.

Substantial decline in mortality among children aged <5 years is still needed to meet MDG4 by 2015. Low-cost prevention and treatment measures are available to improve child survival. Access to prompt treatment for common childhood illnesses and the massive rollout of long-lasting insecticide-treated nets for use against malaria will have an important effect on under-five mortality. Another critical challenge will be to ensure that new vaccines—such as those against pneumococcal pneumonia and rotavirus—are made available on an equitable basis rather than only in wealthier countries, as at present. Yet, the achieved reduction in measles mortality, which contributed 23% to the decline in under-five all-cause mortality between 1990 and 2008, needs to be sustained. The international community and governments of measles-endemic countries need to step up political commitment and financial support to sustain the gains and protect more children against measles—one of the most cost-effective and safe child survival interventions available.

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