Global, regional, and national levels and trends in under-5 mortality between 1990 and 2015, with scenario-based projections to 2030: a systematic analysis by the UN Inter-agency Group for Child Mortality Estimation


Summary
Background In 2000, world leaders agreed on the Millennium Development Goals (MDGs). MDG 4 called for a two-thirds reduction in the under-5 mortality rate between 1990 and 2015. We aimed to estimate levels and trends in under-5 mortality for 195 countries from 1990 to 2015 to assess MDG 4 achievement and then intended to project how various post-2015 targets and observed rates of change will affect the burden of under-5 deaths from 2016 to 2030.

Methods We updated the UN Inter-agency Group for Child Mortality Estimation (UN IGME) database with 5700 country-year datapoints. As of July, 2015, the database contains about 17 000 country-year datapoints for mortality of children younger than 5 years for 195 countries, and includes all available nationally-representative data from vital registration systems, population censuses, household surveys, and sample registration systems. We used these data to generate estimates, with uncertainty intervals, of under-5 (age 0–4 years) mortality using a Bayesian B-spline bias-reduction model (B3 model). This model includes a data model to adjust for systematic biases associated with different types of data sources. To provide insights into the global and regional burden of under-5 deaths associated with post-2015 targets, we constructed five scenario-based projections for under-5 mortality from 2016 to 2030 and estimated national, regional, and global under-5 mortality rates up to 2030 for each scenario.

Results The global under-5 mortality rate has fallen from 90·6 deaths per 1000 livebirths (90% uncertainty interval 89·3–92·2) in 1990 to 42·5 (40·9–45·6) in 2015. During the same period, the annual number of under-5 deaths worldwide dropped from 12·7 million (12·6 million–13·0 million) to 5·9 million (5·7 million–6·4 million). The global under-5 mortality rate reduced by 53% (50–55%) in the past 25 years and therefore missed the MDG 4 target. Based on point estimates, two regions—east Asia and the Pacific, and Latin America and the Caribbean—achieved the MDG 4 target. 62 countries achieved the MDG 4 target, of which 24 were low-income and lower-middle income countries. Between 2016 and 2030, 94·4 million children are projected to die before the age of 5 years if the 2015 under-5 mortality rate remains constant in each country, and 68·8 million would die if each country continues to reduce its mortality rate at the pace estimated from 2000 to 2015. If all countries achieve the Sustainable Development Goal of an under-5 mortality rate of 25 or fewer deaths per 1000 livebirths by 2030, we project 56·0 million deaths by 2030. About two-thirds of all sub-Saharan African countries need to accelerate progress to achieve this target.

Interpretation Despite substantial progress in reducing child mortality, concerted efforts remain necessary to avoid preventable under-5 deaths in the coming years and to accelerate progress in improving child survival further. Urgent actions are needed most in the regions and countries with high under-5 mortality rates, particularly those in sub-Saharan Africa and south Asia.

Funding None.

Copyright © 2015. World Health Organization. Published by Elsevier Ltd/Inc/BV. All rights reserved.
Articles

Research in context

Evidence before this study
Nationally representative high-quality data for mortality of children younger than 5 years are available at regular time intervals from vital registration for only about 60 countries. For the rest of the world, knowledge depends on data from population censuses, household surveys, and sample registration systems. All publicly available data for under-5, infant, and neonatal mortality are compiled annually by the UN Inter-agency Group for Child Mortality Estimation (UN IGME) to improve monitoring of progress towards child survival goals and to enhance the capacity of countries to produce timely estimates of child mortality. The UN IGME global database before this study contained about 16,000 observations with meta-information from 1950 (or earlier) to 2013 available as of July, 2014. The UN IGME uses this information to produce annual updates, typically released in September, of neonatal, infant, and under-5 mortality rates and trends for 195 countries or areas.

Added value of this study
This study provides estimates of under-5 mortality up to the Millennium Development Goal (MDG) target year (2015) and constructs scenario-based projections from 2016 to 2030 to provide insights into the burden of under-5 deaths in the next 15 years. This study extended the existing UN IGME global database by including 5700 new or updated observations and also incorporated updated HIV/AIDS estimates from UNAIDS and revised population numbers from the UN Population Division. On the basis of this empirical database and updated demographic inputs, we constructed country-specific under-5 mortality rate estimates for 195 countries from 1990 (or earlier) to 2015 to assess levels and trends in child mortality and to monitor progress in child survival. These estimates were constructed with the Bayesian B-spline bias-reduction model to produce estimates of mortality rates and associated indicators, such as rates of change and aggregate outcomes, with 90% uncertainty intervals.

Implications of all the available evidence
Although great progress in reducing child mortality has been made since 1990 (more than two-thirds of 195 countries have at least halved their under-5 mortality rate from 1990 to 2015) progress has been insufficient worldwide to achieve MDG 4, which requires a two-thirds reduction in the under-5 mortality rate. Without any acceleration in the pace of reduction in child mortality as compared with country-specific rates of decline in 2000–15, 68.8 million children will die before they reach their fifth birthday in 2016–30. The more ambitious aim of an under-5 mortality rate of 25 or fewer deaths per 1000 livebirths for all countries by 2030 would correspond to substantially fewer deaths in the next 15 years, but requires concerted efforts to enable continued improvements in child survival in countries that have had recent accelerations and moreover, immediate action to accelerate child survival improvements for countries with little progress in the last decades.

address the major health challenges facing women and children around the world. In June, 2012, world leaders renewed their commitment during the global launch of Committing to Child Survival: A Promise Renewed (APR), aiming for a continued post-2015 focus to end preventable child deaths, and with a target U5MR of 25 or fewer deaths per 1000 livebirths by 2030 or 20 or fewer deaths per 1000 livebirths by 2035 for all countries. The international community is in the process of agreeing on a new framework, known as the Sustainable Development Goals (SDGs), that will guide and motivate future global and national action. They seek to build upon the foundation laid by the MDGs, not only completing unfinished business but also working towards setting ambitious new goals that will constitute an integrated and indivisible set of global priorities for sustainable development. Ending preventable deaths of newborn babies and children younger than 5 years by 2030, with all countries aiming to reduce neonatal mortality to at least as low as 12 deaths per 1000 livebirths and under-5 mortality to at least as low as 25 deaths per 1000 livebirths, has been proposed as an SDG target under goal 3, which seeks to ensure healthy lives and promote wellbeing at all ages.

Data-driven estimates for child mortality are necessary to track progress towards child survival goals and to plan national and global health strategies, policies, and interventions for child health. As opposed to adult or old-age mortality, child mortality is the one indicator that is based on a comparably large amount of empirical data in low-income and middle-income countries, which makes it unique from a monitoring perspective. However, the estimation of child mortality is still challenging for the great majority of developing countries without well functioning civil registration systems due to data quality issues. Modelling exercises are usually required to generate reliable and comparable child mortality estimates. With increasing implementation of evidence-based interventions to reduce child mortality, demand is increasing for frequent, accurate, and transparent monitoring.

Many studies have shown that remarkable progress has been made since 1990 to improve child survival but that progress has been insufficient to achieve MDG 4. In the concluding year of the MDGs, it is time to take stock of what has been achieved in improving child survival, and to share success stories and learn lessons from failures. It is also essential to look beyond the MDGs to the post-2015 SDGs to identify potential challenges in ending preventable deaths of children younger than 5 years.

In this Article, we estimate levels and trends for child mortality and provide an overview of global, regional,
and country-specific progress towards MDG 4. We also present projections of USMR and the associated numbers of deaths up to 2030 under five scenarios to provide insight into the post-2015 burden of under-5 deaths.

**Methods**

**Estimation of under-5 mortality**

The UN Inter-agency Group for Child Mortality Estimation (UN IGME) was established in 2004 to improve monitoring of progress towards child survival goals and to enhance the capacity of countries to produce timely estimates of child mortality. It is led by the UN Children’s Fund (UNICEF), and includes WHO, UN Population Division, and World Bank. The group is advised by an independent technical advisory group of leading experts in demography and biostatistics. The UN IGME produces annual updates, usually released in September, of neonatal, infant, and under-5 mortality levels and trends for 195 countries or areas. These UN IGME estimates represent the most up-to-date comprehensive information on child mortality and provide a basis for assessing progress and reaching consensus for action.11

The UN IGME estimation process aims to compile all available nationally-representative empirical data relevant to child mortality, which includes to access various data sources, assess data quality, recalculate harmonised data inputs, and make adjustments, if needed, through standard methods, and then to fit statistical models to these data to generate smoothed time series and uncertainty ranges and extrapolate to a target year.12 Below we summarise our database and analysis approach; details about data sources and methods used to generate mortality rates and number of deaths are available online (appendix pp 2–11).

Nationally-representative data of under-5 mortality can be derived from several different sources, including civil registration, censuses, and sample surveys. Demographic surveillance sites and hospital data are excluded because they are rarely nationally representative. The preferred source of data is a civil registration system that records births and deaths on a continuous basis. If registration is complete and the system functions efficiently, then the resulting estimates will be accurate and timely. However, most low-income and middle-income countries do not have well functioning civil registration systems, and household surveys and periodic population censuses have become the primary source of data for child mortality. However, these data often have (sometimes substantial) sampling or non-sampling errors.17

The UN IGME web portal hosts the full set of empirical data. The 2015 update to the UN IGME database included more than 5700 new or updated country-year datapoints for USMR from more than 130 series. The database, as of July, 2015, contains 17000 country-year datapoints from more than 1500 series across 195 countries from 1990 (or earlier) to 2015.

We estimated USMR (the probability of dying before age 5 years) using the Bayesian B-spline bias-reduction model, referred to as the B3 model.17 This model was developed, validated, and used to produce previous rounds of the UN IGME child mortality estimates published in 201318 and 2014.19 In the B3 model, log(U5MR) is estimated with a flexible spline regression model (appendix pp 2–11). We fitted the spline regression model to all USMR observations (ie, country-year datapoints) in the country. An observed value for USMR is considered to be the true value for USMR multiplied by an error factor—ie, observed USMR = true USMR * error, or on the log-scale, log(observed USMR) = log(true USMR) + log(error), in which error refers to the relative difference between an observation and the true value. While estimating the true USMR, properties of the errors that provide information about the quality of the observation, or in other words, the extent of error that we expect, are taken into account. These properties include: the standard error of the observation (due to sampling) or its stochastic error (for vital registration data to capture the uncertainty in outcomes of random events), the type of data source (eg, Demographic and Health Survey vs census), the type of data collection method (eg, full or summary birth histories), the difference between the observation reference date and the survey time, and if the observation is part of a specific data series (and how consistent the data series is with other series with overlapping observation periods). These properties are summarised in the so-called data model (appendix pp 6–8 and Alkema and New17). When estimating the USMR, the data model accounts for the errors in empirical data (including the average systematic biases associated with different types of data sources), using information on data quality for different types of data sources from all countries in the world.

For countries with high-quality vital registration data, a variation of the B3 model is used to obtain the infant mortality rate (IMR; the probability of dying before age 1 year), whereby estimates are constructed for the logit transform of r—ie, log(r/(1−r)), where r is the ratio of the IMR to the median B3 estimates of USMR in the corresponding country-year. The transform is used to restrict the IMR to be lower than the USMR. For the remaining countries without high-quality vital registration data, the IMR is derived from the USMR through the use of model lifetables that contain known regularities in age patterns of child mortality.18

Given the inherent uncertainty in child mortality estimates, 90% uncertainty intervals (90% UIs) are used by the UN IGME instead of the more conventional 95% intervals. Although reporting intervals that are based on higher levels of uncertainty (ie, 95% instead of 90%) would reduce the chance of not including the true value in the interval, the disadvantage of choosing higher uncertainty levels is that intervals lose their use to...
### Panel: The five projection scenarios

In all scenarios, if a country reaches the current lowest U5MR observed among countries with more than 10 000 livebirths (2·3 deaths per 1000 livebirths in Finland), its U5MR will remain at that level for the remainder of the projection period. For countries with 10 000 livebirths or fewer that had a U5MR lower than 2·3 per 1000 livebirths in 2015 (Iceland and Luxembourg), the U5MR will remain at its current level for the projected years.

**Scenario one: no change from 2015 mortality rate**
For each country, the U5MR for 2015–30 is kept the same as the U5MR estimated for 2015.

**Scenario two: current trends**
For each country, the ARR for 2015–30 is equal to the estimated country-specific ARR from 2000 to 2015. If a country has a negative ARR in 2000–15 (ie, an increase in mortality rates in 2000–15), projections from scenario one are used (constant U5MR).

**Scenario three: best regional performer**
For each country, the ARR for 2015–30 is equal to the ARR from the best performing country in its respective region (with the highest ARR) for 2000–15. The top regional performers in 2000–15 were Belarus (CEE/CIS), Cambodia (east Asia and the Pacific), Estonia (other countries), Lebanon (Middle East and north Africa), Maldives (south Asia), Peru (Latin America and the Caribbean), Rwanda (eastern and southern Africa), and Senegal (west and central Africa).

**Scenario four: SDG target**
For each country, the U5MR in 2030 is equal to 6·8 deaths per 1000 livebirths and ARRs for 2015–30 are calculated on the basis of the country’s mortality level in 2015 and the SDG target. For countries that have already reached the target or are on track to reach the target before 2030 according to scenario two, projections from scenario two are used.

**Scenario five: average mortality rate of high-income countries by 2030**
Same projection strategy as in scenario four, except that the 2030 U5MR target is 6·8 deaths per 1000 livebirths—the average mortality rate in high-income countries as of 2015.

---

Present meaningful summaries of a range of likely outcomes when the indicator of interest is highly uncertain. Given this trade-off and the substantial uncertainty associated with child mortality estimates, the UN IGME chose to report 90% UIs, or, in other words, intervals for which there is a 90% chance that they contain the true value, to encourage wider use and interpretation of the UIs.

The number of estimated deaths was calculated using lifetable approaches, based on the estimated mortality rates, as well as estimates of population numbers by the UN Population Division. All results are presented with 90% UIs, which are constructed from the posterior samples of USMR by excluding 5% of the smallest and 5% of the largest samples. The resulting UIs are not necessarily symmetrical around the point estimates, but reflect the uncertainty range associated with the mortality rates. The UIs for the number of deaths generated by the UN IGME do not account for uncertainty associated with other inputs to its calculation, such as the population under the age of 5 years, because uncertainty assessments of these inputs are not yet available. The B3 model codes are available from the UN IGME on request.

In this round of estimation, the UN IGME generated mortality estimates for 195 countries from 1990 (or earlier) to 2015, depending on availability of empirical data for each country. Estimates are available for all countries from 1990 onwards and for 141 countries from 1970 onwards. Of the 54 countries for which estimates from 1970 are not available, 30 either have small populations or were founded in later years. The 141 countries with available estimates in 1970 account for 94% of the global under-5 population. To construct aggregate estimates of number of deaths from 1970 onwards, regional averages of mortality rates were used for country-years with missing information. If a country was established after 1990, we still generated estimates of USMR in the country starting in 1990. For the years before establishment, we recalculated USMR from empirical data for the territory that subsequently became a country if datasets were available. We then fitted the B3 model to these empirical data to derive trend estimates for the country from 1990.

### Scenarios for projections to 2030

We considered five different scenarios (panel) under which we project annual USMR and number of deaths from 2016 to 2030. Projections are based on either the USMR level for future years or the annual rate of reduction (ARR) in the USMR, which is defined as $ARR = \log(U5MR_{t2}/U5MR_{t1}) / (t_2 - t_1)$ where $t_1$ and $t_2$ refer to different years with $t_1 < t_2$.

We calculated the number of projected deaths using lifetable approaches, based on our projected mortality rates and estimates of projected population numbers by the UN Population Division from 2016 to 2030. The population numbers used to calculate the number of deaths are the same for each scenario. By comparing the numbers of deaths among different scenarios, the number of lives saved due to a faster mortality decline can be calculated. Changes in child mortality might result in some changes in child population. These changes were not taken into account in our projections to allow simple comparisons. Thus, the scenarios do not reflect the real number of lives saved, but rather the potential number of lives that would have been saved due to mortality declines if the child population in each country remains fixed at the median population numbers projected by the UN Population Division. Moreover, the projections rely on historical trends in mortality or were based on the ARR required to achieve specific targets in 2030. They did not take into account potential changes in intervention coverage and other factors associated with child mortality reduction.

### Role of the funding source

There was no funding source for this study. The corresponding author had full access to all the data in the
study and had final responsibility for the decision to submit for publication.

Results

In 2015, the global U5MR is 42·5 (90% UI 40·9–45·6) deaths per 1000 livebirths and the estimated number of under-5 deaths is 5·9 million (90% UI 5·6–6·4 million; table 1). In total, an estimated 236·3 million (233·7 million–240·2 million) children died before their fifth birthday between 1990 and 2015.

Wide disparities in mortality rates exist across regions (figure 1). West and central Africa continues to have the highest U5MR worldwide with a U5MR of 98·7 (90% UI 88·2–113·8) deaths per 1000 livebirths, almost 15 times higher than the average U5MR in high-income countries (6·8 deaths per 1000 livebirths). This region also accounts for a large share of the total number of under-5 deaths in the world—ie, 1·8 million deaths (1·6 million–2·1 million; 31%) of the deaths occurred in south Asia and 1·1 million (1·0 million–1·3 million; 18%) in eastern and southern Africa. At the country level, U5MR ranged from 156·9 (94·8–253·7) deaths per 1000 livebirths in Angola to 1·9 (1·3–2·6) in Luxembourg in 2015 (figure 2; appendix pp 15–23). All seven countries with a U5MR of more than 100 deaths per 1000 livebirths are in sub-Saharan Africa: Angola, Chad, Somalia, Central African Republic, Sierra Leone, Mali, and Nigeria.

### Table 1: Global and regional under-5 mortality rates and number of under-5 deaths, with 90% uncertainty intervals

<table>
<thead>
<tr>
<th>Region</th>
<th>Under-5 mortality rate (deaths per 1000 livebirths)</th>
<th>Number of under-5 deaths (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>144·9</td>
<td>90·6</td>
</tr>
<tr>
<td>By region</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Africa</td>
<td>240·4</td>
<td>164·1</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>244·3</td>
<td>180·2</td>
</tr>
<tr>
<td>Eastern and southern Africa</td>
<td>217·2</td>
<td>166·5</td>
</tr>
<tr>
<td>West and central Africa</td>
<td>275·5</td>
<td>198·4</td>
</tr>
<tr>
<td>Middle East and north Africa</td>
<td>199·5</td>
<td>71·0</td>
</tr>
<tr>
<td>Asia</td>
<td>153·7</td>
<td>90·3</td>
</tr>
<tr>
<td>South Asia</td>
<td>213·2</td>
<td>129·3</td>
</tr>
<tr>
<td>East Asia and the Pacific</td>
<td>116·4</td>
<td>58·3</td>
</tr>
<tr>
<td>Latin America and the Caribbean</td>
<td>119·6</td>
<td>57·9</td>
</tr>
<tr>
<td>CEE/CIS</td>
<td>96·6</td>
<td>47·6</td>
</tr>
<tr>
<td>Other countries</td>
<td>24·5</td>
<td>10·4</td>
</tr>
</tbody>
</table>

For regional classification, including a list of countries in “Other countries”, see appendix pp 12–13. Income group classification is from the World Bank (appendix pp 13–14). CEE/CIS=central and eastern Europe and Commonwealth of Independent States.
Substantial progress was made in reducing child mortality in the last four decades, with the global U5MR falling from 144.9 deaths per 1000 livebirths in 1970 to 42.5 in 2015 (table 1, figure 1). During the MDG period from 1990 to 2015, U5MR reduced by 53% (90% UI 50–55%) worldwide, and therefore missed the MDG 4
target of a two-thirds reduction. All regions in the world, based on the point estimates, have registered at least a 50% reduction in the U5MR since 1990 (table 1). Two regions—east Asia and the Pacific (69% reduction) and Latin America and the Caribbean (67% reduction)—achieved the MDG 4 target (table 1).

At the country level, 62 (32%) of 195 countries for which UN IGME produces estimates achieved the MDG 4 target based on point estimates. Among them, 12 are low-income countries (Cambodia, Ethiopia, Eritrea, Liberia, Madagascar, Malawi, Mozambique, Nepal, Niger, Rwanda, Uganda, and Tanzania) and another 12 are lower-middle-income countries (Armenia, Bangladesh, Bhutan, Bolivia, Egypt, El Salvador, Georgia, Indonesia, Kyrgyzstan, Nicaragua, Timor-Leste, and Yemen). An additional 74 countries reduced their U5MR by at least 50%, and another 41 countries by at least 30%. For a country to meet the MDG 4 target, the ARR in the U5MR between 1990 and 2015 needs to reach 4.4% or higher (equivalent to a two-thirds reduction in 25 years). Online (appendix pp 15–23 and pp 72–73) we provide detailed country information on the ARRs, including point estimates (which are used to assess the MDG 4 achievement) as well as 90% UIs of the ARRs, and the probability that a country achieved the MDG 4 target, which is the percentage of posterior samples with an ARR of 4.4% or higher. The UIs and probabilities quantify the uncertainty associated with the assessment related to MDG 4 achievements. This information allows for pinpointing countries that we are very certain about achievements in reductions in under-5 mortality.
Reductions in under-5 mortality have accelerated worldwide since 1990 (figure 3). The global U5MR dropped at an ARR of between 2% and 3% from 1970 to the early 1980s, but slowed during the 1980s and early 1990s. Slower progress in populous countries including China and Nigeria in the 1980s contributed to the decline in the global ARR in the 1980s. The acceleration in increases in child survival in China from around 1990, in

Nigeria since the mid-1990s, and in India from around 2000 contributed to the increasing global ARR since the early 1990s. The world reached an ARR of about 4% in the early 2000s and remained at that level for a decade. After 2010, the ARR is more uncertain for the world as well as for many regions. This is due to scarcity of empirical data in recent years. South Asia is the only region in which continued acceleration has occurred since 1970. Seven of the eight regions reached an ARR of more than 3% in 2000–15 (figure 3B).

At the country level, 102 (52%) of the 195 countries had a faster decline in 2000–15 than in 1990–2000 based on point estimates of the ARRs (appendix pp 15–23). Of the 49 sub-Saharan African countries, all but five (90%) had a higher ARR in the 2000–15 period than in the 1990s. Among these 49 countries, 21 (43%) countries reversed an increasing U5MR trend in 2000–15 compared with the 1990s or had an ARR over the past 15 years that is at least triple the rate that they achieved in the 1990s: Angola, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Congo (Brazzaville), Côte d’Ivoire, Gabon, Kenya, Lesotho, Mauritania, Namibia, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, Swaziland, Zambia, and Zimbabwe. Many of these countries had a rise in U5MR in the 1990s due to HIV and AIDS, but then reversed U5MR trends around 2000, partly because of efforts in HIV prevention and treatment. The estimates indicate that the accelerated progress globally since 2000 has saved about 18 million children—that is, 18 million children would not have survived to see their fifth birthday had the U5MR declined at the pace recorded in the 1990s.

Figure 4 and table 2 show the scenario-based projections of U5MR and the number of under-5 deaths in the world from 2015 to 2030. Under scenario one (no change from 2015 mortality rate), the global U5MR would be 47·2 deaths per 1000 livebirths and the number of deaths would be 6·6 million in 2030—both higher than the 2015 numbers. This rise is due to the growing number of births and under-5 population and a shift of the share of the population towards sub-Saharan Africa, particularly west and central Africa, within which the

![Figure 4: Projected global under-5 mortality rate and the number of under-5 deaths under various scenarios, 2015–30](image)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Projected under-5 mortality rate (deaths per 1000 livebirths)</th>
<th>Projected under-5 deaths (millions)</th>
<th>Projected total number of deaths (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1: No change from 2015 mortality rate</td>
<td>44·2</td>
<td>45·8</td>
<td>47·2</td>
</tr>
<tr>
<td>Scenario 2: Current trends</td>
<td>36·2</td>
<td>30·8</td>
<td>26·2</td>
</tr>
<tr>
<td>Scenario 3: Best regional performer</td>
<td>28·5</td>
<td>19·4</td>
<td>13·2</td>
</tr>
<tr>
<td>Scenario 4: SDG target</td>
<td>31·3</td>
<td>23·2</td>
<td>17·2</td>
</tr>
<tr>
<td>Scenario 5: Average mortality rate of HIC by 2030</td>
<td>21·6</td>
<td>11·3</td>
<td>6·1</td>
</tr>
</tbody>
</table>

SDG=sustainable development goal. HIC=high-income country.

Table 2: Projected global under-5 mortality rate and under-5 deaths under different scenarios
highest regional USMR persists. Under scenario one, 94.4 million children would die in 2016–30.

If all countries continue their current trends (ie, their average ARR in 2000–15; scenario two), the global USMR would be 26.2 deaths per 1000 livebirths in 2030, down from 42.5 in 2015 (a 38% reduction over 15 years). This would result in 68.8 million under-5 deaths over the next 15 years, with 3.6 million of them in the year 2030—substantial progress compared with scenario one.

Under scenario three (best regional performer scenario), if every country instead obtained the highest ARR achieved by the best performer in its region, the USMR would decline substantially faster, to 13.2 deaths per 1000 livebirths in 2030, and 49.4 million children would die worldwide in 2016–30.

Under SDG target scenario four, if every country in the world managed to reach the SDG target of 25 or fewer under-5 deaths per 1000 livebirths by 2030, the global USMR would fall to 17.2 deaths per 1000 livebirths, and 56.0 million children would die in the next 15 years—12.8 million fewer compared with the current trends scenario and 6.6 million more compared with the best regional performer scenario.

At present, 79 countries have a USMR that is higher than the SDG target of 25 per 1000 livebirths. Of these, 32 need to maintain their current rate of progress but 47 need to accelerate progress to achieve the SDG target (figure 5). Of these 47 countries, 21 are in west and central Africa, 11 in eastern and southern Africa, and two in south Asia. 11 countries (Afghanistan, Angola, Central African Republic, Chad, Comoros, Benin, Kiribati, Lesotho, Mauritania, Pakistan, and Somalia) will need to at least triple their rate of reduction to meet the SDG target while a further 19 will need to make progress at between two and three times the current pace. Among all low-income countries, 68% need to accelerate progress. The proportion drops to 38% among lower-middle-income countries and 10% among upper-middle-income countries.

More ambitiously, if every country in the world managed by 2030 to reduce its USMR to the average of that in high-income countries (ie, scenario five), the global USMR would then be as low as 6.1 deaths per 1000 livebirths and the total number of under-5 deaths would be 35.4 million in 2016–30 (table 2).

Discussion

Remarkable progress has been made worldwide to improve child survival over the past 25 years. The global USMR declined by 53% and the number of under-5 deaths dropped from 236.3 million in 1990 to 53.4 million in 2015. All regions have reduced their USMR at least by half and progress has accelerated worldwide: the global ARR has steadily doubled. In sub-Saharan Africa (the region with the highest USMR in the world) the ARR increased from 1.6% in the 1990s to 4.1% in 2000–15. The recent trend is especially encouraging in eastern and southern Africa, which had an average ARR of almost 5% in 2000–15.

The under-5 mortality estimates indicate that in 2000–15, about 48 million more children survived to age 5 years that would not have done so had the USMR remained at the level estimated for the year 2000. About 37 million of these averted deaths are from the period 2000–13. This estimate is similar to that from the study by Murray and Chambers20 who concluded that more than 34 million children’s lives have been saved in 2000–13 because of investments in child health programmes. Moreover, our estimates show that 18 million of the additional 48 million lives saved were attributable to the acceleration in progress since 2000; most of these children (70%) live in sub-Saharan Africa.

Despite substantial gains in reducing mortality, progress has been insufficient to achieve MDG 4. The 53% decline in the USMR globally is far from the two-thirds reduction needed to meet the MDG 4 target. If current trends continue, the MDG 4 target worldwide would be reached by 2026—more than 10 years behind schedule. The toll of under-5 deaths over the past two decades is large: between 1990 and 2015, an estimated 236.3 million (233.7 million–240.2 million) children worldwide died before their fifth birthday—more than today’s population of Brazil, the fifth most populous country. The UN IGME estimates show that had the...
necessary steady progress been made since 2000 to achieve the MDG 4 target, 14 million more children would have survived to age 5 years since 2000.16

Child survival remains an urgent concern. It is unacceptable that about 16,000 children still die every day, equivalent to 11 deaths every 1 min. Without any acceleration in the pace of reduction in child mortality (projection according to scenario two), 68.8 million children would die before they reach their fifth birthday in the next 15 years, with 3.6 million of these lives lost in the year 2030 alone. These results correspond to the findings from the study by Wang and coauthors17 who projected that 3.8 million children could be expected to die in 2030 if the present rates of change continue according to the UN Population Division fertility projections. These numbers are unacceptably high. For countries that have made very rapid progress since 2000 (eg, Rwanda, Estonia, Cambodia, and China), simply maintaining the current rate of reduction would be remarkable and these countries might need even more investment to do so. The alternative projections indicated what would occur in different scenarios, and resulted in projections of cumulative deaths ranging from 94.4 million (under scenario one: no change from 2015 mortality rate) to the hypothetical best case scenario of 35.4 million if all mortality would drop to the current average U5MR in high-income countries by 2030. The SDG target scenario resulted in a projection of 56.0 million deaths by 2030 and would require an acceleration of progress for most sub-Saharan Africa countries.

Sub-Saharan Africa currently remains the region with the highest U5MR, with one in 12 children dying before his or her fifth birthday. If current trends continue, 37 million children in sub-Saharan Africa would die in the next 15 years, accounting for 53% of the 68.8 million deaths under scenario two. In 2030, around six in ten global under-5 deaths would occur in sub-Saharan Africa. To achieve the U5MR SDG target, 34 sub-Saharan Africa countries need to accelerate progress. In addition, extended efforts are needed to provide the services and interventions necessary to meet the additional demand generated by a growing number of livebirths and child population in this region—there is a 95% probability that the number of children under 5 years will grow by an extra 26–57 million (with a median of 42 million), from 157 million in 2015 to 183–214 million in 2030.18 Hence, sub-Saharan Africa faces unique challenges in reducing the number of child deaths. The number of under-5 deaths in this region might increase or remain stagnant even with a declining U5MR if the decline in mortality rate does not outpace the increase in population, as observed in the 1990s (figure I). South Asia is another region in which acceleration in reducing child mortality is urgently needed. The current average U5MR in this region is still high (52.5 deaths per 1000 livebirths in 2015). Three in ten global under-5 deaths occur in south Asia. Two out of the eight countries in this region, Afghanistan and Pakistan, need to accelerate progress to achieve the USMR SDG target.

The enormous progress in child survival in the 24 low-income and lower-middle-income countries that met the MDG 4 target (Armenia, Bangladesh, Bhutan, Bolivia, Cambodia, Egypt, El Salvador, Ethiopia, Eritrea, Georgia, Indonesia, Kyrgyzstan, Liberia, Madagascar, Malawi, Mozambique, Nepal, Nicaragua, Niger, Rwanda, Timor-Leste, Uganda, Tanzania, and Yemen), and the recent acceleration in ARR in many sub-Saharan African countries suggests that child mortality can decline rapidly, even in poor countries, if the political will and resources exist to maintain long-term focus. In-depth country studies similar to the Countdown country case study22–23 and the Success Factors studies by the Partnership for Maternal, Newborn, and Child Health, WHO, World Bank, and Alliance for Health Policy and Systems Research24 are needed to provide insights on success factors in improvements in child survival and to provide evidence on strategies that can be used to accelerate progress to achieve the SDG target.

Of 195 countries with available estimates, 116 (59%) have already achieved the SDG target with a U5MR of 25 or fewer deaths per 1000 livebirths. Of low-mortality countries that achieved this target, a third have a U5MR that is below five deaths per 1000 livebirths, and 16 still have a U5MR higher than 20. If current trends continue, 44 of these low-mortality countries are not expected to reach the current average U5MR in high-income countries by 2030, and about 6 million children will die in these 116 countries between 2016 and 2030. By contrast, if all these countries, by 2016, reduced their U5MR to the current lowest level of 2.3 deaths per 1000 livebirths observed among countries with more than 10,000 livebirths in 2015, an additional 4 million children would be saved. This means there is still work to be done in improving child survival, even within this group of countries.

Wide gaps in child mortality within countries have been documented in this group of low-mortality countries. For example, Brazil is one of the countries that succeeded in greatly reducing child mortality. The country as a whole has met MDG 4—the U5MR in Brazil declined from 60.8 (90% UI 56.3–65.6) in 1990 to 16.4 (15.5–17.3) in 2015, a 73% reduction. Brazil also managed to reduce regional inequities in child mortality in the past 25 years,19 but disparities still persist. Although more than 1000 of roughly 5500 municipalities had a U5MR of fewer than five deaths per 1000 livebirths in 2013, in 32 municipalities the U5MR exceeded 80 deaths per 1000 livebirths. In addition, Indigenous children are twice as likely to die before reaching their first birthday than other Brazilian children.20 In the USA, a child born in Mississippi is more than twice as likely to die before the age of 1 year than is a child living in Iowa and Massachusetts.21 These examples show that for countries with relatively low mortality, greater efforts to reduce disparities at the subnational level and across different
groups are needed to achieve equity in child survival and lower mortality overall.

Improvements in data availability and advances in analytical methods over the past two decades have greatly expanded knowledge of child mortality rates and trends in the world. Accurate measurement of child mortality is, however, still challenging because of the poor availability of high-quality data in many low-income and middle-income countries. Only about 60 countries have fully functioning and complete civil registration systems, which can be relied on as a single source to produce reliable mortality estimates over time. Household surveys are the main data sources for most low-income and middle-income countries. For these countries, mortality estimates are affected by biases and sampling errors, and are typically not timely (about 40 countries do not have child mortality data sources for 2011 onwards). Hence, a limitation of our study is that for countries and regions that have recently intensified interventions and investments to reduce their USMR but do not have recent data, the true decline over the past 5 years might be greater than we estimate. Estimation of cause-specific mortality is even more hindered by data limitations because fewer than 3% of the global causes of under-5 deaths are medically certified. Longer term, improved monitoring of child mortality requires the development of complete and accurate civil registration systems in low-income and middle-income countries to gather accurate, timely, disaggregated data that can inform evidence-based decision making, programming, and planning. In the short term, we will have to continue using child mortality data from household surveys. In that context, the next 2020 round of censuses will be crucial sources of updated sampling frames for nationally representative household surveys.

To conclude, despite substantial progress in reducing child mortality since 1990, MDG 4 was not met worldwide and the unfinished business of child survival looms large. Every child’s death represents the loss of a unique human being. Countries and the international community must take immediate action to accelerate further the pace of progress to fulfil children’s rights to health and development. Without intensified efforts to reduce child mortality, particularly in the highest mortality areas and in contexts with persistent inequities, the post-2015 SDG target will be unattainable. Child survival must remain at the heart of the SDG agenda.

Contributors
DY and LA conceived the study and provided overall guidance to the study. DY, LH, and SE prepared the first draft. All other authors reviewed results and provided inputs and comments to the Article.

Declaration of interests
We declare no competing interests.

Acknowledgments
We thank Monica Alexander, Fengqing Chao, and Jing Liu for their assistance in the estimation process of the child mortality rates. Thanks to Wahyu Retno Mahanani for assistance to the country consultation process, to Emi Suzuki for her support to the UN IGME work, and to Jan Beise, Lijuan Kang, and Colleen Murray for help in checking numbers. Special thanks to members of the Technical Advisory Group of the UN IGME (Robert Black, Leontine Alkema, Simon Cousens, Trevor Croft, Michel Guillot, Kenneth Hill, Bruno Masquelier, Jon Pedersen, and Neff Walker) for providing technical guidance on child mortality estimation. The content of this article is solely the responsibility of the authors and does not necessarily represent the official views of UNICEF or those of the institutions to which the authors are affiliated (UNICEF, World Health Organization, United Nations, University of California, and University of Massachusetts, Amherst).

References