

Annual rates of decline in child, maternal, HIV, and tuberculosis mortality across 109 countries of low and middle income from 1990 to 2013: an assessment of the feasibility of post-2015 goals

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Summary

Background Measuring a country's health performance has focused mostly on estimating levels of mortality. An alternative is to measure rates of decline in mortality, which are more sensitive to changes in health policy than are mortality levels. Historical rates of decline in mortality can also help test the feasibility of future health goals (eg, post-2015). We aimed to assess the annual rates of decline in under-5, maternal, tuberculosis, and HIV mortality over the past two decades for 109 low-income and middle-income countries.

Methods For the period 1990–2013, we estimated annual rates of decline in under-5 mortality (deaths per 1000 livebirths), the maternal mortality ratio (deaths per 100 000 livebirths), and tuberculosis and HIV mortality (deaths per 100 000 population per year) using published data from UNICEF and WHO. For every 5-year interval (eg, 1990–95), we defined performance as the size of the annual rate of decline for every mortality indicator. Subsequently, we tested the feasibility of post-2015 goals by estimating the year by which countries would achieve 2030 targets proposed by *The Lancet's* Commission on Investing in Health (ie, 20 deaths per 1000 for under-5 mortality, 94 deaths per 100 000 for maternal mortality, four deaths per 100 000 for tuberculosis mortality, and eight deaths per 100 000 for HIV mortality) at observed country and aspirational best-performer (90th percentile) rates.

Findings From 2005 to 2013, the mean annual rate of decline in under-5 mortality was 4·3% (95% uncertainty interval [UI] 3·9–4·6), for maternal mortality it was 3·3% (2·5–4·1), for tuberculosis mortality 4·1% (2·8–5·4), and for HIV mortality 2·2% (0·1–4·3); aspirational best-performer rates per year were 7·1% (6·8–7·5), 6·3% (5·5–7·1), 12·8% (11·5–14·1), and 15·3% (13·2–17·4), respectively. The top two country performers were Macedonia and South Africa for under-5 mortality, Belarus and Bulgaria for maternal mortality, Uzbekistan and Macedonia for tuberculosis mortality, and Namibia and Rwanda for HIV mortality. At aspirational rates of decline, *The Lancet's* Commission on Investing in Health target for under-5 mortality would be achieved by 50–64% of countries, 35–41% of countries would achieve the 2030 target for maternal mortality, 74–90% of countries would meet the goal for tuberculosis mortality, and 66–82% of countries would achieve the target for HIV mortality.

Interpretation Historical rates of decline can help define realistic targets for Sustainable Development Goals. The gap between targets and projected achievement based on recent trends suggests that countries and the international community must seek further acceleration of progress in mortality.

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Introduction

Assessing a country's health performance is difficult. Across and within countries, policies can affect population health directly or indirectly and might vary substantially in scope and delivery. This diversity and complexity challenges our understanding of the systemic causes of success or failure and, ultimately, limits cross-country comparability.¹

A country's performance in health is typically defined by how much better or worse it is faring with respect to a selected outcome (eg, life expectancy) compared with what would be expected in view of selected contextual attributes (eg, income and education).² In the Good

Health at Low Cost study,³ an attempt was made to assess country performances in levels of mortality; a case-study approach was used to examine why three countries and one Indian state had low mortality levels despite scant resources. Later analyses also quantified performance with respect to levels of mortality and fertility.⁴

Numbers of deaths are affected strongly by longstanding country-level determinants. Essentially, a country that starts with a low level of mortality is likely to persist with fewer deaths, whereas a country that begins at a high level might improve substantially but still have comparatively higher mortality. Thinking about alterations in the number of deaths or annual rates of

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See [Comment](#) page e673

See Online for an audio
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change in mortality is useful for understanding how a country's health performance might relate to adjustments in policy. Most published work on country performance focuses on estimates for mortality levels, but some studies are beginning to emerge in which rates of change are investigated.⁵⁻¹³ To the extent that rates of change are responsive to the introduction of health policies (eg, a new immunisation programme), rates of decline in mortality offer a dependent variable to understand the effect on performance of social and system determinants. Nevertheless, rates of change—like any one-dimensional metric—still present weaknesses. Notably, large declines from high levels of mortality will still lead to an unacceptably large number of deaths. Therefore, rates of change complement rather than replace the important information conveyed by estimates of mortality levels.

The need to measure progress in health has been especially apparent in relation to assessing whether countries are on track to achieve the Millennium Development Goals.¹⁰⁻¹³ Measuring progress will also be crucial to ascertain whether countries can achieve the next set of post-2015 Sustainable Development Goals, which are ready to be adopted by UN member states in 2015. The Sustainable Development Goals are likely to include one health goal with an associated set of targets; several proposals are under discussion.¹⁴ *The Lancet's* Commission on Investing in Health proposed the target of achieving a “grand convergence in global health” by 2035, defined as cutting infectious, maternal, and child deaths to universally low levels (eg, those seen today in the best-performing middle-income countries such as Chile and Turkey).¹⁵ Other targets have been proposed by the Global Investment Framework for Women's and Children's Health,¹⁶ UNICEF,¹⁷ the Sustainable

Development Solutions Network,¹⁸ and the High-Level Panel on the post-2015 development agenda¹⁹ (table 1). An intergovernmental open working group recently published a draft of the Sustainable Development Goals.²⁰ Over the next year, these will be debated by all UN member states and might undergo revision, before adoption in September, 2015.

Studying historical rates of change (rates of decline) in mortality across countries over recent decades can be helpful to test the feasibility of these different proposals, many of which include very ambitious targets for child, maternal, tuberculosis, and HIV mortality that would require high rates of decline from 2015 to 2030 (the probable end date for the Sustainable Development Goals). Such targets for mortality can be reality-tested by looking at whether high rates of decline in mortality have ever been achieved by any low-income or middle-income country and could be reproduced for the period 2015–30, to enable such ambitious mortality goals to be achieved.

Assessment of a country's health performance with respect to changes in rates of decline in mortality is, therefore, valuable when studying the effects of policy and for testing the feasibility of proposed post-2015 health goals. We aimed to examine the change in the annual rate of decline of key mortality indicators for 109 low-income and middle-income countries over the period 1990–2013.

Methods

For our analysis, we selected four indicators that were almost always listed among proposals for post-2015 health targets (table 1): under-5 mortality, maternal mortality, tuberculosis mortality, and HIV mortality. For this reason, we did not select malaria and diarrhoea

	<i>The Lancet</i> Commission on Investing in Health ¹⁵	Global Investment Framework for Women's and Children's Health ¹⁶	UNICEF ¹⁷	Sustainable Development Solutions Network ¹⁸	High-Level Panel of eminent persons on the post-2015 development agenda ¹⁹
Timeframe	2035	2035	2035	2030	2030
Under-5 mortality (deaths per 1000 livebirths)	16 (interim target of 20 by 2030)	39 in low-income countries, 22 in low-to-middle-income countries	≤20	≤20	≤20
Maternal mortality ratio (deaths per 100 000 livebirths)	83 (interim target of 94 by 2030)	161 in low-income countries, 103 in low-to-middle-income countries	Eliminate all preventable maternal deaths	≤40	40
Tuberculosis deaths (per 100 000 population per year)	4	No targets given	No targets given	Recommends that “countries adopt suitably updated MDG indicators for HIV/AIDS, tuberculosis, and malaria”	“Decrease the burden of disease from HIV/AIDS, tuberculosis, and malaria” (no numerical targets given)
HIV/AIDS deaths (per 100 000 population per year)	8	No targets given	No targets given	Recommends that “countries adopt suitably updated MDG indicators for HIV/AIDS, tuberculosis, and malaria”	“Decrease the burden of disease from HIV/AIDS, tuberculosis, and malaria” (no numerical targets given)

MDG=Millennium Development Goal. *The post-2015 Sustainable Development Goals are being drafted by an intergovernmental open working group.²⁰

Table 1: Selected proposals for post-2015 global health targets

mortality (incidentally, these indicators are encompassed largely within under-5 mortality) or infectious disease mortality more generally. In some regions (eg, southern Africa), HIV and tuberculosis mortality correlate highly, whereas in others (eg, north Africa and the Middle East), these infectious diseases are not major causes of death. We assessed the rates of decline in the four chosen mortality indicators for 109 low-income and middle-income countries (as defined by the World Bank)²¹ with populations greater than 1 million people.²² The appendix (p 1) lists the countries included in the analysis.

We estimated rates of decline in under-5 mortality (ie, the number of children who die after birth before age 5 years) per 1000 livebirths, the maternal mortality ratio (ie, the number of pregnant women who die) per 100 000 livebirths, tuberculosis mortality (ie, the number of deaths from tuberculosis) per 100 000 population per year, and HIV mortality (ie, the number of HIV-related deaths) per 100 000 population per year. Owing to availability of data, we used a 1992–2012 time series for under-5 mortality²³ and tuberculosis mortality,²⁴ a 1990–2013 time series for the maternal mortality ratio,²⁵ and a 2000–10 time series for HIV mortality.²⁶ We used several time anchor-points for every indicator: 1992, 1997, 2002, 2007, and 2012 for under-5 mortality and tuberculosis mortality; 1990, 1995, 2000, 2005, and 2013 for the maternal mortality ratio; and 2000, 2005, and 2010 for HIV mortality. Thus, our calculations differ from annualised rates of reduction computed using different timeframes. We calculated 95% uncertainty intervals [UIs] around estimates. We used *R* software for all analyses.

We calculated the annual rate of decline from levels of every indicator for every 5-year interval from 1990 to 2013 (figure 1A). In total, we have either two or four estimates for the annual rate of decline for every country: 1992–97, 1997–2002, 2002–07, and 2007–12 for under-5 mortality and tuberculosis mortality; 1990–95, 1995–2000, 2000–05, and 2005–13 for the maternal mortality ratio; and 2000–05 and 2005–10 for HIV mortality. Note that estimates are mostly taken 5 years apart because of estimate availability^{23–26} and for consistency, with the exception of the last increment for maternal mortality, which is over an 8-year period.

We calculated the annual rate of change in the annual rate of decline (either an acceleration or deceleration) for every transition from one 5-year interval to the next, from 1990 to 2013 (figure 1B). In total, we have three values for the rate of change in the rate of decline for every country for under-5 mortality and tuberculosis mortality (1992–97 to 1997–2002, 1997–2002 to 2002–07, and 2002–07 to 2007–12); likewise, we have three estimates corresponding to three transitions for the maternal mortality ratio (1990–95 to 1995–2000, 1995–2000 to 2000–05, and 2000–05 to 2005–13). For HIV mortality, we have only one value (2000–05 to 2005–10). Note that we use the rates of decline from two consecutive 5-year intervals (eg, 1995–2000 and 2000–05) to estimate a rate of change

A Annual rate of change in the level of a selected indicator

$$R(t) = \frac{[L(t+5) - L(t)]}{5L(t)}$$

B Rate of change in the annual rate of change in the level of a selected indicator

$$RCR(t) = \frac{[R(t+5) - R(t)]}{5R(t)}$$

C Number of years to reach a specific target

$$y = \frac{[\ln(T) - \ln(L)]}{R}$$

See Online for appendix

Figure 1: Calculations

(A) $L(t)$ represents the level of a selected indicator—eg under-5 mortality rate—in a given country at time t . We calculated the annual rate of change of $L(t)$, denoted $R(t)$. The denominator 5 corresponds to the 5-year interval in the numerator. Although we generally used 5-year time intervals, occasionally it was appropriate to use a different interval; we have noted these cases in the report and made the appropriate adjustments. (B) Periods of rapid improvements (or worsening) of $R(t)$ are also of policy interest. We calculated $RCR(t)$, the rate of change in $R(t)$. (C) Given a rate of change, R , in an indicator from its initial level, L , we also calculated the number of years, y , it would take to reach a target T —eg, a target under-5 mortality rate of 20 per 1000 livebirths.

in the rate of decline for the transition between those two intervals. When estimates are available, we could analyse continuously a country's rate of decline per year and annual rate of change in the rate of decline. Such an analysis could point to rapid changes over short periods, and whether acceleration or deceleration takes place that is worthy of subsequent assessment. However, annual estimates are only available for under-5 mortality (appendix p 2). Therefore, for the sake of reporting consistency, we present findings in 5-year intervals, which also enables clear and concise interpretation of results.

For every mortality indicator, we estimated the year by which *The Lancet's* Commission on Investing in Health target¹⁵ would be achieved (figure 1C). We obtained estimates for every country's latest rates of decline, aspirational best-performer rates of decline (ie, the 90th percentile for all countries of rates of decline), and aspirational rates of decline at the regional level (ie, 90th percentile for regional rates of decline). The list of regions is presented in the appendix (p 1).

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The funder had no role in study design, data collection, data analysis, data interpretation, or writing of the report. All authors had full access to all data in the paper and SV and DTJ had final responsibility for the decision to submit for publication.

Results

Tables 2 to 5 show the rates of decline in mortality indicators and highlight the best and worst country performers (top-five and bottom-five rates of decline). For under-5 mortality and maternal mortality, the distribution of rates of decline among the 109 low-income and middle-income countries is narrow (appendix p 3) and becomes narrower in the most recent period (2007–12 and 2005–13,

2007–12		2002–07		1997–2002		1992–97		
Country	Rate of decline per year (95% UI)	Country	Rate of decline per year (95% UI)	Country	Rate of decline per year (95% UI)	Country	Rate of decline per year (95% UI)	
Best performers								
1	Macedonia	10.3% (10.0 to 10.7)	Rwanda	11.7% (11.3 to 12.1)	Turkey	8.1% (7.6 to 8.6)	Macedonia	10.8% (10.2 to 11.4)
2	South Africa	9.7% (9.4 to 10.1)	Cambodia	10.4% (10.0 to 10.8)	Belarus	8.1% (7.6 to 8.6)	Serbia	9.3% (8.7 to 9.9)
3	Rwanda	8.6% (8.2 to 9.0)	Turkey	9.3% (8.9 to 9.7)	Peru	7.3% (6.8 to 7.8)	Peru	7.0% (6.4 to 7.6)
4	Belarus	8.4% (8.0 to 8.7)	China	9.1% (8.7 to 9.5)	Egypt	7.3% (6.8 to 7.8)	Turkey	6.5% (5.9 to 7.1)
5	Kazakhstan	8.2% (7.9 to 8.6)	Liberia	8.3% (7.9 to 8.7)	Brazil	7.2% (6.7 to 7.7)	Egypt	6.4% (5.8 to 7.0)
Worst performers								
1	Malaysia	-1.0% (-1.3 to -0.6)	Lesotho	-0.2% (-0.6 to 0.2)	Swaziland	-4.2% (-4.7 to -3.7)	Botswana	-7.3% (-7.9 to -6.7)
2	Costa Rica	1.0% (0.6 to 1.3)	Mauritius	-0.1% (-0.5 to 0.3)	South Africa	-4.1% (-4.6 to -3.6)	Swaziland	-7.0% (-7.6 to -6.4)
3	Vietnam	1.3% (0.9 to 1.6)	Somalia	0.3% (-0.1 to 0.7)	Botswana	-3.4% (-3.9 to -2.9)	Rwanda	-5.6% (-6.2 to -5.0)
4	Zimbabwe	1.3% (1.0 to 1.7)	DRC	0.4% (0.0 to 0.8)	Lesotho	-3.3% (-3.8 to -2.8)	Zimbabwe	-4.3% (-4.9 to -3.7)
5	Mauritius	1.4% (1.1 to 1.8)	Zimbabwe	0.8% (0.4 to 1.2)	Namibia	-1.1% (-1.6 to -0.6)	Lesotho	-3.6% (-4.2 to -3.0)

UI=uncertainty interval.

Table 2: Top-five and bottom-five country performers in rate of decline of under-5 mortality, 1992–2012

2005–13		2000–05		1995–2000		1990–95		
Country	Rate of decline per year (95% UI)	Country	Rate of decline per year (95% UI)	Country	Rate of decline per year (95% UI)	Country	Rate of decline per year (95% UI)	
Best performers								
1	Belarus	38.1% (37.3 to 38.9)	Bulgaria	14.6% (14.0 to 15.2)	Serbia	21.0% (20.1 to 21.9)	Romania	17.2% (16.5 to 17.9)
2	Bulgaria	12.9% (12.1 to 13.7)	Romania	11.4% (10.8 to 12.0)	Mauritius	17.7% (16.8 to 18.6)	Suriname	15.3% (14.6 to 16.0)
3	Macedonia	8.7% (7.9 to 9.6)	Cambodia	10.5% (9.9 to 11.1)	Hungary	16% (15.8 to 17.6)	Eritrea	10.6% (9.9 to 11.3)
4	Botswana	8.7% (7.9 to 9.6)	Rwanda	9.9% (9.3 to 10.5)	Cambodia	9.3% (8.4 to 10.2)	Honduras	7.4% (6.7 to 8.1)
5	Kazakhstan	8.2% (7.4 to 9.0)	Azerbaijan	9.2% (8.6 to 9.8)	Moldova	8.3% (7.4 to 9.2)	Cambodia	6.7% (6.0 to 7.4)
Worst performers								
1	Mauritius	-9.2% (-10.0 to -8.4)	Hungary	-5.2% (-5.8 to -4.6)	Suriname	-22.5% (-23.4 to -21.6)	Tajikistan	-11.4% (-12.1 to -10.7)
2	Serbia	-8.7% (-9.6 to -7.9)	Mauritius	-4.5% (-5.1 to -3.9)	Colombia	-9.5% (-10.4 to -8.6)	Sri Lanka	-7.4% (-8.1 to -6.7)
3	Cuba	-2.2% (-3.0 to -1.4)	Serbia	-2.7% (-3.3 to -2.1)	Bulgaria	-5.5% (-6.4 to -4.6)	Kyrgyzstan	-6.9% (-7.6 to -6.2)
4	Suriname	-2.1% (-2.9 to -1.3)	Côte d'Ivoire	-2.3% (-2.9 to -1.7)	Zimbabwe	-4.2% (-5.1 to -3.3)	Azerbaijan	-6.5% (-7.2 to -5.8)
5	Venezuela	-2.0% (-2.8 to -1.2)	Argentina	-2.1% (-2.7 to -1.5)	Macedonia	-2.9% (-3.8 to -2.0)	Georgia	-5.9% (-6.6 to -5.2)

UI=uncertainty interval.

Table 3: Top-five and bottom-five country performers in rate of decline of maternal mortality, 1990–2013

respectively); notably, several countries had very high or low rates of decline in maternal mortality. For under-5 mortality, in 2007–12, the mean rate of decline was 4.3% per year (95% UI 3.9–4.6); the aspirational rate was 7.1% per year (6.8–7.5) with some variation across regions (6.4% [5.4–7.4] for Asia east and south, 7.5% [6.9–8.1] for sub-Saharan Africa, 5.5% [4.8–6.2] for north Africa and the Middle East, 8.3% [7.3–9.2] for eastern Europe and central Asia, and 5.0% [4.4–5.6] for Latin America and the Caribbean). The top two performers between 2007 and 2012 were Macedonia and South Africa, with rates of 10.3% and 9.7% per year, respectively (table 2). Between 1992 and 2002, for under-5 mortality, countries with the lowest performance had negative rates of decline (ie, mortality increased) and were largely in southern Africa. Some countries (eg, Turkey in 1992–2007)

maintained very high rates of decline in under-5 mortality, above 6.0% per year.

For the maternal mortality ratio, in 2005–13, the mean rate of decline was 3.3% per year (95% UI 2.5–4.1); the aspirational rate was 6.3% per year (5.5–7.1) with some variation across regions (7.6% [6.7–8.6] for Asia east and south, 6.1% [5.3–6.9] for sub-Saharan Africa, 4.0% [3.2–4.8] for north Africa and the Middle East, 9.9% [5.6–14.3] for eastern Europe and central Asia, and 3.3% [2.5–4.1] for Latin America and the Caribbean). The top performers in 2005–13 were Belarus and Bulgaria, with rates of 38.1% and 12.9% per year (table 3). In 1990–95, four of the five worst performers were in central Asia with large negative rates, below -5.0% per year. For 1990–2005, Cambodia maintained very high rates, above 6.0% per year.

2007–12			2002–07		1997–2002		1992–97	
Country	Rate of decline per year (95% UI)		Country	Rate of decline per year (95% UI)	Country	Rate of decline per year (95% UI)	Country	Rate of decline per year (95% UI)
Best performers								
1	Uzbekistan	31.2% (29.9 to 32.5)	Azerbaijan	29.1% (28.1 to 30.1)	Mauritius	21.5% (20.4 to 22.6)	Costa Rica	17.8% (16.4 to 19.2)
2	Macedonia	24.6% (23.3 to 25.9)	Costa Rica	15.7% (14.7 to 16.7)	Cuba	17.3% (16.2 to 17.4)	Suriname	17.4% (16.0 to 18.8)
3	Kazakhstan	19.8% (18.5 to 21.1)	Rwanda	15.7% (14.7 to 16.7)	Rwanda	15.0% (13.9 to 16.1)	Venezuela	14.4% (13.0 to 15.8)
4	Ecuador	17.3% (16.0 to 18.6)	Turkey	13.9% (12.9 to 14.9)	Botswana	12.8% (11.7 to 13.9)	Mexico	13.4% (12.0 to 14.8)
5	Turkmenistan	16.3% (15.0 to 17.6)	Hungary	13.1% (11.1 to 14.1)	Hungary	11.1% (10.0 to 12.2)	Macedonia	10.8% (9.4 to 12.2)
Worst performers								
1	Swaziland	-12.3% (-13.6 to -11.0)	Zimbabwe	-11.5% (-12.5 to -10.5)	Namibia	-14.6% (-15.7 to -13.5)	Kazakhstan	-22.8% (-24.2 to -21.4)
2	Lesotho	-10.6% (-11.9 to -9.3)	Sierra Leone	-11.3% (-12.3 to -10.3)	South Africa	-10.1% (-11.2 to -9.0)	Namibia	-18.0% (-19.4 to -16.6)
3	Libya	-9.6% (-10.9 to -8.3)	Mauritius	-7.7% (-8.7 to -6.7)	Sierra Leone	-8.4% (-9.5 to -7.3)	Tajikistan	-12.3% (-13.7 to -10.9)
4	Suriname	-8.5% (-9.8 to -7.2)	Mauritania	-4.2% (-5.2 to -3.2)	Kenya	-7.7% (-8.8 to -6.6)	Cameroon	-11.5% (-12.9 to -10.1)
5	Angola	-8.1% (-9.4 to -6.8)	Suriname	-3.9% (-4.9 to -2.9)	Belarus	-7.4% (-8.5 to -6.3)	Uzbekistan	-10.9% (-12.3 to -9.5)

UI=uncertainty interval.

Table 4: Top-five and bottom-five country performers in rate of decline of tuberculosis mortality, 1992–2012

Contrary to under-5 mortality and the maternal mortality ratio, for tuberculosis mortality, the distribution of rates of decline is wider and shows little change over time (appendix p 3). During 2007–12, the mean rate of decline was 4.1% per year (95% UI 2.8–5.4); the aspirational rate was 12.8% per year (11.5–14.1) with substantial variation across regions (6.9% [5.6–8.2] for Asia east and south, 9.4% [7.6–11.2] for sub-Saharan Africa, 13.5% [9.2–17.8] for north Africa and the Middle East, 21.7% [17.4–26.0] for eastern Europe and central Asia, and 9.4% [6.7–12.1] for Latin America and the Caribbean). The best country performances in 2007–12 were in Uzbekistan and Macedonia, with rates of 31.2% and 24.6% per year, respectively (table 4). During 1992–97, three of the five lowest performers were in central Asia, with negative rates larger than -10.0% per year. In 1997–2007, Rwanda maintained very high rates of decline of tuberculosis mortality, higher than 15.0% per year.

For HIV mortality, the distribution of rates is rather uniform (appendix p 3). During 2005–10, the mean rate of decline was 2.2% per year (95% UI 0.1–4.3); the aspirational rate was 15.3% per year (13.2–17.4) with important variation across regions (12.8% [6.2–19.3] for Asia east and south, 16.4% [13.9–18.8] for sub-Saharan Africa, 6.9% [0.2–13.7] for north Africa and the Middle East, 10.6% [6.3–14.9] for eastern Europe and central Asia, and 15.7% [12.3–19.1] for Latin America and the Caribbean). Four of the best country performances were in sub-Saharan Africa, with rates higher than 17.0% per year (table 5).

The rate of change in the rate of decline enables identification of rapid transitions in performance over time (tables 6 to 9). For example, in sub-Saharan African countries (eg, Botswana), accelerated improvements have been seen in under-5 mortality from 1997–2002 to 2002–07 (table 6). Likewise, eastern European and central Asian countries (eg, Azerbaijan) have seen accelerated

2005–10		2000–05		
Country	Rate of decline per year (95% UI)	Country	Rate of decline per year (95% UI)	
Best performers				
1	Namibia	22.8% (20.7 to 24.9)	Hungary	18.0% (15.4 to 20.6)
2	Rwanda	22.5% (20.4 to 24.6)	Romania	14.3% (11.7 to 16.9)
3	Burkina Faso	17.7% (15.6 to 19.8)	Serbia	12.0% (9.4 to 14.6)
4	Botswana	17.2% (15.1 to 19.3)	Uganda	10.6% (8.0 to 13.2)
5	Cambodia	17.0% (14.9 to 19.1)	Burkina Faso	10.6% (8.0 to 13.2)
Worst performers				
1	Mongolia	-34.4% (-36.5 to -32.3)	Kazakhstan	-56.7% (-59.3 to -54.1)
2	Mauritius	-24.3% (-26.4 to -22.2)	Belarus	-51.0% (-53.6 to -48.4)
3	Indonesia	-23.2% (-25.3 to -21.1)	Kyrgyzstan	-46.5% (-49.1 to -43.9)
4	Pakistan	-16.7% (-18.8 to -14.6)	Indonesia	-36.7% (-39.3 to -34.1)
5	Iran	-16.4% (-18.5 to -14.3)	Mongolia	-36.4% (-39.0 to -33.8)

UI=uncertainty interval.

Table 5: Top-five and bottom-five country performers in rate of decline of HIV mortality, 2000–10

improvements in the maternal mortality ratio from 1990–95 to 1995–2000 (table 7). Some countries have constantly accelerated progress towards higher performance (eg, Uzbekistan, with tuberculosis mortality over the period 1997–2012; table 8). Progress has been made in central Asia and eastern Europe with respect to declines in HIV mortality over time (table 9).

A country's performance with respect to the rate of change in mortality differs greatly from its performance with respect to the number of deaths. Examining rates of decline versus number of deaths for under-5 mortality and the maternal mortality ratio from 1990 to 2013, we found little correlation between the two indicators (figure 2). Specifically, for under-5 mortality, the correlation was 0.18 for 1992–97, -0.30 for 1997–2002, -0.13 for 2002–07, and -0.07 for 2007–12; for maternal

2002–07 to 2007–12			1997–2002 to 2002–07		1992–97 to 1997–2002	
Country	Rate of change in the rate of decline per year (95% UI)		Country	Rate of change in the rate of decline per year (95% UI)	Country	Rate of change in the rate of decline per year (95% UI)
Best performers						
1	South Africa	1.6% (1.5 to 1.7)	Botswana	2.0% (1.9 to 2.1)	Rwanda	2.5% (2.4 to 2.6)
2	Macedonia	1.5% (1.4 to 1.6)	Namibia	1.2% (1.1 to 1.3)	Belarus	1.8% (1.7 to 1.9)
3	Swaziland	1.2% (1.1 to 1.3)	South Africa	1.2% (1.1 to 1.3)	Mauritius	1.6% (1.5 to 1.7)
4	Lesotho	0.8% (0.7 to 0.9)	Swaziland	1.2% (1.1 to 1.3)	Georgia	1.5% (1.4 to 1.6)
5	Bosnia and Herzegovina	0.7% (0.6 to 0.8)	Rwanda	0.9% (0.8 to 1.0)	Cambodia	1.5% (1.4 to 1.6)
Worst performers						
1	Cambodia	-0.9% (-1.0 to -0.8)	Mauritius	-1.4% (-1.5 to -1.3)	Macedonia	-0.9% (-1.0 to -0.8)
2	Botswana	-0.7% (-0.8 to -0.6)	Malaysia	-0.9% (-1.0 to -0.8)	Serbia	-0.8% (-0.9 to -0.7)
3	Serbia	-0.6% (-0.7 to -0.5)	Bosnia and Herzegovina	-0.9% (-1.0 to -0.8)	South Africa	-0.4% (-0.5 to -0.3)
4	Rwanda	-0.6% (-0.7 to -0.5)	Macedonia	-0.6% (-0.7 to -0.5)	Philippines	-0.3% (-0.4 to -0.2)
5	Malaysia	-0.6% (-0.7 to -0.5)	Costa Rica	-0.5% (-0.6 to -0.4)	Namibia	-0.2% (-0.3 to -0.1)

UI=uncertainty interval.

Table 6: Top-five and bottom-five country performers in rate of change in the rate of decline for under-five mortality, 1992–2012

2000–05 to 2005–13		1995–2000 to 2000–05		1990–95 to 1995–2000		
Country	Rate of change in the rate of decline per year (95% UI)	Country	Rate of change in the rate of decline per year (95% UI)	Country	Rate of change in the rate of decline per year (95% UI)	
Best performers						
1	Belarus	5.0% (4.9 to 5.1)	Suriname	4.8% (4.6 to 5.0)	Serbia	4.6% (4.4 to 4.8)
2	Macedonia	1.2% (1.1 to 1.3)	Bulgaria	4.0% (3.8 to 4.2)	Tajikistan	3.5% (3.3 to 3.7)
3	Namibia	1.1% (1.0 to 1.2)	Colombia	3.1% (2.9 to 3.3)	Mauritius	3.4% (3.2 to 3.6)
4	Botswana	1.1% (1.0 to 1.2)	Belarus	2.1% (1.9 to 2.3)	Hungary	3.3% (3.1 to 3.5)
5	Zimbabwe	1.0% (0.9 to 1.1)	Afghanistan	1.3% (1.1 to 1.5)	Azerbaijan	2.8% (2.6 to 3.0)
Worst performers						
1	Romania	-1.3% (-1.4 to -1.2)	Serbia	-4.7% (-4.9 to -4.5)	Suriname	-7.8% (-8.0 to -7.6)
2	Serbia	-1.1% (-1.2 to -1.0)	Mauritius	-4.4% (-4.6 to -4.2)	Colombia	-2.7% (-2.9 to -2.5)
3	Mauritius	-1.0% (-1.1 to -0.9)	Hungary	-4.4% (-4.6 to -4.2)	Romania	-2.2% (-2.4 to -2.0)
4	Mexico	-0.5% (-0.6 to -0.4)	The Dominican	-1.9% (-2.1 to -1.7)	Bulgaria	-1.5% (-1.7 to -1.3)
5	Moldova	-0.5% (-0.6 to -0.4)	Bosnia and Herzegovina	-1.1% (-1.3 to -0.9)	Belarus	-1.4% (-1.6 to -1.2)

UI=uncertainty interval.

Table 7: Top-five and bottom-five country performers in rate of change in the rate of decline for maternal mortality, 1990–2013

mortality the correlation was 0.01 for 1990–95, 0.01 for 1995–2000, 0.13 for 2000–05, and 0.08 for 2005–13. These findings show that high rates of decline in mortality can be achieved even at low levels of mortality. For example, Turkey had a relatively low under-5 mortality of 47 per 1000 livebirths in 2002, which was reduced to 32 per 1000 livebirths in 2007, representing a high rate of decline (8.1% per year) for 2002–07.

Figure 3 shows the year when *The Lancet's* Commission on Investing in Health targets could be achieved with the latest rates of decline. For under-5 mortality, 37 (34%) of 109 countries have already achieved the interim 2030 target of 20 deaths per 1000 livebirths and 72 have not. At current rates of mortality decline, only 25 (35%, 95% UI 35–39) of these 72 countries would achieve the target by 2030 and a further 22 (31%, 29–31) would

achieve it between 2030 and 2050 (figure 3A). With an aspirational best-performer rate of decline (at the 90th percentile), 41 (57%, 50–64) of the 72 countries would achieve the target by 2030 and all remaining countries (31 [43%, 36–50]) would achieve it over the period 2030–50 (figure 3B). With regional aspirational rates, 32 (44%, 42–61) of the 72 countries would achieve the target by 2030 and the remaining countries (40 [56%, 39–58]) would achieve it between 2030 and 2050 (figure 3C).

For the maternal mortality ratio, 46 (42%) of 109 countries have already achieved *The Lancet's* Commission on Investing in Health interim 2030 target of 94 deaths per 100 000 livebirths and 63 have not. At current rates, 13 (21%, 95% UI 17–29) of these 63 countries would achieve the target by 2030 and 19 (30%, 24–33) would meet the target over the period

2002-07 to 2007-12			1997-2002 to 2002-07		1992-97 to 1997-2002	
Country	Rate of change in the rate of decline per year (95% UI)		Country	Rate of change in the rate of decline per year (95% UI)	Country	Rate of change in the rate of decline per year (95% UI)
Best performers						
1	Uzbekistan	3.9% (3.6 to 4.2)	Azerbaijan	5.0% (4.7 to 5.3)	Kazakhstan	6.2% (5.9 to 6.5)
2	Macedonia	3.7% (3.4 to 4.0)	Namibia	4.8% (4.5 to 5.1)	Mauritius	4.9% (4.6 to 5.2)
3	Kazakhstan	2.4% (2.1 to 2.7)	Uzbekistan	3.4% (3.1 to 3.7)	Cuba	4.2% (3.9 to 4.5)
4	Ukraine	2.3% (2.0 to 2.6)	Kyrgyzstan	3.1% (2.8 to 3.4)	Rwanda	4.2% (3.9 to 4.5)
5	Zimbabwe	2.2% (1.9 to 2.5)	Thailand	2.7% (2.4 to 3.0)	Bulgaria	3.9% (3.6 to 4.2)
Worst performers						
1	Azerbaijan	-5.8% (-6.1 to -5.5)	Mauritius	-5.8% (-6.1 to -5.5)	Suriname	-3.8% (-4.1 to -3.5)
2	Lesotho	-3.7% (-4.0 to -3.4)	Lebanon	-2.3% (-2.6 to -2.0)	Kenya	-3.2% (-3.5 to -2.9)
3	Cuba	-3.1% (-3.4 to -2.8)	Cuba	-2.0% (-2.3 to -1.7)	South Africa	-3.2% (-3.5 to -2.9)
4	Georgia	-3.1% (-3.4 to -2.8)	Zimbabwe	-1.8% (-2.1 to -1.5)	Costa Rica	-2.6% (-2.9 to -2.3)
5	Costa Rica	-3.0% (-3.3 to -2.7)	Botswana	-1.7% (-2.0 to -1.4)	Sierra Leone	-2.1% (-2.4 to -1.8)

UI=uncertainty interval.

Table 8: Top-five and bottom-five country performers in rate of change in the rate of decline for tuberculosis mortality, 1992-2012

2030-50 (figure 3D). At the aspirational rate, 24 (38%, 35-41) would achieve the target by 2030 and 37 (59%, 54-59) would achieve it between 2030 and 2050 (figure 3E). At regional aspirational rates, 25 of the 63 countries (40%, 30-46) would achieve the target by 2030 and 30 (48%, 48-53) would achieve it between 2030 and 2050 (figure 3F). If the target were 40 per 100 000,^{18,19} only 11 (13%, 8-14) of 86 countries (among those having not yet achieved target) would achieve the target by 2030 at current rates, with 27 (31%, 29-37) meeting the target at aspirational rates.

For tuberculosis mortality, 32 (29%) of 109 countries have already achieved *The Lancet's* Commission on Investing in Health target of four deaths per 100 000 population per year and 77 have not. At current rates, 18 (23%, 95% UI 21-34) of these 77 countries would achieve the target by 2030 and 20 (26%, 19-26) would achieve it between 2030 and 2050 (figure 3G). At the aspirational rate, 61 (79%, 74-90) countries would achieve the target by 2030 and the remaining 16 (21%, 10-26) would achieve it between 2030 and 2040 (figure 3H). At regional aspirational rates, 48 (62%, 52-78) countries would achieve the target by 2030 and the remaining 29 (38%, 22-48) would achieve it between 2030 and 2050 (figure 3I).

For HIV mortality, 47 (43%) of 109 countries have already achieved *The Lancet's* Commission on Investing in Health target of eight deaths per 100 000 population per year and 62 have not. At current rates, 28 (45%, 95% UI 26-50) of these 62 countries would achieve the target by 2030 and 11 (18%, 18-29) would achieve it over the period 2030-50 (figure 3J). At the aspirational rate, 49 (79%, 66-82) would achieve the target by 2030 and the remaining 13 (21%, 18-34) would achieve it over the period 2030-40 (figure 3K). At regional aspirational rates, 42 (68%, 52-82) would achieve the target by 2030 and

2000-05 to 2005-10		
Country	Rate of change in the rate of decline per year (95% UI)	
Best performers		
1	Kazakhstan	8.4% (8.0 to 8.8)
2	Belarus	7.0% (6.6 to 7.4)
3	Turkey	6.6% (6.2 to 7.0)
4	Kyrgyzstan	6.5% (6.1 to 6.9)
5	Namibia	6.1% (5.7 to 6.5)
Worst performers		
1	Hungary	-5.7% (-6.1 to -5.3)
2	Tunisia	-4.9% (-5.3 to -4.5)
3	Serbia	-4.0% (-4.4 to -3.6)
4	Mauritius	-3.0% (-3.4 to -2.6)
5	Morocco	-1.6% (-2.0 to -1.2)

UI=uncertainty interval.

Table 9: Top-five and bottom-five country performers in rate of change in the rate of decline for HIV mortality, 2000-10

16 (26%, 18-32) countries would achieve it over the period 2030-40 (figure 3L).

Discussion

We studied over the past two decades the historical rates of decline of under-5, maternal, tuberculosis, and HIV mortality for 109 countries of low and middle income. Between 2005 and 2013, the mean rates of decline were 4.3% (95% UI 3.9-4.6) per year for under-5 mortality, 3.3% (2.5-4.1) per year for maternal mortality, 4.1% (2.8-5.4) per year for tuberculosis mortality, and 2.2% (0.1-4.3) per year for HIV mortality. Best-performer rates of decline per year were 7.1% (6.8-7.5), 6.3% (5.5-7.1), 12.8% (11.5-14.1), and 15.3% (13.2-17.4), respectively, with substantial variation across countries

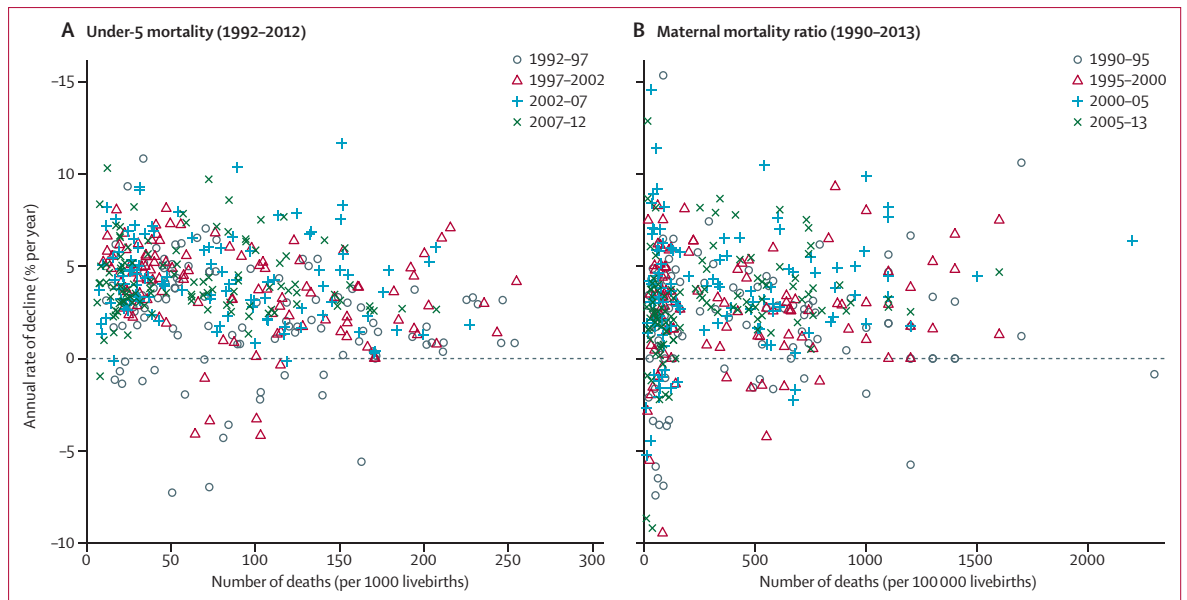


Figure 2: Correlation of rate of decline in mortality with number of deaths

and regions. During the period 1990–2013, we also identified countries with the best and worst performances and regions in which rapid changes had taken place towards higher or lower performance. Our two aims in looking at trends in the rates of decline were to provide a dependent variable to assist in identifying potential health policy determinants of performance and to find an approach to testing the feasibility of proposed post-2015 health goals.

We aimed to identify specific countries and periods with good and bad performances in rates of decline of mortality indicators, for which further assessment would be valuable. Analysing all potential determinants of the rates of decline—including contextual factors, specific circumstances, and system and policy elements—could provide useful lessons for improvement of population health in the future. Importantly, a country's health performance could be classified by how much the rate of decline of a selected outcome (eg, under-5 mortality) is better or worse than what would be expected with selected contextual attributes (eg, income, education). In a subsequent analysis, specific variables could be analysed (eg, health expenditure, foreign aid) that might isolate the remaining determinants of country performance.

Analysis of rates of change in health is useful because rapid alterations in rates of decline—whether accelerations or decelerations—can point to a potential effect of policy changes and provide a mechanism to better understand what constitutes good policy. We noted almost no correlation between numbers of deaths and rates of decline in mortality indicators (figure 2), which suggests that rates of change augment the information conveyed by mortality estimates but cannot replace the important part played by examination of numbers of

deaths, particularly in terms of capturing the underlying intensity of country-level mortality.

Rates of decline in child mortality indicate the severe effect that the HIV/AIDS epidemic had in southern Africa. In this region, very large increases were recorded in child mortality over the period 1997–2002, but numbers of deaths fell rapidly from 2002 to 2007, probably because of rollout of antiretroviral therapy (ART) for the prevention of mother-to-child transmission of HIV.^{27,28} Likewise, rates of decline in maternal and tuberculosis mortality deteriorated during 1990–97 in many central Asian countries after the collapse of the Soviet Union in 1991, and rates of decline in child mortality dropped abruptly in Rwanda from 1992 to 1997, probably because of the genocide in 1994. A few countries have sustained high rates of decline—eg, child mortality in Turkey from 1992 to 2007, maternal mortality in Cambodia over the period 1990–2005, tuberculosis mortality in Rwanda between 1997 and 2007, and HIV mortality in Burkina Faso during 2000–10. Did unusual circumstances or specific policies account for these changes in mortality? Indeed, subsequent assessments could control for contextual determinants (eg, income) and exceptional events (eg, natural disasters and political instabilities) and try to identify the contributions of specific policies implemented. For instance, Turkey's high rates of decline in child mortality coincide with substantial economic growth, political stability, and introduction of the Health Transformation Program, which rapidly expanded access to health-care services.²⁹ Cambodia's progress in maternal mortality can probably be attributed to socioeconomic improvements and better primary education and to specific policies leading to increases in skilled birth attendance.³⁰ For Burkina Faso,



Figure 3: Year by which *The Lancet's* Commission on Investing in Health targets could be achieved

Grey line represents 2012 for under-5 and tuberculosis mortality, 2013 for maternal mortality, and 2010 for HIV mortality. Dotted lines are at 2030 and 2050. Regions and country codes are defined in the appendix (p 1).

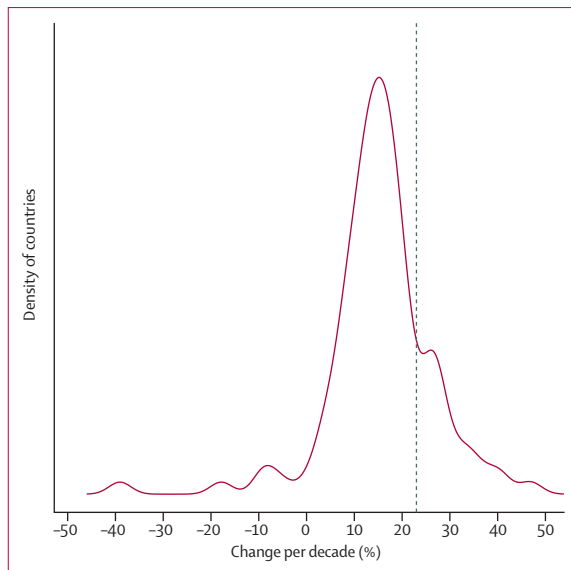


Figure 4: Distribution of predicted change in premature deaths by 2030 among countries of low and middle income

Age-standardised death rates from 2000 and 2010 (which were generally lower than in 2000) were applied to the 2030 population (UNPD medium-variant projection), yielding two numbers for deaths in 2030. The change per decade (%) compares these values. To achieve a 40% reduction in premature (younger than 70 years) deaths by 2030, a change of 23% per decade (dotted line) will be needed.

a rapid expansion of ART (up to 70% in 2012) led to striking improvements in HIV mortality.³¹

We used the rates of decline in mortality to test the feasibility of achieving post-2015 goals, with a particular focus on the 2030 targets proposed by *The Lancet's* Commission on Investing in Health. Because post-2015 goals present ambitious targets for levels of mortality, they would need high (aspirational) rates of mortality decline from 2015 to 2030. Hence, we used historical rates of decline—including best-performer aspirational rates—to identify how many countries would achieve these ambitious targets if they were to have these similar rates of decline over the period 2015–30. If all countries of low and middle income were able to achieve best-performer aspirational rates of decline in mortality, most would meet the targets for tuberculosis and HIV mortality, about half would reach the child mortality target, but fewer than half would meet the maternal mortality target.

Similar methods can be used to assess the feasibility of other possible Sustainable Development Goal targets. Norheim and colleagues³² suggested (in addition to specific subtargets for under-5 mortality, etc) an overarching goal to reduce premature (younger than 70 years) deaths by 40% in 2030 from what they would have been in 2010. Figure 4 shows mortality estimates for 2030 that were predicted from the distribution of changes in rates of decline in premature deaths across countries in 2000–10. To the right of the cutoff, 21 countries had rates of decline sufficiently rapid that, if continued for two decades to 2030, they would meet the 40% reduction target.

Periods of high rates of decline in mortality, such as those seen among best-performers (tables 2 to 5), can be difficult to sustain. Indeed, we noted a strong negative correlation between the rate of decline and the rate of change in the rate of decline (eg, -0.60 and -0.80 for under-5 mortality and the maternal mortality ratio, respectively). Thus, when high rates of decline were recorded, negative rates of change in rates of decline (ie, decelerations) were sometimes recorded, leading to a reduction from higher to lower rates of decline.

Even if some countries can emulate the best performances recorded in recent years with respect to rates of decline in infectious, child, and maternal mortality, our findings suggest they will not meet proposed 2030 global health targets. These countries will need to achieve highly accelerated rates of decline in mortality. How can such acceleration be achieved? A first approach would be aggressive and accelerated scale-up of evidence-based medicines, vaccines, diagnostics, and other health strategies to very high coverage levels; a second would be to scale-up investments in discovery, development, and delivery of new health technologies. Both these approaches were captured in *The Lancet's* Commission on Investing in Health modelling method but were not included in our best-performer modelling. Two methodological differences could account for why some countries in our model did not reach 2030 targets. First, the Commission's approach began by modelling the scale-up of a wide range of evidence-based interventions (eg, ART and skilled birth attendance) to very high (typically 90%) coverage levels by 2030. The model assumes that very aggressive intervention scale-up will be possible across all countries of low and middle income based on actual rates of scale-up in recent years in several countries. Second, the Commission's model also assumes that discovery and development of new medicines, vaccines, and diagnostics will lead to an additional 2% per year decline in under-5, maternal, HIV, and tuberculosis mortality, an assumption based on empirical research on the effect of research and development on mortality declines.³³ Taken together, these differences indicate that the Commission's modelling is more optimistic than is ours about what can be achieved by 2030.

Our analysis has four key limitations. First, for some countries with poor data, the mortality estimates we used^{23–26} were predicted largely from past trends. Many countries, particularly those with high mortality, do not have vital registration so mortality estimates are not always reliable. In view of the large number of countries and distinct mortality indicators analysed, some findings might also be attributable to poor quality of data. We used UNICEF and WHO mortality estimates^{23–26} to draw general lessons, but our findings could be further strengthened by incorporation of additional sources (panel).^{12,13,34–36}

Second, 5-year intervals were chosen because of the availability of estimates^{23–26} and for conciseness, but this

Panel: Research in context**Systematic review**

Suggested post-2015 targets (eg, the Sustainable Development Goals) have only recently been published,^{14,20} and a preliminary search by us did not identify any study addressing exactly our aim to estimate the annual rates of decline in under-5, maternal, tuberculosis, and HIV mortality over the past two decades. Therefore, we did not do a systematic review. Published work has begun to emerge in which the rates of change (rates of decline) in mortality indicators are used to identify rapid alterations in numbers of deaths in selected countries and over periods that are worthy of further exploration.^{5,9,11–13,34–36} The motivation for studying rates of change is that these data are expected to be sensitive to changes in intersectoral, social, and health system policies. In particular, assessment of country performances with respect to rates of decline in mortality indicators enables reporting on progress towards achieving goals such as the “grand convergence in global health” objective highlighted by *The Lancet’s* Commission on Investing in Health and extrapolating on what could be post-2015 targets (eg, the Sustainable Development Goals). Here, we report trends in rates of decline of under-5, maternal, tuberculosis, and HIV mortality for 109 low-income and middle-income countries over the period 1990–2013.

Interpretation

Country performance with respect to rates of decline in mortality indicators provides a quantitative starting point for assessment of the importance of intersectoral, social, and system determinants of health and for realistic achievement of future set objectives, such as the Sustainable Development Goals.

period might oversmooth changes of interest. If available, alternative intervals could be analysed, which would affect country performance rankings. Despite noise, annual outcomes could be looked at to isolate inflection points that capture times when countries make performance transitions (appendix p 2). This approach would also help identify seasonal variations and cyclical patterns that longer intervals (eg, every 5 years) might be unable to flag. The choice of interval represents a trade-off between accuracy and the relevance of findings to policy.

A third limitation is that our analysis includes four mortality indicators that correlate highly across countries for a specific period and over time for a particular country. For example, correlation over the entire period was 0·90 between the maternal mortality ratio and under-5 mortality, 0·58 for under-5 and tuberculosis mortality, and 0·59 for the maternal mortality ratio and tuberculosis mortality. Correlation might affect the feasibility of the post-2015 targets, because countries achieving poor results for one indicator might be faring badly in another. Nevertheless, we noted little correlation between the rates of decline of the

four indicators: 0·35 between under-5 mortality and the maternal mortality ratio, 0·15 for under-5 and tuberculosis mortality, and –0·01 for the maternal mortality ratio and tuberculosis mortality, which suggests that successful improvements towards targets might not be affected.

The final limitation is that other modelling techniques could be used to forecast the rates of decline in mortality and to ascertain whether countries would achieve targets by 2030. For instance, specific explanatory variables related to declines in mortality could be used, and regression models could be fitted to mortality time series to make future predictions. However, we opted for a simple and intuitive approach based on historical rates of decline in mortality, which are easily communicable to policymakers.

In conclusion, if recent aspirational best-performer rates of decline could be achieved in countries of low and middle income, most would meet *The Lancet’s* Commission on Investing in Health targets for 2030 for tuberculosis and HIV mortality, about half would reach the child mortality target, and fewer than half would meet the maternal mortality target. Aggressive scale-up of evidence-based interventions together with discovery and development of new health strategies will be needed to achieve further acceleration of declines in mortality. Rates of decline provide a necessary starting point for assessment of the importance of health policy determinants and for defining realistic targets for the Sustainable Development Goals.

Contributors

SV and DTJ initiated the study. SV coordinated the research and did the analysis, with help from OFN, ZDO, GY, and DTJ. SV wrote the initial report and all authors revised and approved the final report. All authors had full access to all data in the study. SV and DTJ had final responsibility to submit for publication.

Declaration of interests

GY and DTJ were coauthors of *The Lancet’s* Commission on Investing in Health report, which is discussed here. All other authors declare no competing interests.

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