Can we achieve Millennium Development Goal 4? New analysis of country trends and forecasts of under-5 mortality to 2015

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Summary

Background **Global efforts have increased the accuracy and timeliness of estimates of under-5 mortality; however, these estimates fail to use all data available, do not use transparent and reproducible methods, do not distinguish predictions from measurements, and provide no indication of uncertainty around point estimates. We aimed to develop new reproducible methods and reanalyse existing data to elucidate detailed time trends.**

Methods **We merged available databases, added to them when possible, and then applied Loess regression to estimate past trends and forecast to 2015 for 172 countries. We developed uncertainty estimates based on different model specifications and estimated levels and trends in neonatal, post-neonatal, and childhood mortality.**

Findings **Global under-5 mortality has fallen from 110 (109–110) per 1000 in 1980 to 72 (70–74) per 1000 in 2005. Child deaths worldwide have decreased from 13·5 (13·4–13·6) million in 1980 to an estimated 9·7 (9·5–10·0) million in 2005. Global under-5 mortality is expected to decline by 27% from 1990 to 2015, substantially less than the target of Millennium Development Goal 4 (MDG4) of a 67% decrease. Several regions in Latin America, north Africa, the Middle East, Europe, and southeast Asia have had consistent annual rates of decline in excess of 4% over 35 years. Global progress on MDG4 is dominated by slow reductions in sub-Saharan Africa, which also has the slowest rates of decline in fertility.**

Interpretation **Globally, we are not doing a better job of reducing child mortality now than we were three decades ago. Further improvements in the quality and timeliness of child-mortality measurements should be possible by more fully using existing datasets and applying standard analytical strategies.**

Introduction

Child mortality is an important measure of health and development.[1] Sound measurement is needed so that we can learn from national success and identify countries where extra efforts are needed to accelerate the rate of decline in under-5 mortality (formally defined as the probability of death between birth and age 5 years per 1000 births). As performance-related disbursement by global-health initiatives gains momentum, robust measurement of under-5 mortality will take on even greater operational importance for development assistance.

In view of the importance of under-5 mortality, annual or periodic assessments are produced by UNICEF,[2] WHO,[3] UN Population Division,[4] and the World Bank.[5] These assessments are based on a mixture of data sources: complete vital registration systems for some countries, partial vital registration systems, complete birth histories implemented in the Demographic and Health Surveys (DHS) or similar surveys, survey or census questions on the number of children ever born and the number surviving, and sample registration systems.[6,7] Over the past decade, WHO, UNICEF, UN Population Division, and the World Bank have not always agreed on past estimates, predictions for a recent period, or forecasts. Advances have been made to put all data sources used for tracking child mortality by these agencies in the public domain and to harmonise the work of identifying past trends and generating current estimates across the agencies.[8]

For the **UNICEF public domain database** see http://newsite.unicef.org/childmortality/

Despite these welcome advances, five main issues continue to limit the quality and usefulness of evidence on child mortality. First, for many countries we strongly suspect that data sources for child mortality are missing from international databases. For example, as of May 1, 2007, the most recent measurement in the UNICEF public domain database for Mexico was 1990 and for India it was 1997. In fact, since 1990, Mexico has had four national surveys containing data for child mortality, two censuses with questions on children ever born or children surviving, and nearly complete vital registration data available up until 2005. In the case of India, Indian sample registration system data are available up to the end of 2005, as are the 2000 census results and data from two rounds of district-level surveys that include child-mortality measurements.

Second, figures produced and published do not distinguish between statistics based on actual measurements corrected for a range of known biases, and predictions based on a model.[9,10] Distinguishing between observed, corrected, and predicted figures is essential for monitoring and evaluation work, for which predictions have no real role.[9]

Third, in principle, UNICEF fits historical data and predicts beyond the most recent measurement using a type of interval regression.[7] However, the exact application of these methods and how and when forecasts are modified from the basic model are not reported for every country. For example, the estimate for Cote d'Ivoire of a 2005 under-5 mortality of 195 per 1000 is difficult to reproduce from the data and methods published by UNICEF. Fourth, despite calls from the scientific community,[11,12] estimates of levels and trends in child mortality do not routinely come with uncertainty bounds. In the absence of such limits, users of data naturally assume that all figures are known with equal precision.

Finally, there seems to have been a tendency to overestimate levels of child mortality in several sub-Saharan African countries. This situation might have arisen from a scarcity of recent data, judgments about the expected effects of the HIV epidemic influencing the interpretation of incomplete data, exclusion of some survey datapoints as outliers based on expectations of mortality increases, or a combination of these factors.

Here, we attempt to address some of these limitations by proposing new reproducible methods and, in doing so, contribute to the movement towards enhanced transparency of measurement by using all datasets available in the public domain and reanalysing existing surveys to elucidate more detailed time trends.

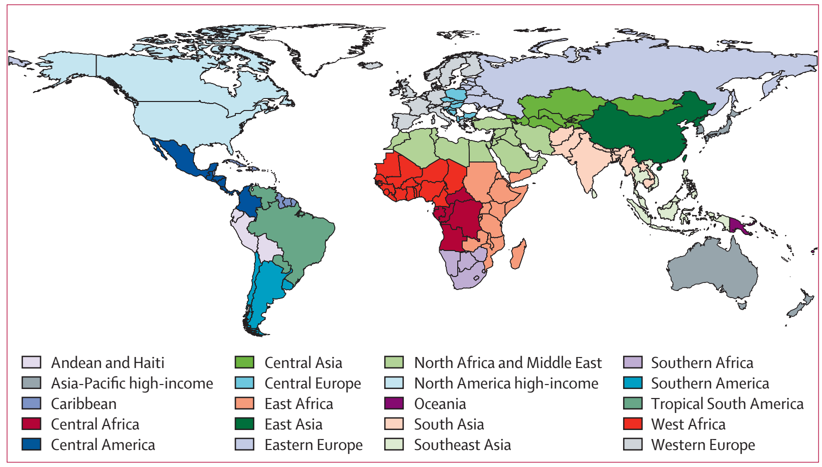

Figure 1: **Global Burden of Disease 2005 study regions**

Methods

Child mortality measurements database

We compared databases of country measurements of child mortality maintained by UNICEF and WHO as of April 4, 2007. The UNICEF database contained 4167 entries whereas the WHO database included 8774 entries from surveys, censuses, or vital registration systems for 192 countries. We amalgamated these two databases and removed duplicate measurements.

We reanalysed data from 152 DHS surveys to generate estimates of under-5 mortality for every 2-year period before the survey, up to 24 years before the date of every survey. 2-year estimates have wide sampling uncertainty because of small numbers but provide increased information for recent trends; under-5 mortality estimates can be generated for single years but, for many countries, have very wide uncertainty intervals.

Sample registration system data for India were added for 2000–04. Data from the Registrar General's Department of Sri Lanka were added for 1995–98. Available Mexican data were supplemented with the 2000 and 2005 censuses and the 1997 and 2006 Encuesta Nacional de la Dinámica Demográfica (ENADID) surveys. Survey data were included for the Democratic Republic of the Congo.[13] Preliminary results from multiple indicator cluster surveys (MICS3), available as of Aug 20, 2007, were included for the Dominican Republic, Djibouti, Tajikistan, Uzbekistan, Malawi, Iraq, the Occupied Palestinian Territories, Syria, Ghana, Sierra Leone, Mongolia, and Niger. Based on ongoing reanalysis of MICS3 results for Iraq, we chose to exclude from the analysis the results of the 1999 child and maternal mortality survey.

Our final database contained 9067 observations, from which 637 datapoints based on reports about children ever born and children surviving of women younger than age 25 years were excluded because these data are known to be biased upwards.[14] 190 extreme outliers that clearly differ from the rest of the datapoints were excluded from the statistical analysis but included on country plots (shown as small grey points). Identification of extreme outliers was based on examination of the country plots and not on any one specific statistical test. Overall, 8243 empirical observations were available for direct estimation in 189 countries. 17 countries with very small populations were not analysed, leaving 172 for this analysis.

For the **WHO database** see http://www.who.int/whosis

Fitting past trends

We fitted past trends in child mortality for years when empirical measurements were available with Loess regression,[15] a type of local regression. Loess regression allows us to closely fit complex non-linear trends in data based on replicable methods that yield parameter confidence intervals. In Loess regression, the α parameter controls the weight attached to datapoints that are farther away from the estimation point. The precise definition of α is provided in the webappendix. We used a range of

See Online for webappendix

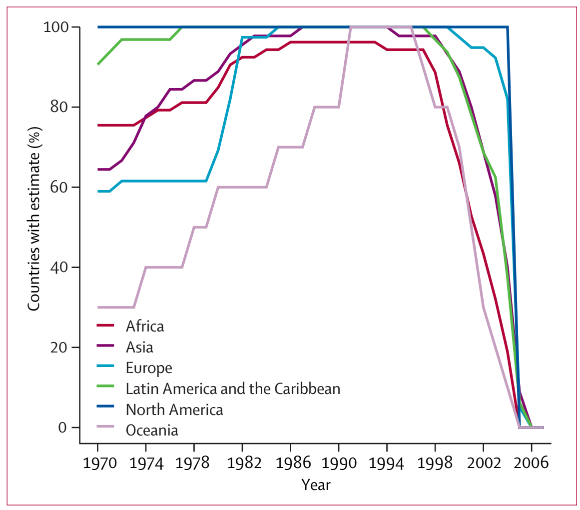

Figure 2: **Proportion of countries with empirically informed estimate of under-5 mortality by year, for all major United Nations regions**

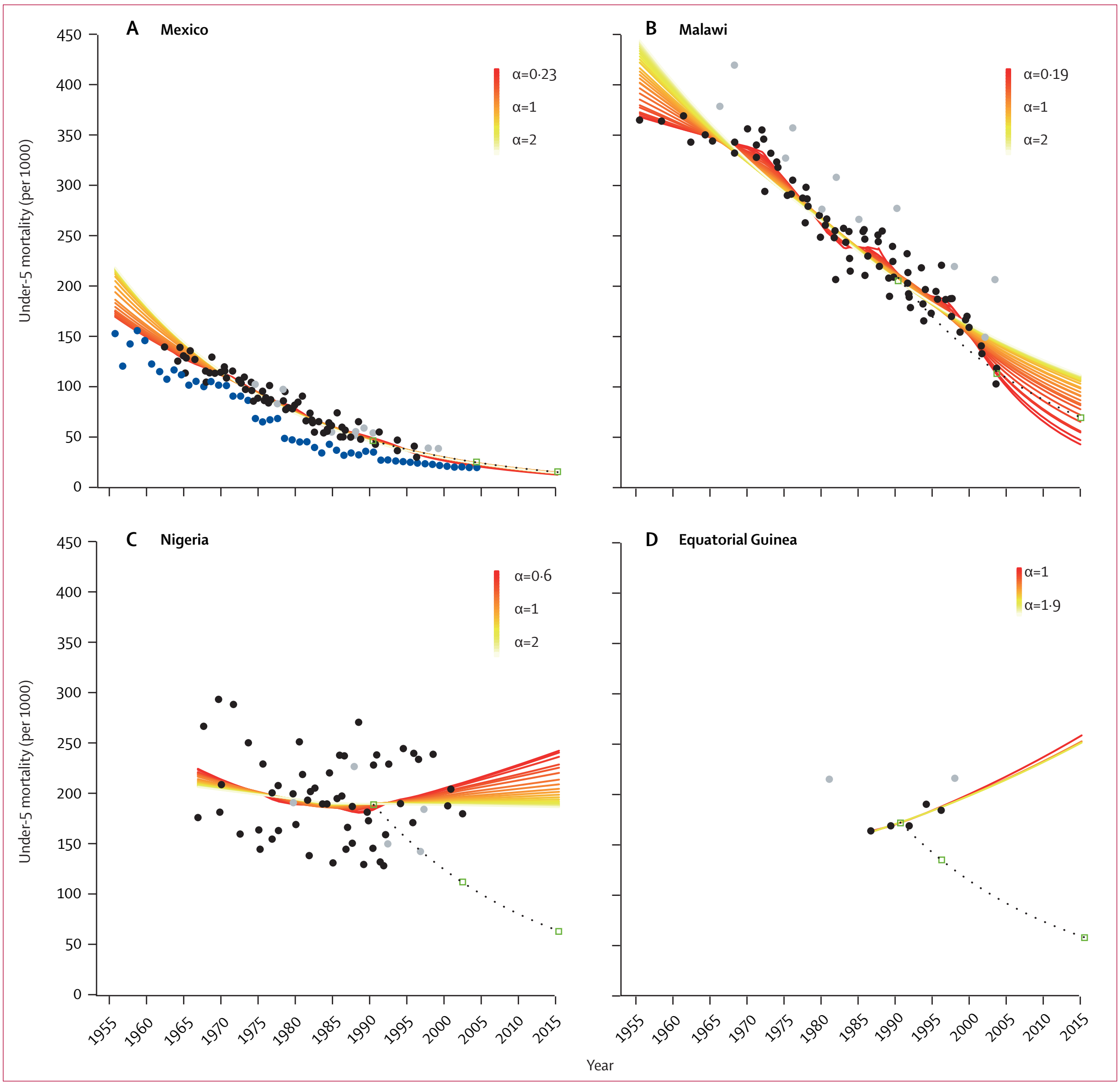

Figure 3: **Estimates and forecasts of under-5 mortality for (A) Mexico, (B) Malawi, (C) Nigeria, and (D) Equatorial Guinea**
Available data are shown as circles. Blue points represent vital registration data, black points are non-vital registration data, and grey points show extreme outliers. Blue and black points were used in the estimates whereas grey points were excluded. Every coloured line represents an estimate or forecast based on a different value of the Loess parameter α. The value of every estimate in 1990 is marked with a box. The dotted line shows the constant rate of reduction needed to reach MDG4 exactly. The values of this target curve in 2015 and in the last available data year are also marked with boxes.

different α parameters for every country to produce models with higher or lower sensitivity to recent data trends. The basic model we estimate is

$$Ln5q0=\delta+\beta_1 T+\beta_2 VR+\varepsilon$$

where $5q0$ is under-5 mortality, T is calendar year and VR is a dummy variable that takes the value 1 when the observation comes from a vital registration system. β_2 is a parameter estimated through the regression model that specifies the completeness of the vital registration system for child deaths relative to levels recorded in surveys or censuses, and β_1 is an estimate of the expected change in $Ln5q0$ for any single year. This formulation allows incomplete vital registration data to inform estimation of time trends in child mortality without biasing the level of child mortality. Local regression also means that the coverage of vital registration relative to survey or census data can change over time.

Forecasting out of time

We forecast from the year with the most recent empirical measurement to 2015, using the last set of parameter estimates from every Loess regression for every value of α. The set of forecasts captures some of the uncertainty attributable to specification. Low values of α mean the

	1970	1975	1980	1985	1990
Under-5 deaths (thousands)					
Western Europe	147 (144–150)	102 (100–104)	72 (71–72)	54 (53–54)	41 (41–42)
Central Europe	106 (101–111)	87 (84–89)	70 (69–71)	53 (52–54)	40 (39–41)
Eastern Europe	107 (104–110)	103 (102–105)	100 (99–100)	96 (96–96)	80 (79–82)
North Africa and Middle East	1312 (1274–1352)	1176 (1156–1197)	1035 (1018–1053)	869 (861–877)	674 (667–681)
Central Asia	160 (148–174)	151 (142–160)	149 (143–154)	152 (149–154)	146 (144–147)
South Asia	5661 (5628–5703)	5471 (5444–5506)	5286 (5247–5330)	5072 (5029–5127)	4767 (4726–4831
Southeast Asia	1277 (1250–1306)	1123 (1110–1137)	972 (966–979)	830 (812–849)	674 (661–694)
East Asia	2889 (2637–3172)	1871 (1813–1931)	1254 (1213–1281)	1059 (976–1111)	984 (957–992)
Asia-Pacific high-income	98 (95–101)	68 (62–71)	42 (37–44)	31 (29–32)	22 (22–23)
Oceania	19 (17–20)	18 (17–19)	18 (17–18)	18 (18–18)	19 (18–19)
North America high-income	86 (84–90)	69 (68–70)	59 (57–60)	53 (51–54)	49 (48–49)
Caribbean	45 (44–46)	36 (35–36)	28 (28–29)	24 (23–24)	20 (19–21)
Central America	428 (422–433)	375 (371–380)	306 (302–313)	244 (240–248)	199 (195–205)
Southern America	56 (55–56)	47 (46–48)	40 (39–42)	33 (32–34)	28 (27–30)
Tropical South America	464 (461–467)	406 (401–414)	363 (354–373)	300 (295–309)	226 (222–232)
Andean and Haiti	211 (208–215)	194 (193–196)	178 (174–182)	156 (153–159)	131 (130–133)
West Africa	1256 (1242–1271)	1339 (1333–1346)	1436 (1424–1445)	1563 (1551–1575)	1695 (1673–1708)
Central Africa	342 (327–363)	376 (367–388)	421 (416–427)	476 (472–479)	548 (538–553)
East Africa	1275 (1256–1310)	1349 (1332–1375)	1425 (1410–1442)	1507 (1493–1523)	1570 (1559–1582)
Southern Africa	134 (123–149)	135 (129–145)	132 (129–137)	126 (124–127)	116 (113–119)
World	16 212 (15 922–16 530)	14 613 (14 523–14 707)	13 488 (13 418–13 556)	12 815 (12 709–12 908)	12 121 (12 063–12 195)
Under-5 mortality (per 1000)					
Western Europe	24·8 (24·4–25·4)	19·3 (19·1–19·7)	14·9 (14·8–15·0)	11·5 (11·4–11·6)	9·0 (9·0–9·2)
Central Europe	54·4 (51·8–56·9)	42·4 (41·1–43·6)	33·7 (33·1–34·2)	27·5 (26·9–28·0)	22·7 (22·3–23·1)
Eastern Europe	36·1 (35·2–37·3)	32·9 (32·4–33·5)	30·0 (29·8–30·3)	27·4 (27·3–27·5)	25·0 (24·6–25·8)
North Africa and Middle East	186·3 (181·0–191·9)	151·3 (148·7–153·9)	119·7 (117·7–121·7)	92·3 (91·4–93·2)	71·4 (70·7–72·2)
Central Asia	113·7 (104·7–123·3)	100·6 (94·8–106·8)	90·3 (87·1–93·8)	82·2 (80·9–83·3)	74·5 (73·5–75·4)
South Asia	196·2 (195·1–197·6)	175·8 (175·0–176·9)	157·0 (155·9–158·3)	139·3 (138·1–140·8)	123·3 (122·3–125·1)
Southeast Asia	124·9 (122·3–127·8)	106·3 (105·1–107·7)	90·5 (89·9–91·1)	76·3 (74·7–78·1)	62·5 (61·3–64·4)
East Asia	102·6 (93·6–112·6)	77·3 (74·9–79·8)	58·7 (56·8–60·0)	46·1 (42·5–48·4)	40·7 (39·6–41·1)
Asia-Pacific high-income	29·9 (28·8–30·8)	20·3 (18·8–21·3)	14·6 (13·0–15·5)	12·0 (11·3–12·3)	9·6 (9·5–9·7)
Oceania	120·8 (109·8–128·1)	105·5 (99·6–111·5)	98·2 (96·3–100·5)	92·6 (91·6–93·4)	88·5 (85·1–90·9)
North America high-income	22·0 (21·5–23·1)	18·4 (18·2–18·6)	15·3 (14·8–15·5)	12·9 (12·4–13·1)	11·0 (10·8–11·1)
Caribbean	72·4 (71·1–73·8)	62·8 (62·1–63·5)	54·1 (53·6–54·7)	44·4 (43·2–45·6)	36·8 (35·6–39·2)
Central America	113·2 (111·6–114·6)	92·6 (91·6–93·9)	74·3 (73·3–75·9)	58·6 (57·7–59·5)	46·7 (45·9–48·1)
Southern America	63·3 (63·0–63·5)	49·7 (49·0–51·1)	40·2 (39·2–41·6)	32·7 (31·9–33·4)	26·7 (25·5–28·1)
Tropical South America	120·3 (119·6–121·0)	100·0 (98·7–101·9)	82·1 (80·2–84·4)	65·5 (64·4–67·5)	51·4 (50·6–52·8)
Andean and Haiti	181·1 (178·3–184·2)	154·8 (153·6–156·5)	132·6 (129·9–135·7)	110·7 (108·5–113·2)	90·3 (89·3–91·7)
West Africa	235·7 (233·1–238·5)	220·5 (219·6–221·6)	205·4 (203·6–206·7)	193·9 (192·5–195·4)	187·1 (184·6–188·5)
Central Africa	236·4 (225·9–250·8)	226·1 (220·9–233·6)	217·8 (214·8–220·7)	211·6 (209·7–213·1)	209·6 (205·7–211·7)
East Africa	214·7 (211·5–220·5)	198·8 (196·3–202·9)	183·3 (181·3–185·5)	170·4 (168·8–172·2)	158·0 (156·8–159·2)
Southern Africa	110·7 (102·1–123·2)	99·2 (94·6–106·4)	88·3 (86·2–91·1)	78·7 (77·5–79·5)	71·0 (69·1–72·4)
World	137·0 (134·6–139·6)	122·3 (121·5–123·0)	109·6 (109·0–110·1)	97·5 (96·7–98·2)	89·1 (88·7–89·7)

Table 1: **Estimated and expected under-5 deaths and under-5 mortality, with uncertainty intervals, by Global Burden of Disease 2005 study subregions and different years (1970–1990)**

forecasts are more sensitive to recent time trends but are also more sensitive to potential sampling and non-sampling error in recent measurements. Forecasts based on high values of α are largely capturing the long-term trends. We used standard methods (described in the webappendix) to capture uncertainty in the forecasts.

Neonatal, post-neonatal, and childhood death rates

We estimated the levels of neonatal (NN), post-neonatal (PNN), and childhood mortality (CHM) for every country-year. We created a dataset of these three death rates based on all available DHS findings and vital registration data reported to WHO that allows for this age breakdown. In total, 1456 country-years for 121 countries were available.

	1995	2000	2005	2010	2015
Under-5 deaths (thousands)					
Western Europe	31 (31–32)	25 (24–25)	20 (19–20)	16 (15–17)	13 (12–14)
Central Europe	27 (27–27)	19 (18–19)	14 (14–15)	11 (11–12)	9 (8–9)
Eastern Europe	53 (52–54)	40 (40–41)	38 (37–38)	34 (33–35)	29 (28–31)
North Africa and Middle East	495 (487–506)	366 (355–379)	294 (281–309)	242 (226–258)	194 (177–211)
Central Asia	119 (114–125)	84 (81–90)	67 (64–70)	56 (53–60)	46 (41–50)
South Asia	4330 (4256–4430)	3806 (3684–3952)	3359 (3196–3553)	3038 (2836–3295)	2747 (2509–3068)
Southeast Asia	521 (512–531)	403 (375–428)	321 (277–357)	250 (200–290)	193 (143–232)
East Asia	779 (746–826)	625 (575–668)	500 (437–578)	439 (361–549)	393 (301–531)
Asia-Pacific high-income	17 (17–18)	13 (12–14)	9 (8–10)	7 (6–8)	5 (4–6)
Oceania	20 (19–21)	21 (19–23)	20 (17–24)	19 (15–23)	18 (13–23)
North America high-income	42 (41–42)	35 (35–36)	32 (31–33)	28 (27–31)	25 (23–28)
Caribbean	16 (16–16)	13 (12–13)	10 (9–11)	8 (7–9)	6 (5–7)
Central America	160 (157–164)	125 (119–130)	97 (91–103)	76 (70–82)	59 (54–65)
Southern America	23 (22–25)	18 (17–20)	15 (13–17)	12 (11–14)	10 (9–12)
Tropical South America	172 (166–178)	139 (132–148)	111 (103–121)	87 (78–97)	66 (58–76)
Andean and Haiti	108 (106–110)	85 (81–89)	67 (61–72)	54 (47–60)	44 (36–50)
West Africa	1829 (1812–1850)	1955 (1906–2019)	2076 (1984–2199)	2149 (1999–2358)	2178 (1967–2483)
Central Africa	641 (635–645)	742 (719–772)	864 (812–941)	1003 (911–1143)	1133 (994–1355)
East Africa	1594 (1575–1614)	1603 (1538–1655)	1616 (1496–1720)	1613 (1447–1771)	1583 (1381–1788)
Southern Africa	117 (115–118)	117 (114–120)	116 (110–124)	113 (103–127)	111 (96–130)
World	11 185 (11 088–11 300)	10 314 (10 140–10 504)	9720 (9461–10 012)	9326 (8964–9736)	8928 (8463–9467)
Under-5 mortality (per 1000)					
Western Europe	7·1 (7·0–7·2)	5·7 (5·7–5·7)	4·6 (4·5–4·7)	3·7 (3·6–4·0)	3·0 (2·8–3·3)
Central Europe	18·3 (18·2–18·5)	14·8 (14·7–14·9)	12·0 (11·6–12·2)	9·6 (9·2–10·0)	7·8 (7·3–8·2)
Eastern Europe	22·5 (22·2–23·1)	20·2 (20·2–20·4)	18·2 (17·8–18·4)	16·3 (15·7–16·7)	14·6 (13·8–15·2)
North Africa and Middle East	55·1 (54·2–56·3)	42·7 (41·4–44·2)	33·4 (31·9–35·0)	26·3 (24·7–28·1)	21·0 (19·2–22·9)
Central Asia	65·7 (63·1–69·2)	54·0 (52·0–57·7)	43·3 (41·4–45·6)	34·9 (32·6–37·1)	28·4 (25·5–31·2)
South Asia	109·1 (107·2–111·7)	96·7 (93·6–100·5)	86·2 (82·0–91·2)	77·8 (72·6–84·4)	70·6 (64·5–79·0)
Southeast Asia	49·7 (48·8–50·7)	39·4 (36·7–41·9)	31·3 (27·0–34·7)	24·9 (19·9–28·8)	19·9 (14·8–24·0)
East Asia	36·3 (34·7–38·5)	32·0 (29·4–34·1)	28·0 (24·5–32·3)	24·5 (20·1–30·6)	21·5 (16·5–29·0)
Asia-Pacific high-income	7·6 (7·4–7·9)	5·9 (5·6–6·4)	4·6 (4·2–5·2)	3·7 (3·2–4·2)	2·9 (2·5–3·5)
Oceania	84·7 (79·2–88·9)	81·0 (72·6–90·0)	76·9 (65·0–90·6)	73·0 (58·2–90·9)	69·6 (52·0–91·6)
North America high-income	9·4 (9·2–9·4)	8·1 (8·0–8·3)	7·0 (6·8–7·4)	6·0 (5·7–6·6)	5·2 (4·8–5·9)
Caribbean	30·6 (30·1–31·1)	25·3 (24·4–26·2)	20·8 (19·1–22·1)	16·9 (14·7–18·7)	13·7 (11·3–15·7)
Central America	37·0 (36·4–37·8)	29·5 (28·1–30·6)	23·6 (22·1–24·9)	19·0 (17·5–20·4)	15·2 (13·8–16·8)
Southern America	21·8 (20·6–23·8)	18·0 (16·7–20·1)	14·7 (13·5–16·9)	12·1 (10·9–14·1)	9·9 (8·8–11·9)
Tropical South America	40·3 (39·0–41·8)	31·7 (30·1–33·7)	24·9 (23·1–27·2)	19·6 (17·6–22·0)	15·5 (13·5–17·8)
Andean and Haiti	73·0 (71·7–74·6)	58·9 (56·2–61·6)	47·7 (43·6–51·5)	38·7 (33·7–43·0)	31·4 (26·1–35·9)
West Africa	181·7 (180·0–183·8)	176·5 (172·2–182·3)	171·9 (164·3–182·0)	167·7 (155·9–183·9)	163·6 (147·7–186·4)
Central Africa	211·4 (209·5–212·7)	215·0 (208·4–223·8)	219·2 (206·2–238·9)	223·7 (203·2–255·2)	228·5 (200·4–273·2)
East Africa	145·6 (143·9–147·4)	133·0 (127·7–137·4)	122·3 (113·2–130·2)	113·4 (101·7–124·4)	105·7 (92·2–119·4)
Southern Africa	69·4 (68·5–70·2)	69·0 (67·3–71·0)	69·1 (65·5–74·0)	69·1 (62·6–77·3)	69·2 (59·6–81·0)
World	82·9 (82·2–83·8)	77·3 (76·0–78·8)	72·3 (70·4–74·5)	68·1 (65·5–71·1)	64·7 (61·4–68·7)

Table 2: **Estimated and expected under-5 deaths and under-5 mortality, with uncertainty intervals, by Global Burden of Disease 2005 study subregions and different years (1995–2015)**

We addressed the difficulty of age-heaping in the DHS birth histories with local smoothing algorithms. This approach gives nearly identical results to alternative methods for dealing with age-heaping.[16] We estimated the relation between LnNN and Ln5q0, LnPNN and Ln5q0, and LnCHM and Ln5q0 by independent ordinary least-squares regressions. Regression equations included Ln5q0, $(\text{Ln5q0})^2$, and fixed effects for countries. Predicted values were adjusted so that neonatal, post-neonatal, and childhood mortality rates were consistent with the overall under-5 mortality.

Aggregate death numbers

With the estimated number of births for every country from the UN Population Division 2006 revision, we calculated the number of child deaths for every country in every period. For some small populations not included in the child mortality database, we scaled regional results to the regional total number of births. To generate comparable assessments of aggregate death numbers, especially before 1982 when empirical measurements were not readily available, we used the exact same methods described in the section on forecasting to backcast for every country and every value of α to obtain predictions of under-5 mortality back to 1970. Uncertainty in aggregate numbers has been assessed by drawing one of the 1000 values of under-5 mortality for every country in every year and calculating the regional or global aggregate number of deaths, and then repeating this process 10 000 times.

For presentation reasons, we have used the 20 subregions proposed for the Global Burden of Disease 2005 study,[17] which are a further modification of areas used by WHO. Figure 1 shows the composition of every region. These areas have been designed not only to maximise differences between regions in the levels and age patterns of mortality while minimising differences within regions but also to preserve as far as possible geographic proximity.

Role of the funding source

The funding source had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all study data and had final responsibility for the decision to submit for publication.

Results

Figure 2 shows the proportion of countries with an empirically informed estimate of under-5 mortality by year for six large geographic areas built up from the 20 subregions. The figure extends to 2006 and shows that the lag for measurements, even in high-income countries with complete vital registration systems, is usually 2–3 years. On average, the most recent empirical measurement for Africa is 2000, for Latin America 2002, and for Asia 2002. Only for North America and Europe is the most recent year later than 2002. Despite concerted attempts through internationally funded survey programmes such as DHS and MICS, empirical knowledge of under-5 mortality in some developing regions is 22 years (Liberia) to less than 2 years (Haiti, Honduras, Kazakhstan, Nepal, Ukraine, and Uzbekistan) behind the current period.

Figure 3 (A–D) shows the historical fits and forecasts for four countries. Figure 3A for Mexico indicates how the level of mortality is set by surveys and census results while the trend, particularly from 1990 onwards, is estimated by the vital registration data. The results are reasonably invariant across values of α because child mortality has been declining at a steady pace in Mexico. Malawi, shown in figure 3B, has many survey-based measurements and census estimates with reference dates back to the mid-1950s. For any given time, considerable variation is seen in the measurements of under-5 mortality from different surveys and censuses, indicating both sampling and non-sampling errors. The most recent DHS findings for Malawi imply a rapid decline in under-5 mortality since 2000. Only the low values of α track this recent trend because it is at odds with long-term trends in the data. The trend as estimated based on low values of α could be the real trend; alternatively, some non-sampling error might exist that has affected the most recent DHS results. Figure 3C for Nigeria shows a country with many highly inconsistent measurements for which assessment of past trends is difficult. Measurements for the period around 1990 suggest a range for under-5 mortality of 126–266. In this case, all the values of α are tracking near the mean of the measurements in the dataset. Figure 3D for Equatorial Guinea shows a case for which only one data source over the past 40 years is available. Although values of α do not differ much in view of the paucity of data, the forecasts for every value of α are uncertain, as indicated by the uncertainty intervals in tables 1 and 2. Tables 1 and 2 summarise the number of child deaths estimated and expected for different periods for every region. Careful examination of these country-specific plots provides a very useful visual overview of available evidence for child mortality and its consistency.

For **Global Burden of Disease project** see http://www.globalburden.org/

Figure 4 shows the evolution of the mean estimated value for global under-5 mortality from 1980 to 2015, including 95% uncertainty intervals, and suggests that global child deaths have fallen from 13·5 (13·4–13·6) million in 1980 to 9·7 (9·5–10·0) million in 2005. Based on current trends, the number of child deaths is expected to decline only a further 8% over the next 10 years to reach 9·0 (8·5–9·5) million by the year 2015. The number of child deaths is affected by trends in the underlying rates of under-5 mortality and by the trend in the number of births (expected to increase worldwide from 136 million in 1990 to 138 million in 2015). The

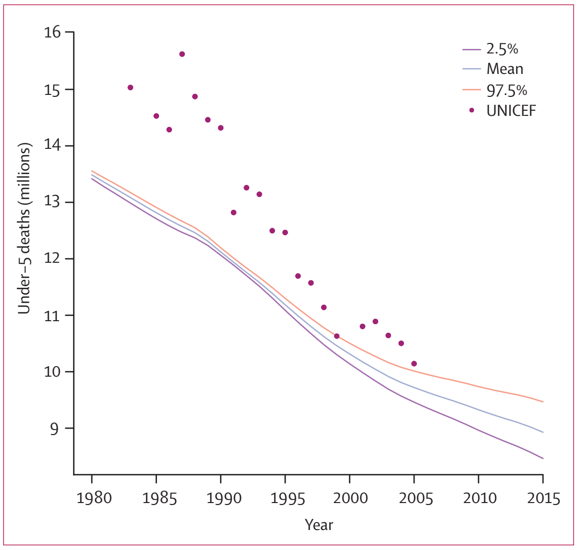

Figure 4: **Estimated time trend of global under-5 deaths, with 95% uncertainty intervals**
Annual UNICEF estimates of this value are plotted in purple.

For **country-specific plots for 172 countries included in the analysis** see http://www.healthmetricsandevaluation.org/

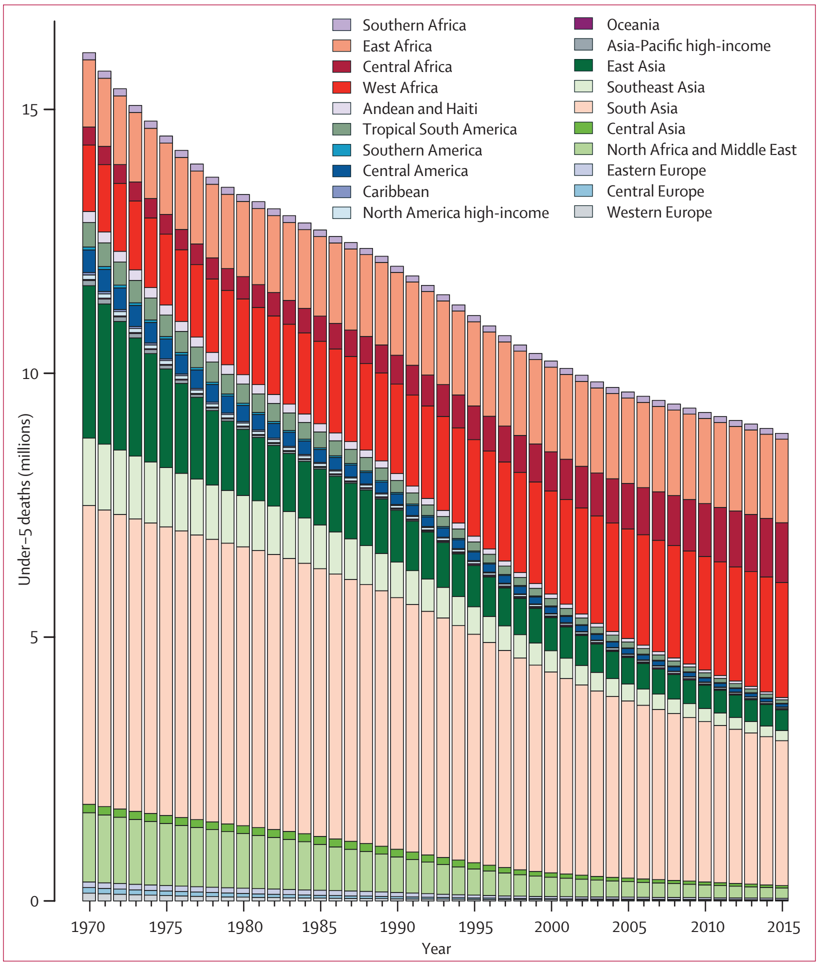

Figure 5: **Regional composition of estimated global time trend in under-5 deaths**

uncertainty intervals widen after 1996 because forecasts are increasingly being used for countries without empirical measurements. At the global level, uncertainty is fairly small, in large part because we have assumed that the correlation in measurement uncertainty across countries is zero. At the regional or country level, however, much wider uncertainty is present in the number of child deaths, particularly for sub-Saharan African regions.

Figure 4 also shows UNICEF estimates of global child deaths for 1983–2005, as reported in every *State of the World's Children* report from 1985 to 2007. These data are not a consistent time series but represent UNICEF's most recent assessment of global child mortality at the time of every annual report; normally, every report gives child death figures for the previous 2 years. Our analysis suggests that during the 1980s, and to a lesser extent in the 1990s, UNICEF seems to have consistently overestimated child mortality—in some years, the overestimate was more than 3·0 million child deaths—and has continued to do so, albeit by a smaller margin than in the 1980s. UNICEF increased its estimates of global child deaths from 1999 to 2002, although our analysis suggests deaths were declining.

Examination of trends in the number of under-5 deaths for the 20 subregions (figure 5) indicates that the expected number of deaths is decreasing in nearly all areas. By 2005, child deaths in the Americas, Europe, and the Middle East accounted for only 7·2% of all child deaths. Particularly impressive declines in the number of deaths have taken place in east Asia and, to a lesser extent, in south Asia. These falls are attributable both to reductions in fertility and decreases in under-5 death rates. Only in the subregions of west, east, and central Africa have the number of deaths risen by more than 25% between 1970 and 2005. This increase is due to slow rates of decline in under-5 mortality, minimal reductions in the total fertility rate, and rising total population. West Africa has very wide uncertainty intervals around the number of child deaths because of the many births in Nigeria and substantial uncertainty about levels and trends of child mortality. By 2015, 56% of all under-5 deaths will be in sub-Saharan Africa, a striking increase from 19% in 1970. Although a 30% decline in the number of child deaths has taken place in south Asia from 1990 to 2005, under-5 deaths in this region are still expected to account for almost a third (31%) of global under-5 deaths in 2015.

Figure 6 shows the estimated level of under-5 mortality in 2005 for every one of the 20 subregions: estimates for other periods are provided in tables 1 and 2. Despite great progress in many regions, the range of values across areas remains substantial, from 219 per 1000 in central Africa to 5 per 1000 in western Europe.

Uncertainty intervals are much larger for neonatal, post-neonatal, and childhood mortality because we have included both uncertainty in the measurement of under-5 mortality and uncertainty in the relation between neonatal, post-neonatal, and childhood mortality and the under-5 death rate. Figure 7 shows the trend in the number of deaths for these three categories from 1970 to 2015. Over this period, the estimated annual number of childhood deaths dropped by 1·7 million (44%), the number of post-neonatal deaths fell by 3·5 million (47%), and the number of neonatal deaths decreased by 1·3 million (26%). Although these trends are based on model predictions and should be interpreted cautiously, seemingly much greater success has been achieved in reducing post-neonatal deaths and, to a slightly lesser extent, childhood deaths than in lowering neonatal deaths. As a result, by 2015, we expect that neonatal deaths will make up 37% of all under-5 deaths, up from 31% in 1970.

Figure 8 (A, B) shows annual rates of change in child mortality calculated for every year for the 20 subregions included in the analysis; regions are shown on two figures to facilitate examination of trends. Over the period 1970–2005, annual rates of decline at the regional level have ranged from more than 8% in Asia-Pacific high-income countries in the early 1970s to an increase of nearly 0·4% in central Africa between 2000 and 2005. From the late 1990s onwards, the 20 regions converge into three groups. 11 areas have rates of decline that are between 3·8% and 5·0%, which puts these regions on or nearly on track to achieve the MDG4 target (to achieve MDG4, the rate of decline must exceed 4·3% per year). These 11 high-performing regions, ordered from the highest rates of reduction down, are: north Africa and the Middle East, tropical South America, Asia-Pacific high-income, southeast Asia, central Asia, central Europe, Central America, western Europe, Andean and Haiti, southern America, and the Caribbean. Five further regions had annual rates of decline of 1·6–2·9% between 2000 and 2005: North America high-income, east Asia, eastern Europe, south Asia, and east Africa. Oceania, west Africa, southern Africa, and central Africa had strikingly lower rates of decline than other regions.

Figure 8 shows that for many regions, the annual rates of reduction in child mortality have been quite consistent over a 35-year period. In the 1970s and early 1980s, an acceleration of decline is seen in some of the high-performing regions, but this increase was small compared with the differences across regions. Sub-Saharan African regions and Oceania showed a pronounced deceleration in rates of decline that began in the 1980s and extended into the middle of the 1990s. In addition to these general patterns, four regions showed striking and abrupt changes in their rates of reduction. Asia-Pacific high-income, which includes South Korea, had a major deceleration from 1970 to 1985, but even after this slowdown they maintained one of the highest rates of decline across regions. East Asia, predominantly China, also showed great deceleration in annual rates of reduction from more than 5% during 1980–85 to less than 3% for the period since 1985. This striking slowdown has been attributed to major changes in the Chinese health system that took place in the early 1980s associated with major economic reforms.[18] In the past 10 years, rates of decline in central Asia have accelerated, and rates of reduction in southern Africa fell sharply around 1990, most probably because of HIV/AIDS in children.

Notwithstanding the temporal patterns for these four regions, the overall picture of stability in the rates of decline of under-5 mortality over long periods, spanning distinctly different global and national policy environments, warrants further analysis. To investigate whether rates of decline have been faster or slower on average in countries with high or low mortality and whether trends are accelerating or decelerating over time, we have regressed country annual rates of change on the level of under-5 mortality, dummy variables for time, and dummy variables for every country. The webtable provides detailed regression results. The coefficient for the level of under-5 mortality is –0.0079 ($p<0·0001$), implying that rates of decline, on average, are higher

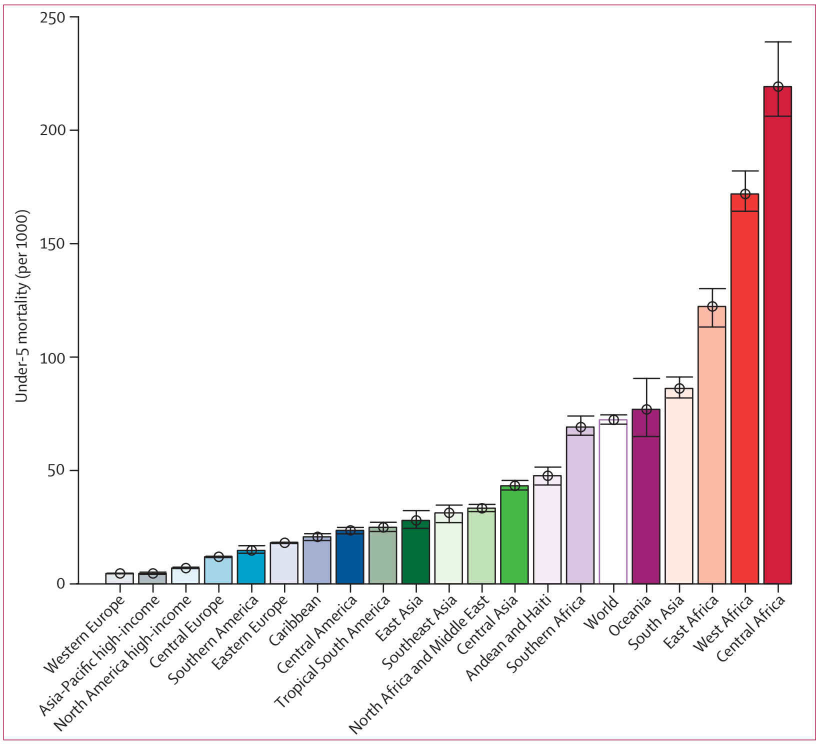

Figure 6: **Estimated level of under-5 mortality in 2005, by region**
Error bars indicate 95% uncertainty intervals.

when child mortality is lower. For example, a country that has an under-5 mortality of 200 per 1000 would, generally, have a rate of decline that is 0·79 percentage points lower than a country with an under-5 mortality of 100 per 1000. Time effects show that rates of reduction decelerated over the period 1970–89 but have remained constant since then, controlling for the relation between under-5 mortality and rate of decline. Most of the variance in annual rates of reduction is captured by the dummy variables for every country; the overall regression has an R^2 of 0·881 but a regression with only country dummy variables has an R^2 of 0·875. In other words, over more than three decades, most of the variation in rates of decline is between rather than within countries. Expressed another way, the annual rate of decline in under-5 mortality in 1970 compared with the rate in 2000 has a correlation coefficient of 0·7.

Table 3 summarises for every country, the mean percentage decline in under-5 mortality over the period 1970–2000; the mean estimated reduction in child mortality from 1990 to 2015; estimates of under-5 mortality for 2005, and the number of neonatal, post-neonatal, and childhood deaths, with uncertainty intervals. Figure 9 shows the expected annual rate of decline from 1990 to 2015 for every country; for comparison, a two-thirds reduction in child mortality from 1990 to 2015 (MDG4 target) is equivalent to an annual rate of decline of 4·3%. The country-specific results suggest that for several regions, remarkable

See Online for webtable

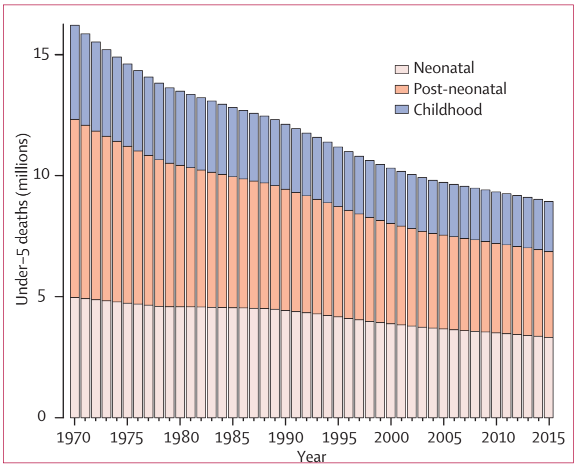

Figure 7: **Age composition of global time trend in under-5 deaths**

homogeneity exists within the region. Exceptions that stand out within regions as having lower rates of decline than neighbouring countries include Guyana, Suriname, and Paraguay. Within south Asia, pronounced differences are evident in rates of reduction between Pakistan, India, and Bangladesh. Afghanistan, included in the central Asian group, is also a clear outlier with an expected rate of decline of only 0·9%. Canada, included with its much larger neighbour the USA in the North America high-income region, has an expected annual rate of decline over the same period of 3·5% compared with 3·0% in the USA. Figure 9 also shows that, although all sub-Saharan African regions are doing poorly compared with the rest of the world, considerable variation exists within Africa. The better performance of east Africa is in large part being driven by the rate of reduction in Ethiopia, expected to be 2·4% annually. The two other large population countries, Nigeria and the Democratic Republic of the Congo, have very low rates of expected decline.

The probability of achieving MDG4 (table 3) has been calculated as the percentage of the full set of forecasts, which capture specification and parameter uncertainty, that yield a decline in under-5 mortality between 1990 and 2015 of greater than 67%. We should stress that the forecasts of under-5 mortality and the probability of achieving MDG4 are forecasts assuming that past trends will continue in the future. As such, they must be seen as business-as-usual forecasts and do not capture what could be achieved through more concerted efforts to reduce child mortality through proven interventions. Although high-income countries are not committed to the MDG4 targets, we have nonetheless calculated for all countries the probability of achieving MDG4. Note that two countries with the same median and mean declines in under-5 mortality could have different probabilities of achieving MDG4 based on the width of the uncertainty interval. Paradoxically, a wider uncertainty interval can increase the estimated probability of achieving MDG4. The distribution of these probabilities is highly bimodal with many countries having zero probability of achieving MDG4, even though some might come close to the expected decline, and many with a very high probability of achieving MDG4. Although the overall distribution of expected decreases from 1990 to 2015 is not bimodal, the fact that we calculate the probability of being below a threshold generates the bimodal pattern seen in table 3.

According to our estimates, 49 countries (17 high-income, 28 middle-income, and four low-income) have a greater than 75% chance of achieving MDG4, and a further 13 countries (three high-income, eight middle-income, and two low-income) currently are expected to achieve a mean or median decline in under-5 mortality of at least 67%. 94 countries (13 high-income, 37 middle-income, and 44 low-income) have a less than 20% chance of meeting the target.

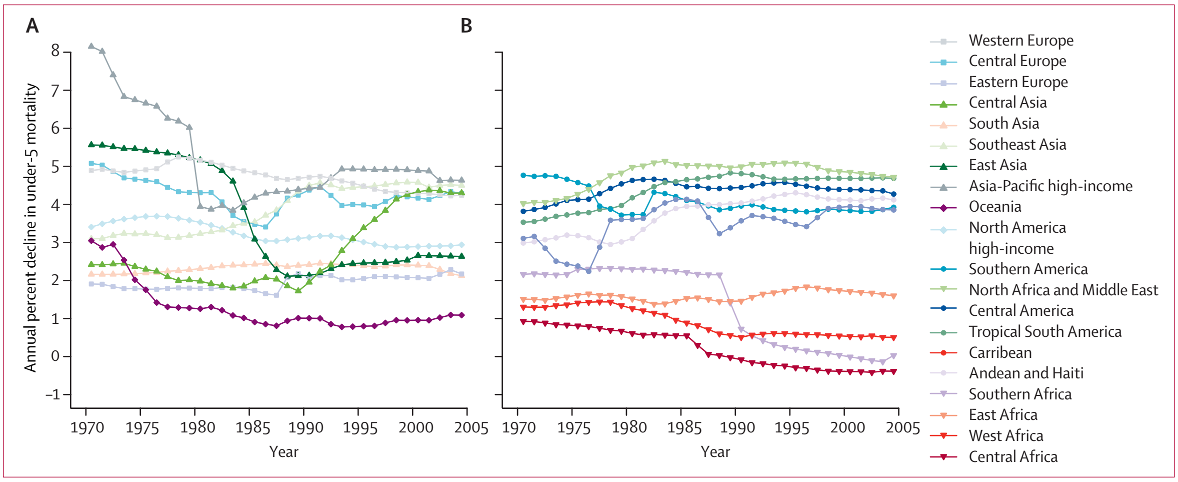

Figure 8: **Annual percentage decline in under-5 mortality by 5-year periods**
(A) European, Asian, Oceania, and North American regions. (B) Central American, South American, and African regions.

	Mean annual percentage decline in under-5 mortality				Probability of achieving MDG4 (%)	Under 5 mortality (2005) per 1000	Deaths in 2005 (thousands)			
	1970–80	1980–90	1990–2000	1990–2015			Under-5	Neonatal	Post-neonatal	Childhood
Afghanistan	0·9	0·9	0·9	0·9 (–0·4 to 1·6)	0	232 (179–383)	278 (215–459)	69 (63–77)	122 (87–233)	87 (64–149)
Albania	5·2	4·9	6·2	6·9 (6·3–7·5)	100	15 (15–16)	1 (1–1)	0 (0–0)	0 (0–0)	0 (0–0)
Algeria	4·1	5·2	5·4	5·4 (4·7–6·1)	99	31 (29–33)	21 (20–22)	10 (10–11)	4 (4–5)	6 (6–7)
Angola	0·5	0·4	0·4	0·4 (–0·5 to 1·7)	0	242 (206–269)	183 (156–203)	40 (38–41)	64 (52–73)	79 (66–89)
Argentina	3·3	3·4	3·5	3·5 (2·9–3·8)	0	17 (16–20)	12 (11–14)	6 (6–7)	3 (3–4)	2 (2–3)
Armenia	3·4	3·2	4	4·1 (3·6–5·2)	33	28 (25–30)	1 (1–1)	1 (0–1)	0 (0–0)	0 (0–0)
Australia	3·6	3·8	3·8	3·7 (3·1–3·9)	0	5 (5–5)	1 (1–1)	1 (1–1)	0 (0–0)	0 (0–0)
Austria	5	5·4	5·2	5 (3·9–5·3)	90	4 (4–5)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Azerbaijan	1·2	1·8	3·5	3·7 (3–5)	26	64 (54–69)	8 (7–9)	3 (3–3)	3 (3–4)	1 (1–2)
Bahamas	1·3	2·7	5	5 (3·5–7·4)	61	10 (7–12)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Bahrain	7·2	6·2	5·9	6·1 (5·4–7·4)	100	7 (6–7)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Bangladesh	1·9	3	4·1	4·1 (3·1–5·8)	43	76 (61–90)	307 (246–364)	136 (117–151)	115 (87–142)	56 (43–69)
Barbados	5·1	4·1	3·4	3·4 (1·2–4·3)	12	11 (10–15)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Belarus	2·5	2·3	2·4	3·5 (2·5–5·2)	29	10 (9–11)	1 (1–1)	1 (0–1)	0 (0–0)	0 (0–0)
Belgium	4·4	4·2	4·6	4·5 (4·3–4·8)	95	5 (5–5)	1 (1–1)	0 (0–0)	0 (0–0)	0 (0–0)
Belize	4·4	4·3	2·9	2·8 (–0·1 to 3·5)	0	16 (15–25)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Benin	1·6	1·6	2·2	2·2 (1·7–3·1)	0	134 (118–140)	46 (40–48)	16 (15–16)	20 (17–21)	10 (8–10)
Bhutan	3	4·2	4·4	4·3 (3·9–4·6)	69	66 (64–70)	1 (1–1)	0 (0–0)	0 (0–0)	0 (0–0)
Bolivia	3·1	3·4	3·6	3·6 (3·2–4·1)	1	67 (63–71)	18 (17–19)	8 (8–8)	6 (6–7)	3 (3–3)
Bosnia and Herzegovina	7·1	7·2	5	5·1 (4·4–5·7)	99	8 (8–9)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Botswana	4·4	3	1·7	1·8 (–1·3 to 3·7)	0	40 (32–70)	2 (1–3)	1 (1–1)	1 (0–1)	0 (0–1)
Brazil	3·7	4·6	4·9	4·9 (4·4–5·5)	97	26 (24–28)	97 (89–104)	52 (49–57)	28 (26–32)	14 (13–16)
Brunei Darussalam	3·9	3·7	3·5	3·6 (2·6–4·9)	10	7 (6–8)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Bulgaria	2·8	2·2	1·5	1·7 (1·2–2·4)	0	15 (14–16)	1 (1–1)	1 (1–1)	0 (0–0)	0 (0–0)
Burkina Faso	1·6	1·6	1·3	1·4 (1–2·3)	0	168 (154–177)	103 (94–109)	32 (31–33)	49 (43–52)	22 (20–24)
Burundi	1·3	0·4	–0·2	0 (–1·5 to 0·8)	0	190 (171–236)	66 (59–82)	19 (18–21)	32 (28–43)	15 (13–19)
Cambodia	3·9	2·6	1·3	2·1 (1·1–4·4)	5	94 (73–98)	35 (27–37)	14 (12–15)	14 (10–15)	7 (5–7)
Cameroon	2·1	1·6	0·7	0·7 (–0·4 to 1·2)	0	128 (120–151)	82 (77–97)	29 (28–32)	36 (33–44)	17 (16–21)
Canada	4·7	4·1	3·6	3·5 (2·1–4)	0	5 (5–6)	2 (2–2)	1 (1–1)	1 (0–1)	0 (0–0)
Cape Verde	2·8	2·7	4·3	4·4 (2·9–5·9)	58	34 (30–39)	1 (0–1)	0 (0–0)	0 (0–0)	0 (0–0)
Central African Republic	2·4	0·9	0·5	0·6 (–1·2 to 1·7)	0	149 (127–195)	23 (20–30)	8 (7–9)	10 (9–15)	5 (4–7)
Chad	0·9	1	0·8	0·9 (0·5–1·8)	0	180 (168–184)	82 (77–84)	25 (24–25)	40 (36–41)	18 (17–19)
Chile	6·7	5·8	6	6·1 (5·2–6·6)	99	8 (7–12)	2 (2–3)	1 (1–2)	1 (1–1)	0 (0–0)
China	5·4	3·6	2·4	2·6 (1·4–3·5)	0	28 (24–32)	491 (421–561)	237 (211–270)	143 (124–169)	108 (94–128)
Colombia	5·1	4·7	3·9	4 (2·4–5·1)	48	18 (15–22)	16 (14–20)	9 (8–11)	5 (4–6)	2 (2–3)
Comoros	1·8	3·9	4·2	4·2 (2·7–7·6)	39	57 (34–68)	2 (1–2)	1 (0–1)	1 (0–1)	0 (0–0)
Congo	–0·7	–0·8	–1·1	–1 (–1·4 to –0·5)	0	122 (120–123)	16 (15–16)	4 (4–5)	6 (6–6)	6 (5–6)
Costa Rica	5·8	5·2	4·8	4·8 (3·8–5·5)	72	12 (11–14)	1 (1–1)	1 (0–1)	0 (0–0)	0 (0–0)
Cote d'Ivoire	2·7	1·8	1·6	1·6 (1–2·3)	0	114 (110–119)	77 (74–80)	29 (29–30)	32 (31–34)	16 (15–16)
Croatia	5·8	5·9	4·5	4·2 (3·5–4·6)	40	7 (7–7)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Cuba	4·6	4·5	4·6	4·6 (4·4–4·8)	81	7 (7–8)	1 (1–1)	0 (0–1)	0 (0–0)	0 (0–0)
Cyprus	5·6	5·3	5	5·2 (4·7–5·8)	100	5 (5–5)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Czech Republic	4·5	4·5	6·4	6·6 (6·3–7)	100	4 (4–4)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Democratic Republic of the Congo	0·8	0·4	–0·5	–1 (–1·4 to 0)	0	218 (210–248)	621 (598–706)	123 (121–127)	261 (248–306)	238 (227–275)
Denmark	3·9	2·9	3·5	3·3 (2·1–3·7)	0	5 (5–5)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Dominican Republic	3·6	3·9	4·9	4·9 (4·8–5·9)	96	28 (24–29)	6 (6–7)	3 (3–4)	2 (2–2)	1 (1–1)
Ecuador	4·2	5·2	4·9	5 (4·5–5·3)	99	25 (25–28)	7 (7–8)	4 (4–4)	2 (2–2)	1 (1–1)
Egypt	4·4	5·6	6	6 (5·6–6·5)	100	36 (34–39)	65 (61–70)	34 (33–36)	20 (19–22)	10 (10–11)
El Salvador	4	5·8	6·2	6·3 (5·5–7·3)	100	22 (20–25)	4 (3–4)	2 (2–2)	1 (1–1)	1 (0–1)
Equatorial Guinea	–1·1	–1·2	–1·3	–1 (–1·7 to 0)	0	207 (178–220)	4 (3–4)	1 (1–1)	1 (1–1)	2 (1–2)
Eritrea	3·3	3·2	4·8	4·8 (3·8–6·5)	76	71 (55–80)	12 (10–14)	4 (4–5)	4 (3–5)	4 (3–4)

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Estonia	2·7	2·5	4·4	5·2 (4·2–6·6)	88	8 (7–9)	0 (0–0))	0 (0–0)	0 (0–0)	0 (0–0)
Ethiopia	1·5	2	2·4	2·4 (0·6–4·7)	5	120 (86–145)	370 (265–447)	137 (112–151)	158 (103–201)	75 (50–94)
Fiji	5·8	5·2	2·1	2 (–0·2 to 3·4)	1	15 (13–21)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Finland	5	3·9	4·2	4·1 (3·7–4·4)	32	3 (3–4)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
France	4	3·9	4·2	4·2 (3·9–4·4)	22	4 (4–5)	3 (3–4)	2 (2–2)	1 (1–1)	1 (1–1)
Gabon	3·2	2·6	1·3	1·4 (0·6–2·1)	0	76 (70–83)	3 (2–3)	1 (1–1)	1 (1–1)	0 (0–1)
Gambia	3	3·1	2·6	2·6 (0·8–3·4)	0	102 (95–139)	6 (6–8)	2 (2–2)	2 (1–2)	2 (2–3)
Georgia	4·2	4·1	2·2	1·9 (0·2–3·1)	0	38 (34–45)	2 (2–2)	1 (1–1)	1 (1–1)	0 (0–0)
Germany	5·4	5·4	4·7	4·3 (3–4·9)	62	4 (4–5)	3 (3–4)	2 (1–2)	1 (1–1)	1 (1–1)
Ghana	1·7	2·1	1·7	1·7 (0·7–1·9)	0	92 (90–105)	64 (62–73)	26 (26–29)	25 (24–30)	12 (12–14)
Greece	4·7	5·4	5·2	5·3 (5–6·2)	100	5 (4–5)	1 (0–1)	0 (0–0)	0 (0–0)	0 (0–0)
Guatemala	3·5	4·4	4·5	4·5 (4–5)	64	38 (36–42)	17 (16–18)	9 (8–9)	5 (5–6)	3 (2–3)
Guinea	1·3	2·2	3·3	3·3 (2·5–4·4)	8	136 (116–153)	50 (42–56)	17 (16–18)	22 (18–26)	10 (9–12)
Guinea-Bissau	–0·1	–0·1	1·8	1·9 (0·7–3·2)	0	193 (161–226)	15 (12–18)	4 (4–4)	5 (4–6)	6 (5–7)
Guyana	1·5	1·5	1·1	1·1 (–0·4 to 2·6)	0	74 (61–88)	1 (1–1)	0 (0–1)	0 (0–1)	0 (0–0)
Haiti	1·7	2·8	3·3	3·4 (2·8–4·6)	11	87 (77–94)	23 (21–25)	10 (9–10)	9 (8–10)	4 (4–5)
Honduras	4·4	4·8	4·6	4·7 (4·3–4·7)	97	29 (29–30)	6 (6–6)	3 (3–3)	2 (2–2)	1 (1–1)
Hungary	4·1	4·3	4·7	4·7 (4·5–5·3)	98	8 (8–8)	1 (1–1)	0 (0–0)	0 (0–0)	0 (0–0)
Iceland	4·2	4·3	4·5	4·6 (4·4–5·7)	83	3 (3–3)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
India	2·4	2·5	2·7	2·7 (2·5–3)	0	77 (74–79)	2103 (2021–2157)	928 (899–938)	792 (747–810)	388 (367–396)
Indonesia	3·2	3·5	4·5	4·6 (3·8–6·6)	50	43 (33–48)	192 (148–215)	98 (79–107)	62 (46–71)	31 (23–35)
Iran (Islamic Republic of)	3·9	4·5	4·6	4·6 (4·3–5·1)	96	39 (37–40)	52 (50–54)	26 (25–27)	16 (15–16)	10 (9–10)
Iraq	3·2	2·1	2·3	2·3 (1·7–2·8)	0	44 (41–50)	41 (39–47)	21 (19–23)	11 (10–13)	9 (8–11)
Ireland	4·4	4·3	3·6	3·6 (2·2–3·9)	0	5 (5–6)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Israel	5·3	4·8	4·8	4·6 (3·9–4·8)	83	5 (5–6)	1 (1–1)	0 (0–0)	0 (0–0)	0 (0–0)
Italy	5·8	5·4	5·3	5·3 (5–5·5)	100	4 (4–4)	2 (2–2)	1 (1–1)	1 (1–1)	0 (0–0)
Jamaica	4·9	4·7	4	4 (2·3–4·7)	49	11 (11–15)	1 (1–1)	0 (0–0)	0 (0–0)	0 (0–0)
Japan	5·8	4·6	4·3	4·3 (3·6–5·1)	49	4 (3–4)	4 (3–4)	2 (2–2)	1 (1–1)	1 (1–1)
Jordan	5	4·5	4·4	4·4 (3·7–4·8)	69	19 (18–21)	3 (3–3)	2 (1–2)	1 (1–1)	0 (0–0)
Kazakhstan	1·7	1·7	2·6	3·2 (2·5–4·4)	4	34 (31–35)	9 (8–9)	5 (4–5)	3 (3–3)	1 (1–1)
Kenya	2·5	1·2	0·4	0·4 (–1·1 to 1·5)	0	96 (80–119)	131 (109–162)	53 (48–60)	52 (42–69)	25 (20–33)
Kuwait	6·6	3·9	4·3	4·5 (3·3–5)	77	10 (9–12)	0 (0–1)	0 (0–0)	0 (0–0)	0 (0–0)
Kyrgyzstan	3	3·1	3·2	3·3 (2·7–3·7)	0	48 (46–53)	5 (5–6)	3 (3–3)	2 (2–2)	1 (1–1)
Lao Peoples Democratic Republic	2·5	2·7	3·7	3·7 (2·6–5·6)	15	84 (66–95)	13 (10–15)	5 (4–5)	5 (4–6)	3 (3–4)
Latvia	1	0·9	1·7	2 (1·4–3·3)	0	13 (12–14)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Lebanon	2·1	1·2	1·4	1·4(0·1–3·2)	1	33 (26–39)	2 (2–3)	1 (1–1)	1 (1–1)	0 (0–1)
Lesotho	2·5	2·2	1·3	1·3(–0·6 to 1·9)	0	79 (76–106)	5 (5–6)	2 (2–2)	2 (1–2)	1 (1–2)
Liberia	1	1·2	1·2	1·2 (0·4–2·5)	0	173 (125–201)	30 (21–34)	9 (8–10)	14 (9–17)	6 (4–8)
Libyan Arab Jamahiriya	6·9	6·7	6·7	6·7 (5·8–7·6)	100	12 (10–14)	2 (1–2)	1 (1–1)	0 (0–1)	0 (0–0)
Lithuania	2·5	2·4	3·6	4·2(3·4–5·3)	37	9 (8–9)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Luxembourg	4·6	4·6	4·9	4·8 (4·1–5·2)	94	4 (4–4)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Madagascar	0·3	1·1	3	3·1 (1·9–5)	18	96 (76–111)	67 (53–77)	27 (23–30)	27 (20–32)	13 (10–15)
Malawi	2·1	2·3	2·9	3·4 (2·5–6)	19	134 (100–143)	74 (55–79)	26 (22–27)	33 (22–35)	15 (11–17)
Malaysia	5·8	5·7	5·8	5·8 (5·6–6)	100	6 (6–7)	3 (3–4)	2 (2–2)	1 (1–1)	1 (1–1)
Maldives	5·4	5·4	7·1	7·4 (6·8–8)	100	34 (33–36)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Mali	2	2	1·6	1·6 (0·9–2)	0	191 (182–210)	105 (100–115)	30 (30–31)	51 (48–58)	23 (22–26)
Malta	4·4	4·1	4·1	4·1 (3·8–4·3)	4	6 (6–6)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Mauritania	3·1	2·1	1·5	1·4 (0–2·2)	0	99 (91–117)	10 (9–12)	4 (4–4)	4 (4–5)	2 (2–2)
Mauritius	5·3	4·8	4	4 (3·3–4·3)	40	14 (13–16)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Mexico	4·1	4·4	4·7	4·6 (4·5–5)	96	23 (20–23)	49 (43–49)	27 (24–28)	14 (13–15)	7 (7–8)
Mongolia	2·9	2·9	6·1	6·5 (5·6–7·7)	100	40 (34–43)	2 (2–2)	1 (1–1)	1 (1–1)	0 (0–0)
Morocco	3·4	4·4	4·5	4·4 (3·9–5·1)	65	42(40–44)	26 (25–28)	14 (13–14)	9 (8–9)	4 (4–5)
Mozambique	0·4	0·5	1·8	2 (0·8–4·4)	4	172 (120–190)	145 (101–161)	45 (38–46)	69 (43–79)	32 (21–36)
Myanmar	1·9	1·5	1·6	0·9 (0·4–1·5)	0	99 (92–106)	90 (84–96)	39 (37–41)	25 (23–27)	26 (23–28)
Namibia	1·6	2·6	2·4	2·3 (0·6–3·3)	0	47 (44–59)	3 (2–3)	1 (1–1)	1 (1–1)	0 (0–1)

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Nepal	2·1	3·2	4·7	4·9 (3·6–6·9)	58	66 (52–79)	52 (41–62)	24 (20–27)	19 (14–24)	9 (7–12)
Netherlands	3·3	3·5	3·8	3·5 (1·8–4·1)	1	4 (4–5)	1 (1–1)	0 (0–1)	0 (0–0)	0 (0–0)
New Zealand	2·9	3·4	3·7	3·7 (3·3–4·2)	2	6 (6–7)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Nicaragua	4·1	4·9	4·8	4·8 (4·5–5·7)	99	30 (26–31)	4 (4–4)	2 (2–2)	1 (1–1)	1 (1–1)
Niger	0·6	0·5	2·2	2·3 (1·5–3·5)	0	209 (183–238)	136 (119–155)	37 (35–38)	68 (58–81)	31 (26–36)
Nigeria	0·8	0·2	–0·3	0 (–1·2 to 0·2)	0	193 (182–215)	1113 (1049–1240)	318 (311–331)	546 (507–628)	248 (232–281)
Norway	3·6	3·5	4·2	4 (3·9–4·6)	24	4 (4–4)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Oman	12	11·4	10·6	11 (9·5–12)	100	5 (4–6)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Occupied Palestinian Territory	3·7	3·8	2·9	2·7 (1·6–3·3)	0	26 (25–28)	4 (3–4)	2 (2–2)	1 (1–1)	1 (1–1)
Pakistan	1·6	1·3	1	1 (0–1·5)	0	111 (105–127)	473 (447–541)	182 (176–195)	198 (184–234)	95 (89–111)
Panama	3·8	3·4	2·6	2·5 (1·5–3·4)	0	22 (19–25)	2 (1–2)	1 (1–1)	0 (0–1)	0 (0–0)
Papua New Guinea	1·7	1	1·1	1·1 (0·1–2·1)	0	84 (71–99)	16 (14–19)	6 (5–7)	6 (5–7)	4 (3–5)
Paraguay	2·4	2·8	2·8	2·9 (1·5–3·4)	0	26 (26–36)	4 (4–5)	2 (2–3)	1 (1–2)	1 (1–1)
Peru	3·5	4·4	5·6	5·6 (4·5–7·7)	99	31 (24–38)	18 (14–22)	10 (8–12)	6 (4–7)	3 (2–4)
Philippines	1·6	2·9	4·1	4·1 (3·3–5)	38	31 (27–34)	70 (61–77)	38 (33–41)	21 (18–24)	11 (9–12)
Poland	4·1	3·9	4·7	4·9 (4·5–6·1)	82	8 (7–8)	3 (3–3)	1 (1–1)	1 (1–1)	0 (0–0)
Portugal	6·9	6·9	6·8	6·8 (6·7–7)	100	5 (5–5)	1 (1–1)	0 (0–0)	0 (0–0)	0 (0–0)
Qatar	2·8	3·1	2·9	2·8 (2·4–3·6)	0	18 (15–18)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Republic of Korea	8·4	4	5	5·3 (3·7–6·2)	89	7 (6–9)	3 (3–4)	2 (1–2)	1 (1–1)	1 (1–1)
Republic of Moldova	4·1	3·9	4·1	4·5 (3·7–6·2)	50	18 (14–18)	1 (1–1)	0 (0–0)	0 (0–0)	0 (0–0)
Romania	3	2·6	2·5	2·5 (2·4–2·7)	0	26 (26–27)	6 (6–6)	3 (3–3)	2 (2–2)	1 (1–1)
Russian Federation	1·8	1·7	2·1	2 (2–2·2)	0	20 (20–21)	29 (29–31)	16 (16–16)	9 (9–9)	5 (5–5)
Rwanda	0·5	0·9	0·5	0·4 (–0·6 to 0·8)	0	168 (164–197)	65 (63–76)	20 (20–21)	31 (30–38)	14 (14–17)
Saint Lucia	5·2	4·4	3·2	3·3 (2·9–3·5)	0	14 (14–15)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Saint Vincent and Grenadines	4·8	5·4	3·3	3·1 (1·5–3·9)	10	17 (15–21)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Sao Tome and Principe	1·1	0	–0·6	0 (–1·5 to 1·6)	0	131 (103–149)	1 (1–1)	0 (0–0)	0 (0–0)	0 (0–0)
Saudi Arabia	10·1	8·2	7·1	7·2 (2·2–9·9)	93	9 (6–21)	5 (4–13)	3 (2–7)	2 (1–4)	1 (1–2)
Senegal	3·2	3·2	2·2	2·2 (1·2–2·6)	0	104 (96–120)	44 (41–51)	17 (17–19)	18 (16–22)	9 (8–10)
Serbia and Montenegro	6	6·1	6·2	6·2 (5·5–6·8)	100	10 (10–11)	1 (1–1)	1 (1–1)	0 (0–0)	0 (0–0)
Sierra Leone	1·3	1	0·6	0·6 (–0·7 to 0·9)	0	254 (245–308)	63 (61–76)	13 (13–14)	22 (21–29)	27 (26–34)
Singapore	6	6	6	5·9 (5·2–6·2)	100	3 (3–3)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Slovakia	4·1	4·1	4·1	3·7 (1·9–4·3)	2	8 (8–9)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Slovenia	6·3	6·3	6·3	6 (5·3–6·4)	100	4 (4–4)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Somalia	0·2	–0·4	–0·2	0·1 (–1·5 to 2·8)	0	220 (151–262)	79 (54–94)	20 (18–21)	34 (21–43)	24 (16–30)
South Africa	2·1	2·2	–0·2	0 (–0·9 to 0·2)	0	69 (66–73)	77 (73–81)	35 (34–36)	28 (27–30)	14 (13–15)
Spain	5·2	5	5	4·9 (4·6–5·2)	100	4(4–4)	2 (2–2)	1 (1–1)	1 (1–1)	0 (0–0)
Sri Lanka	4·7	5·2	5·3	5·3 (5–5·9)	100	12(11–13)	4 (3–4)	2 (2–2)	1 (1–1)	1 (1–1)
Sudan	1·3	1·6	1·8	1·8 (1·1–3·5)	0	94 (71–102)	114 (86–124)	47 (39–49)	46 (32–50)	22 (16–24)
Suriname	2·7	1·6	0·4	0·5 (–1·3 to 1·9)	0	28 (24–37)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Swaziland	2·4	2·4	2·3	2·3 (0·6–3·5)	1	81 (68–100)	3 (2–3)	1 (1–1)	1 (1–1)	1 (1–1)
Sweden	3·8	3·4	3·9	3·7 (3–4·1)	2	3 (3–4)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Switzerland	4·4	3·5	3·5	3·4 (2·7–3·7)	0	5 (4–5)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Syrian Arab Republic	4·8	4·4	4·3	4·2 (3·4–4·7)	50	24 (23–25)	12 (12–13)	6 (6–7)	3 (3–4)	2 (2–2)
Tajikistan	2·7	2·3	4·1	4·9 (3·9–6·5)	82	60 (53–64)	11 (10–12)	5 (4–5)	5 (4–5)	2 (2–2)
TFYR Macedonia	6·4	6·3	7·8	7·9 (7·5–8·4)	100	11 (10–11)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Thailand	5·1	5·6	4·6	4·5 (0·4–5·8)	67	14 (13–26)	13 (12–25)	7 (7–14)	4 (3–7)	2 (2–4)
Timor Leste	2·8	2·8	3·6	3·6 (2–5)	17	108 (96–126)	5 (4–5)	2 (2–2)	1 (1–2)	1 (1–2)
Togo	2·3	1·8	1·8	1·8 (0·6–2·8)	1	110 (98–131)	26 (23–31)	10 (9–11)	11 (9–13)	5 (5–6)
Trinidad and Tobago	3·5	2·5	1·9	2 (–1·4 to 3·6)	1	20 (16–42)	0 (0–1)	0 (0–0)	0 (0–0)	0 (0–0)
Tunisia	5·5	5·5	5·3	5·3 (4·8–5·7)	100	23 (22–25)	4 (4–4)	2 (2–2)	1 (1–1)	1 (1–1)
Turkey	3·6	4·9	5	5 (4·1–6·5)	78	34 (29–42)	47 (40–58)	25 (22–30)	15 (12–19)	7 (6–9)
Turkmenistan	2·7	2·6	2·6	2·9 (1·7–4·6)	4	66 (57–78)	7 (6–8)	3 (3–3)	3 (3–4)	1 (1–2)
Uganda	0·6	1·2	1·3	1·3 (0·9–1·8)	0	136 (123–141)	181 (163–187)	63 (60–64)	80 (70–84)	38 (33–39)
Ukraine	1·8	1·8	1·8	2·4 (1·8–3·2)	0	13 (12–14)	5 (5–6)	3 (3–3)	2 (1–2)	1 (1–1)

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United Arab Emirates	8·1	7·6	7·2	7·2 (5·8–8)	100	6 (5–7)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
UK	3·5	3·9	3·7	3·6 (3–3·8)	0	5 (5–6)	4 (4–4)	2 (2–2)	1 (1–1)	1 (1–1)
United Republic of Tanzania	1·8	1·2	1·7	1·9 (1·4–3·5)	0	121 (97–124)	187 (150–192)	69 (61–70)	80 (60–83)	38 (29–39)
USA	3·5	3·2	3	3 (2·5–3·1)	0	7 (7–8)	29 (29–33)	16 (16–17)	9 (9–9)	5 (5–5)
Uruguay	3·1	4·2	3·8	3·9 (3·6–4·1)	2	14 (13–14)	1 (1–1)	0 (0–0)	0 (0–0)	0 (0–0)
Uzbekistan	1·7	1·3	3	4 (3·5–4·5)	22	34 (34–40)	21 (21–24)	11 (11–13)	7 (6–8)	3 (3–4)
Vanuatu	3·4	3·6	1·5	1·3 (0·4–1·7)	0	43 (41–47)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Venezuela	3·8	3	3·3	3·3(2·8–3·6)	0	18 (18–23)	11 (11–14)	6 (6–8)	3 (3–4)	2 (2–2)
Vietnam	2·5	2·9	5·3	5·4 (4·1–7·6)	84	23 (17–27)	38 (28–45)	21 (15–24)	11 (8–13)	6 (4–7)
Yemen	4·1	3·5	2·8	2·9 (1·7–3·5)	0	88 (81–101)	71 (65–81)	30 (28–32)	27 (25–33)	13 (12–16)
Zambia	0·9	–0·1	0	0·1 (–0·4 to 0·4)	0	164 (156–177)	76 (72–82)	24 (23–25)	36 (33–39)	16 (16–18)
Zimbabwe	2·4	2	0·6	0·5 (–0·9 to 1·3)	0	67 (63–85)	25 (23–32)	11 (11–13)	9 (8–12)	4 (4–6)

Table 3: Country-specific summary of mean estimated decline in child mortality and 2005 estimates of under–5 mortality and number of deaths, with uncertainty intervals

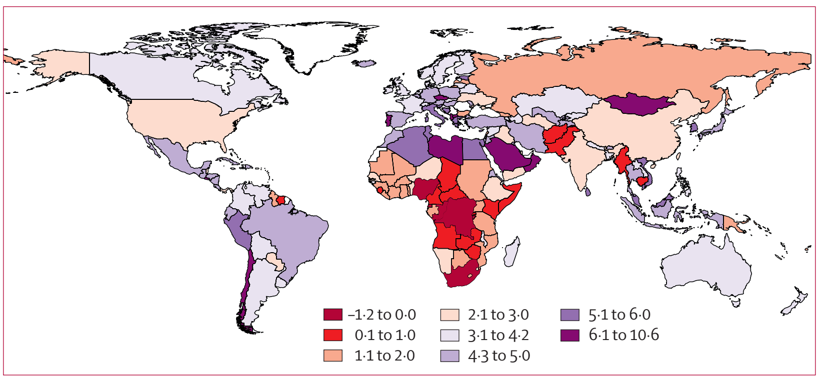

Figure 9: Expected annual percentage decline in under-5 mortality over the period 1990–2015

Discussion

Globally, the risk of child death (under-5 mortality) has declined from 110 (109–110) per 1000 in 1980 to 73 (70–75) per 1000 in 2005 based on empirical calculations and predictions beyond the latest available measurement. In terms of numbers, global child deaths have decreased from 13·5 (13·4–13·6) million in 1980 to an estimated 9·7 (9·5–10·0) million in 2005. Based on empirically observed trends, the under-5 death rate for the world is expected to fall by 27% from 1990 to 2015. This reduction is substantially less than the MDG4 goal of a 67% decline. This rate of decline represents an annual decrease of 1·3%, which is substantially slower than the 2·2% rate of reduction recorded for the world between 1970 and 1985. Most regions of the world are undergoing declines that are considerably faster than 1·3%, but areas with the slowest rates of reduction in fertility (sub-Saharan Africa) also have the slowest rates of decline in child mortality.

Although we can easily identify that the main challenge for globally achieving MDG4 is in sub-Saharan Africa, as previously recognised by WHO and UNICEF,[19,20] for the world as a whole, we are not doing a better job of reducing child mortality now than we were doing two or three decades ago. The renewed commitment to enhancing child survival through mechanisms such as GAVI (Global Alliance for Vaccines and Immunisation) or increasing global attention on achieving MDG4 might be working, but it is too early to tell from real data for levels of child mortality.

Consistently high rates of decline in under-5 mortality for nearly all countries in Central and South America, the Middle East, and southeast Asia need explanation. With case studies of child mortality, researchers have looked at individual countries[6,21–25] and proposed explanations that emphasise national policy initiatives and other determinants. Common patterns in Latin America and the Middle East raise the possibility that specific regional convergence has taken place of various policies and practices, perhaps mediated through common language, regional institutions, or informal policy networks. Alternatively, some other factors might have been shared across these regions, such as educational or environmental policies or the key driver of mortality change—accumulation of stocks of household, community, and national physical and human capital.[26] Considerably more research would be needed to investigate effectively the possibility of such regional policy effects. By contrast, the strikingly divergent patterns for Pakistan, India, and Bangladesh, with expected annual rates of decline from 1990 to 2015 of 1·0%, 2·7%, and 4·1%, respectively, are noteworthy. When diversity of rates of decline happens within regions with similar culture, history, and institutions, opportunities could exist to identify effective policy adoption and implementation.

The poor performance of west, central, southern, and many parts of east Africa in the 1990s has been variously attributed in part to the HIV epidemic, to conflict, or to rising malaria drug resistance.[27–29] The worst rates of decline in central Africa are mainly driven by the large population in the Democratic Republic of the Congo, where conflict has led to increased mortality.[14] In east Africa, rates of decline are increasing at the same time as the HIV epidemic unfolds, which does not support the contention that malaria drug resistance is driving child mortality rates up. The absence of population-based data for cause of death at the national level for nearly all countries in sub-Saharan Africa restricts direct empirical investigation of the role of malaria drug resistance in accounting for child mortality trends. Further investment in measurement of cause-specific mortality in sub-Saharan Africa is urgently needed if these important policy questions are to be answered.

Accelerated declines in Madagascar, Malawi, Mozambique, Niger, and Tanzania, based on DHS data, raise several questions. First, are these declines real? Could they be an artefact of decreasing quality of the DHS owing to a longer, more complex methodology or because of poor implementation in these countries? Alternatively, is mortality attributable to HIV removing mothers whose children are at high risk of death from the population to be surveyed? Since the levels of adult mortality now being recorded in eastern and southern Africa are unprecedented, the robustness of the birth history in this context has been examined by simulation studies.[30] These findings suggest that the bias for DHS-style direct birth histories could be less than 7% underestimation. If, in subsequent surveys, these declines turn out to be real, what might be the reason for a rate of reduction that has not been noted in sub-Saharan Africa before? Are GAVI, the Global Fund to Fight AIDS, Tuberculosis and Malaria, and other global-health initiatives having an effect in these, but not other, sub-Saharan African countries? One intervention that has been rapidly scaled up in sub-Saharan Africa according to the MICS surveys is vitamin A supplementation. UNICEF estimates that 37 countries had levels of coverage greater than 75% in children aged 6–59 months in 2004. Resolving both the validity and potential causes of the declines in these five countries is vital, not only for monitoring of child health but also for assessment of the effect of various global strategies and initiatives.

This study has several important limitations. First, we cannot know how many data sources exist in low-income and middle-income countries that have not been included in our analysis. As existing datasets come to light and new ones are produced, historical trends and the conclusions based on these trends might need to be revised. Second, the large non-sampling error present in some countries such as Nigeria, even for high-quality survey programmes, remains unexplained. Without a better understanding of why such large errors arise, forecasts based on recent time trends could overestimate or underestimate probable trends. Finally, our forecasts, which are based on recent time trends, do not indicate in any way what can be achieved by intensified efforts to reduce child mortality in low-income and middle-income countries.

Several differences in our results for 2004 compared with those reported by Bryce and colleagues[10] based on UNICEF estimates are noteworthy. The correlation for 1990 between our estimates and those of UNICEF is 0·99 and that for 2004 is 0·97. In terms of percentage change in under-5 mortality from 1990 to 2004, the correlation between those reported by UNICEF in 2006 and what is reported here falls to 0·66. Our mean percentage decline is 36% and theirs is 29%. The correlation for percentage changes from 1990 to 2005 with UNICEF figures published in *State of the World's Children 2007* drops to 0·27. Applying a criterion of greater than 50 000 child deaths in 2004 or an under-5 mortality greater than 90, Bryce and colleagues identify 60 priority countries for the Countdown effort. The Child Survival Countdown is "a worldwide effort to monitor coverage of key child-survival interventions in 60 countries with the world's highest numbers or rates of child mortality".[10] Applying the same criteria to our estimates of child mortality we identify 53 priority countries. Nine are included in Bryce's priority set but do not meet the same criteria in our dataset: Azerbaijan, Botswana, Gabon, Iraq, Papua New Guinea, Swaziland, Tajikistan, Turkmenistan, and Zimbabwe. For all these countries, except Papua New Guinea, we find much faster rates of decline than UNICEF; for Botswana, Iraq, Swaziland, Turkmenistan, and Zimbabwe we actually note trends of the opposite sign. Only three countries are included in our priority set but not in the Countdown list: Iran, Sao Tome and Principe, and Timor Leste. Finally, Djibouti, which Bryce and colleagues assign priority status, is not included in our study owing to data limitations.

This study has shown that, in the case of populations such as Iran, Mexico, India, and China, many more local surveys, sample registration data, and census data are available for child mortality that are not being captured in UNICEF or WHO databases. For these four countries, we know about these data sources through direct collaborations, but most probably other data sources are available in many, if not all, countries that are not being included in international databases. A key challenge, therefore, is to ensure that all available evidence is used for global monitoring. The newly formed Institute for Health Metrics and Evaluation (IHME) will work alongside others such as UNICEF and WHO to create an enriched global data bank to support development of better monitoring and evaluation in global health. The challenge is how best to systematically collect, compile, analyse, and share data by making the most of existing channels and by facilitating collaborations with countries where routine reporting to the international agencies is not working well. How can the global community harness extensive local knowledge of demographers, epidemiologists, public-health researchers, and government statisticians that exists in many, if not all, developing countries? One model is to try and foster a community of analysts working on these issues, for which the pros and cons of different datasets and analyses are openly debated and discussed. Noting the success of various user-driven internet efforts, the IHME will host an internet-based environment to stimulate and respond to criticism, analysis, and alternative interpretations. As a first step in encouraging this global debate, we are making available in full all aspects of our analysis country by country. We firmly believe that evidence on

For **IHME** see http://www.healthmetricsandevaluation.org/

levels and trends in child mortality is a global public good and that the entire worldwide public-health community will benefit from more concerted efforts to enhance it. Since the methods proposed in this report are easy to implement, we plan to update our assessment of child mortality levels and trends since 1970 and forecasts to 2015 every 3 months and make these available for public comment and debate.

Here, we have tried to systematically analyse all internationally available data for child mortality and to apply entirely transparent and replicable methods. Although this work could be improved by incorporation of the many data sources that must exist in various countries, substantial additional improvement in our knowledge about child mortality will require better primary data collection. The analysis clearly shows the power of a well-functioning vital registration system that provides periodic and timely information on trends in child mortality.[31] Initiatives such as the Health Metrics Network, which will assist countries in strengthening vital registration systems for both child and adult mortality, must be a key priority for the global-health development community and should be accorded equal priority to the improvement of other aspects of the health system.

Contributors

CJLM had the idea for the study, played a key part in methodological development and analysis of data, and wrote the report. TL undertook primary data analysis for the study and did the forecasting calculations. KS participated in data analysis and writing of the report. KH had a role in methodological development and in writing of the report. ADL contributed to the analytical plan for the report and assisted with interpretation of results and writing of the report. All authors read and approved the final version of the report.

Conflict of interest statement

CJLM is institute director of the Institute for Health Metrics and Evaluation and is a former executive director of the Evidence and Information for Policy Cluster at WHO. ADL was formerly coordinator of the Epidemiology and Burden of Disease Unit at WHO and is an affiliate professor of the Institute for Health Metrics and Evaluation.

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