Changes in Child Mortality Over Time Across the Wealth Gradient in Less-Developed Countries

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KEY WORDS
child mortality, health disparities, wealth inequalities, global health

ABBREVIATIONS
CI—confidence interval
DHS—Demographic and Health Surveys
GDPpc—gross domestic product per capita
LMICs—low- or middle-income countries
MDGs—Millennium Development Goals
TFR—total fertility rate
5q0—probability of dying before reaching age 5 per 1000 live births

Dr Bendavid had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. He also conceived and designed the analysis, acquired and analyzed the data, and drafted and revised the manuscript.

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WHAT'S KNOWN ON THIS SUBJECT: In developed countries, child health disparities across wealth gradients are commonly widening; at the same time, child mortality in low- and middle-income countries is declining. Whether these declines are associated with widening or narrowing disparities is unknown.

WHAT THIS STUDY ADDS: A systematic analysis of the evidence on child mortality gradients by wealth in less-developed countries shows that mortality is declining fastest among the poorest in most countries, leading to declining disparities in this important indicator of child health.

abstract

BACKGROUND: It is unknown whether inequalities in under-5 mortality by wealth in low- and middle-income countries (LMICs) are growing or declining.

METHODS: All Demographic and Health Surveys conducted between 2002 and 2012 were used to measure under-5 mortality trends in 3 wealth tertiles. Two approaches were used to estimate changes in under-5 mortality: within-survey changes from all 54 countries, and between-survey changes for 29 countries with repeated survey waves. The principal outcome measures include annual decline in mortality, and the ratio of mortality between the poorest and least-poor wealth tertiles.

RESULTS: Mortality information in 85 surveys from 929 224 households and 1 267 167 women living in 54 countries was used. In the subset of 29 countries with repeat surveys, mortality declined annually by 4.36, 3.36, and 2.06 deaths per 1000 live births among the poorest, middle, and least-poor tertiles, respectively (P = .031 for difference). The mortality ratio declined from 1.68 to 1.48 during the study period (P = .006 for trend). In the complete set of 85 surveys, the mortality ratio declined in 64 surveys (from 2.11 to 1.55), and increased in 21 surveys (from 1.58 to 1.88). Multivariate analyses suggest that convergence was associated with good governance ($P \leq .03$ for 4 governance indicators: government effectiveness, rule of law, regulatory quality, and control of corruption).

CONCLUSIONS: Overall, under-5 mortality in low- and middle-income countries has decreased faster among the poorest compared with the least poor between 1995 and 2012, but progress in some countries has lagged, especially with poor governance. *Pediatrics* 2014;134:e1551–e1559

Narrowing the gaps in mortality and preventable burden of disease between rich and poor nations was a central motivation behind the creation of and support for the Millennium Development Goals (MDGs). The signatories of the United Nation's Millennium Declaration, which laid the foundation for the MDGs, stated that "In addition to our separate responsibilities to our individual societies, we have a collective responsibility to uphold the principles of human dignity, equality and equity at the global level."[1] The MDGs set targets that defined success based on national improvements, and progress for health-related MDGs has commonly focused on measuring changes in national indicators, such as maternal and under-5 mortality.[2–4]

National trends, however, say little about health inequalities within countries. Improvements in population health metrics may be associated with either narrowing or widening gaps in mortality among socioeconomic strata. Faster declines in mortality among the wealthy compared with the poor may lead to widening differences across the wealth gradient, whereas faster declines among the poor may lead to convergence. Preferential use of health care or the development of new health technologies that address diseases whose burden is differentially distributed across the wealth gradient may lead to uneven progress. These processes have been used to explain widening gaps in life expectancy in the United States by education, race, and wealth.[5–7]

The literature characterizing changing health inequalities is predominantly from developed countries, whereas the trends in low- and middle-income countries (LMICs) are largely unknown.[8,9] One analysis of nationally representative child mortality data in 22 LMICs between 1991 and 2001 found no evidence to suggest that inequalities in under-5 mortality by wealth changed over that 10-year span.[10] Modeling studies suggest that inequalities in child mortality could grow or shrink based on relative progress in achieving the MDGs by different wealth groups.[11] These studies argue that, because the burden from communicable diseases in LMICs is highest among the poorest, whereas that from noncommunicable diseases is highest among the least poor, accelerating control of communicable diseases would decrease rich-poor gaps, and accelerating control of noncommunicable diseases could increase inequalities.[12] Since 2000, substantial efforts and resources have been invested in the control of communicable diseases, such as HIV, malaria, tuberculosis, and vaccine-preventable illnesses.[13] At the same time, the poorest appear to use the health services afforded by these investments (immunizations, antiretroviral drugs, or oral rehydration therapy) less than those who are better off.[11] In addition, data on the overall balance of efforts to control communicable and noncommunicable diseases in LMICs is scant because accounting of domestic resource for disease control is rarely available, posing challenges to any projections of health inequalities.

Understanding whether countries are experiencing converging or diverging under-5 mortality matters for policymaking. Child survival improvements that are associated with growing health inequalities may lead to different policy decisions in comparison with improvements with converging mortality trends. This analysis addresses this knowledge gap.

METHODS

Data Sources

This study uses all standard Demographic and Health Surveys (DHSs) with nationally representative information on wealth status and complete birth registries, a total of 85 surveys from 54 countries conducted between 2002 and 2012.[14] In a subset of 29 countries, 2 DHS waves have been completed. This subset was used in an analysis of repeated measurements of child mortality (the earliest and most recent waves were used for Indonesia and Bangladesh, where 3 waves have been completed during this period); the entire set of 54 countries was used in creating and analyzing longitudinal records from the birth registries. Table 1 contains the list of surveys and relevant descriptive information.

Wealth Status

Wealth status in DHSs is indicated in each survey by using quintiles of a continuous wealth index, normalized to each survey's information. The index is obtained by using a principal components analysis of household assets and services, such as electricity, water supply, and floor material.[15,16] Wealth was regrouped into tertiles from the household population datasets, such that the analyses compared the poorest, middle, and least-poor tertiles. This regrouping was done to increase the sample size within each tertile and to reduce measurement error from miscategorization of individuals into the wrong quantile because of inaccurate measurement of household assets or changes in the household's relative wealth status over time. Additional details on the wealth tertile regrouping procedure are in Supplemental Appendix 1.

Under-5 Mortality

Under-5 mortality was estimated from the DHS birth registries. Complete birth registries, obtained from women 15 to 49 years old in sampled households, contain, for every live birth, the month of birth, survival status, and age at death (in months) for children who died. Using this information, synthetic cohort life tables for under-5 children were constructed following the DHS approach to produce a standard metric of under-5 mortality, the probability of dying before reaching age 5 per 1000 live births (5q0).[17] Although recent studies suggest short time windows may be appropriate

TABLE 1 DHS Surveys Used in the Analysis and the Most Recent Under-5 Mortality by Wealth in Each Survey

Country	Survey Year	No. of Mothers	No. of Under-5 Children at Time of Survey	Mortality by Wealth During the 5-y Period Preceding the Survey		
				Least Poor (95% CI)	Middle (95% CI)	Poorest (95% CI)
Multiple surveys						
Armenia	2005	6566	1430	21.9 (11.3 to 42.2)	25.2 (17.3 to 41.7)	36.3 (22.7 to 57.9)
Armenia	2010	5922	1473	16.9 (7.9 to 36)	13.6 (6.1 to 30.2)	24.7 (12.6 to 48)
Bangladesh	2004	11 440	6908	56.7 (46.9 to 68.4)	80.0 (68.6 to 93.2)	89.0 (78.2 to 101.1)
Bangladesh	2007	10 996	6150	48.0 (38.0 to 60.5)	73.4 (61.5 to 87.4)	67.4 (57.7 to 78.5)
Bangladesh	2011	17 842	8753	41.1 (33.7 to 50.0)	50.0 (42.1 to 59.4)	58.0 (50.2 to 66.8)
Bolivia	2003	17 654	10 448	35.3 (26.1 to 47.6)	64.9 (56.6 to 74.3)	84.5 (76.7 to 93.1)
Bolivia	2008	16 939	8605	32.9 (24.9 to 43.5)	34.4 (27.9 to 42.4)	71.1 (63.3 to 79.8)
Burkina Faso	2003	12 477	10 645	119.2 (105.2 to 134.9)	162.9 (149.1 to 177.9)	174.4 (160.4 to 189.4)
Burkina Faso	2010	17 087	15 045	73.1 (63 to 84.6)	114.1 (103.9 to 125.4)	137.1 (126.8 to 148.1)
Cambodia	2005	16 823	8290	34.8 (26.6 to 45.3)	84.3 (72.7 to 97.7)	102.5 (92.0 to 114.1)
Cambodia	2010	18 754	8232	26.5 (19.6 to 35.7)	51.4 (42.9 to 61.4)	72.2 (63.6 to 81.8)
Cameroon	2004	10 656	8125	101.6 (86.3 to 119.4)	152.6 (117.2 to 197.6)	150.1 (135.2 to 166.5)
Cameroon	2011	15 426	11 732	78.2 (65.9 to 92.6)	92.9 (81.7 to 105.5)	146.1 (134 to 159.3)
Colombia	2004	41 344	14 621	15.4 (11.3 to 20.9)	20.6 (16.8 to 25.3)	31.6 (27.5 to 36.4)
Colombia	2009	53 521	17 756	14.6 (11.2 to 19.1)	15.4 (12.3 to 19.2)	24.5 (21 to 28.7)
Congo	2005	7051	4835	69.1 (54.3 to 87.9)	96.1 (78.8 to 116.9)	123.8 (108 to 141.7)
Congo	2011	10 819	9329	63.1 (52.5 to 75.7)	60.6 (51.7 to 71)	63.7 (54.9 to 73.9)
Cote d'Ivoire	2005	9686	3644	100.2 (79.8 to 125.4)	120.9 (99.7 to 146.3)	135.8 (116.5 to 157.8)
Cote d'Ivoire	2011	10 060	7776	97.7 (80.7 to 118)	109 (96.4 to 123.2)	110.2 (98.1 to 123.8)
Egypt	2005	19 474	13 851	31 (25.8 to 37.3)	35.3 (30.2 to 41.2)	48.9 (42.9 to 55.7)
Egypt	2008	16 527	10 872	20.5 (15.9 to 26.5)	25.9 (21 to 32)	35.3 (29.7 to 41.9)
Ethiopia	2005	14 070	9861	59.9 (48 to 74.7)	120.7 (108.6 to 134)	111.3 (100.3 to 123.4)
Ethiopia	2011	16 515	11 654	75.6 (60.2 to 94.8)	88.6 (74.4 to 105.2)	106.3 (89.1 to 126.6)
Ghana	2003	5691	3844	92.8 (67.6 to 126.8)	103.9 (86 to 125.3)	105 (88.1 to 124.9)
Ghana	2008	4916	2992	68.5 (50.4 to 92.7)	84 (64.9 to 108.4)	80.6 (64.9 to 99.9)
Haiti	2005	10 757	6015	51.3 (39.5 to 66.4)	81.5 (69.1 to 95.9)	98.3 (86.2 to 112)
Haiti	2012	14 287	7247	64.6 (50.6 to 82.1)	99.9 (87.3 to 114.1)	77.5 (67.2 to 89.3)
Honduras	2005	19 948	10 800	13.6 (9.5 to 19.4)	23.3 (18.5 to 29.3)	44.2 (37.9 to 51.6)
Honduras	2011	22 757	10 888	28.7 (22.6 to 36.4)	28.9 (22.8 to 36.8)	33.9 (28.6 to 40.1)
Indonesia	2002	29 483	16 206	28.6 (23.9 to 34.3)	46.7 (40.6 to 53.7)	68.7 (61.7 to 76.5)
Indonesia	2007	32 895	18 645	36.2 (29.6 to 44.2)	38.9 (33.7 to 44.8)	62.7 (56.1 to 70)
Indonesia	2012	45 607	18 021	24.8 (20.6 to 29.9)	34.7 (29.7 to 40.4)	55.4 (49.9 to 61.5)
Jordan	2007	10 876	10 426	23.3 (17.5 to 31.1)	15.6 (11.8 to 20.6)	21.5 (17.3 to 26.6)
Jordan	2009	10 109	9650	25.6 (19.8 to 33.1)	25.3 (20.1 to 31.7)	30.6 (24.7 to 37.9)
Kenya	2003	8195	5949	93.1 (78 to 111)	90.6 (75.8 to 108.1)	127.4 (99.7 to 162.1)
Kenya	2008	8444	6079	63.9 (51.9 to 78.5)	73.3 (60.7 to 88.5)	72.5 (62.3 to 84.4)
Lesotho	2004	7095	3697	108.6 (87.4 to 134.5)	116 (97.9 to 137.2)	103.6 (88.7 to 120.8)
Lesotho	2009	7624	3999	93.9 (74.7 to 117.7)	125.4 (99.4 to 157.6)	123.3 (106.8 to 142.2)
Madagascar	2003	7949	5415	54.1 (40.2 to 72.6)	61.8 (49.4 to 77.1)	88.8 (77.1 to 102.3)
Madagascar	2008	17 375	12 448	54.2 (44.9 to 65.4)	73.5 (57.7 to 93.3)	92.6 (62.9 to 135.2)
Malawi	2004	11 698	10 915	99 (87.6 to 112)	112.4 (101.6 to 124.3)	139.2 (126.6 to 153)
Malawi	2010	23 020	19 967	93.7 (84.6 to 103.8)	104.9 (96.4 to 114.2)	101.3 (93.1 to 110.2)
Mozambique	2003	12 418	10 326	103.5 (90.8 to 117.9)	153.7 (140.3 to 168.3)	149 (136.2 to 162.8)
Mozambique	2011	13 745	11 102	80.8 (69.2 to 94.2)	90.3 (75.8 to 107.3)	91.5 (82.2 to 101.9)
Nepal	2006	10 793	5783	40.3 (30.8 to 52.7)	67.7 (55.6 to 82.5)	68.4 (58.8 to 79.7)
Nepal	2011	12 674	5306	29.4 (20.8 to 41.4)	48.9 (39.1 to 61.1)	60.8 (51.7 to 71.3)
Nigeria	2003	7620	6029	110.3 (90.9 to 133.6)	186 (164.9 to 209.5)	228.1 (207.3 to 250.6)
Nigeria	2008	33 385	28 653	114.3 (82.4 to 157.4)	150.9 (142.1 to 160.2)	190.5 (159.2 to 227.1)
Philippines	2003	13 633	7145	20.5 (14.2 to 29.6)	30.7 (23.8 to 39.4)	57.5 (48.9 to 67.6)
Philippines	2008	13 594	6572	19.8 (11.6 to 33.8)	27.3 (20.8 to 35.7)	44.2 (35.9 to 54.3)
Rwanda	2005	11 321	8649	100.4 (87.9 to 114.6)	138.6 (124.2 to 154.4)	151.9 (134.8 to 170.9)
Rwanda	2010	13 671	9002	58.2 (48.7 to 69.6)	65.9 (56.6 to 76.6)	69.6 (60.8 to 79.5)
Senegal	2005	14 602	10 947	57.8 (47.9 to 69.7)	90.8 (80.5 to 102.3)	124.1 (112.5 to 136.8)
Senegal	2010	15 688	12 337	46.4 (38.8 to 55.4)	66.9 (58.1 to 77)	88 (74.1 to 104.4)
Tanzania	2004	10 329	8564	77.6 (65.1 to 92.4)	107.2 (94.9 to 121)	110.6 (98.9 to 123.5)
Tanzania	2009	10 139	8023	74.8 (63 to 88.7)	72.8 (62.9 to 84.2)	71.3 (61.5 to 82.5)
Uganda	2006	8531	8369	93.1 (79.2 to 109.1)	112.4 (100 to 126.2)	121.1 (109.2 to 134.2)

TABLE 1 Continued

Country	Survey Year	No. of Mothers	No. of Under-5 Children at Time of Survey	Mortality by Wealth During the 5-y Period Preceding the Survey		
				Least Poor (95% CI)	Middle (95% CI)	Poorest (95% CI)
Uganda	2011	8674	7879	68.4 (56.1 to 83.2)	84.3 (72.2 to 98.4)	84.3 (74.1 to 95.8)
Zimbabwe	2005	8907	5247	70.7 (56 to 89)	80.4 (67.2 to 96.2)	93.6 (80.5 to 108.8)
Zimbabwe	2010	9171	5563	64.9 (50.1 to 83.9)	93.5 (79.4 to 110)	79.1 (66.7 to 93.8)
Single surveys						
Albania	2008	7584	1616	9.1 (3.4 to 24.2)	26.4 (15.7 to 44.2)	20 (11.4 to 34.9)
Azerbaijan	2006	8444	2297	33.9 (20.7 to 55.3)	50.3 (36 to 69.9)	59 (44.2 to 78.5)
Benin	2006	17 794	16 075	80.8 (71.7 to 90.9)	116.8 (107.1 to 127.4)	122.4 (112.3 to 133.4)
Burundi	2010	9389	7742	54.8 (44.8 to 67)	81.7 (70.2 to 95)	99.8 (86.1 to 115.5)
Chad	2004	6085	5635	153 (133.4 to 175.2)	167.1 (148.4 to 187.9)	157.9 (139.1 to 179.1)
Democratic Republic of the Congo	2007	9995	8994	87.5 (74.5 to 102.6)	142.2 (127.8 to 158.1)	165.5 (151.6 to 180.6)
Dominican Republic	2007	27 195	11 149	23.6 (17.5 to 31.8)	33.1 (26.9 to 40.8)	41.5 (36.1 to 47.6)
Gabon	2012	8422	6067	58.5 (44.9 to 75.9)	68.6 (55.7 to 84.4)	76 (63.1 to 91.4)
Guinea	2005	7954	6364	119.5 (101 to 141.3)	149.2 (132.1 to 168.2)	160.9 (143.1 to 180.8)
Guyana	2009	4996	2178	35.1 (21.3 to 57.5)	32.8 (21 to 51)	39.6 (28.6 to 54.5)
India	2005	124 385	51 555	30.6 (27.6 to 34.1)	50.5 (47 to 54.2)	86.4 (82.4 to 90.6)
Liberia	2006	7092	5799	102.4 (85.4 to 122.6)	103.6 (90.2 to 119)	97.2 (83.5 to 113)
Maldives	2009	7131	3817	17.5 (11.3 to 27)	12.6 (7.7 to 20.6)	20.1 (11.4 to 35.3)
Mali	2006	14 583	14 238	115.5 (103.6 to 128.7)	165 (153 to 177.8)	191.2 (178.4 to 204.9)
Moldova	2005	7440	1552	11.6 (4.8 to 7.8)	8.8 (3.3 to 23.4)	16.7 (9 to 30.8)
Morocco	2003	16 798	6180	25.9 (18.8 to 35.7)	40.1 (30.7 to 52.4)	63.2 (54.1 to 73.7)
Namibia	2006	9804	5168	63.5 (50 to 80.4)	75 (61.2 to 91.8)	76.1 (63.9 to 90.5)
Niger	2006	9223	9193	98.1 (84.4 to 113.9)	165 (149.2 to 182.2)	152.8 (138.3 to 168.8)
Pakistan	2006	10 023	9177	61.5 (52.3 to 72.2)	78.8 (68.7 to 90.2)	117.9 (105.9 to 131.3)
Sierra Leone	2008	7374	5631	134.5 (114.8 to 157.4)	133.6 (115.6 to 154.1)	122.8 (107.5 to 140.1)
Swaziland	2006	4987	2812	118.8 (95.9 to 146.8)	118.1 (96.5 to 144.2)	104.6 (87 to 125.6)
Timor	2009	13 137	9806	40.5 (33.2 to 49.3)	75.2 (63.9 to 88.3)	67.3 (58.6 to 77.2)
Turkey	2003	8075	4533	18.9 (12.1 to 29.7)	34.4 (24.9 to 47.4)	51.2 (42.3 to 62)
Ukraine	2007	6841	1221	8.9 (2.9 to 27.4)	16.2 (7.3 to 35.8)	26.7 (15.2 to 46.7)
Zambia	2007	7146	6401	119.7 (99.6 to 143.5)	105.5 (92.1 to 120.7)	98.4 (86.1 to 112.3)

with larger DHS surveys, 5-year windows were used throughout.[18]

Estimating Trends in Under-5 Mortality by Wealth

Two principal approaches were used for examining the trends in mortality over time. The first approach measured between-survey changes among those 29 countries that had >1 DHS wave. These countries are in the first portion of Table 1. Two measures were used to characterize changes in under-5 mortality in repeated surveys: the average annual change in under-5 mortality between the first and second wave for each wealth tertile (slope), and the ratio between under-5 mortality among the poorest and least-poor tertiles (mortality ratio). Nonparametric analysis of variance (Kruskal-Wallis) was used to test the equality of the slopes among the 3 wealth tertiles. The change in under-5 mortality ratio between surveys was estimated with a linear regression model, in which the dependent variable was the mortality ratio in each survey, and the independent variables included the year of the survey and country dummies (fixed effects). This provided the estimated within-country annual change in the mortality ratio between repeated surveys. All regression specifications are in Supplemental Appendix 2.

The second analysis used the information contained within each survey to create longitudinal within-survey estimates of inequalities in under-5 mortality. This was accomplished by restricting the birth cohort to the 5-year period preceding each year, up to 10 years before the year of the survey. For example, for a survey conducted in 2007, the estimated under-5 mortality in 2007 used birth registry data from 2002 to 2007; in the same survey, under-5 mortality in 2006 used data from 2001 to 2006, and so on until 1997 (the first year of measurement was 1995). This approach has several limitations: distant retrospective data suffer from recall bias, retrospective cohorts may not be nationally representative, and the wealth status of households whose relative wealth changed significantly over the 10-year period may be misclassified. On the other hand, it allows an examination of a greater number of countries, 54 as compared with 29, by using longitudinal analyses of single survey data, whereas consecutive surveys may differ based on sampling or other chance events.[19] The combined data for all 85 survey waves is in Figure 1; separate figures for all surveys are available in Supplemental Appendix 3. These data were used to analyze the differences in under-5 mortality rate declines by wealth, as well as the changes in the mortality ratio within surveys.

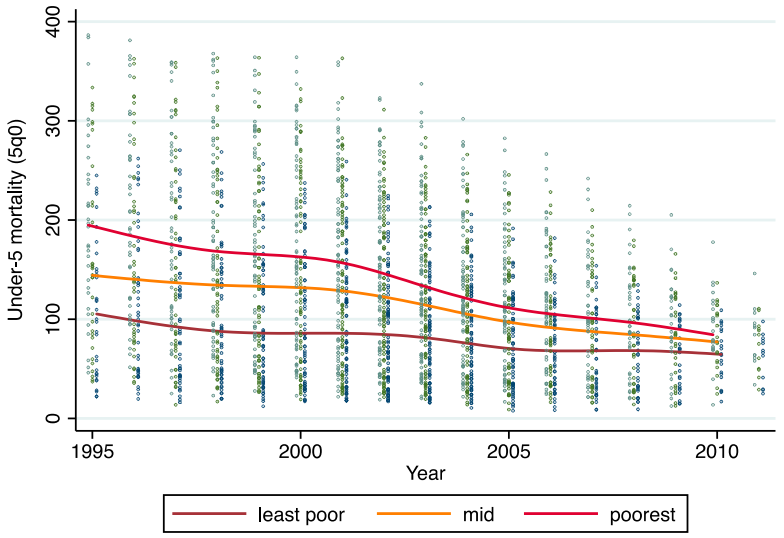

FIGURE 1

Under-5 mortality (5q0) among the poorest, middle, and least-poor tertiles estimated annually up to 10 years before the year of the survey (starting in 1995) in 85 surveys. The scatter represents the annual estimates in each year in each tertile (poorest is the left-most column of dots). Smoothed median spline curves fit to each wealth tertile's data show the convergence in mortality. Under-5 mortality in the highest mortality groups, mostly the poorest, approached 400 per 1000 live births in the 1990s and declined precipitously.

Finally, additional analyses explored the correlates of mortality ratio changes. The difference in the mortality ratio between the first year of measurement and the most recent year for each survey was used to define the changing mortality ratio. This difference in the mortality ratio was then associated in univariate and multivariate ordinary least squares regressions with gross domestic product per capita (GDPpc), total fertility rate (TFR), urbanization (percentage living in cities), HIV prevalence among adults, the portion of gross domestic product spent on public health, and all 6 Worldwide Governance Indicators (Government Effectiveness, Rule of Law, Control of Corruption, Regulatory Quality, Voice and Accountability, and Political Stability and Absence of Violence) from the World Bank.[20,21] These regressions were not intended to suggest causal pathways, but to explore broad relationships between development indicators and convergence of under-5 mortality. All the analytic code (in Stata version 13.1 [Stata Corp, College Station, TX]) is available on request from the author.

RESULTS

Information in 85 surveys (54 countries) from 1 267 167 women living in 929 224 households was used to create datasets with under-5 mortality estimates by wealth tertile. Overall, there is consistent evidence to suggest that the wealth gradient in under-5 mortality has been closing between 1995 and 2011. This convergence is measurable in both the mortality rate difference and in the ratio of under-5 mortality rates between the poorest and least poor.

Convergence in Repeated Surveys

The first wave of surveys among the 29 countries with repeat surveys was conducted between 2002 and 2007, and the second wave between 2008 and 2012 (Table 1). Convergence in mortality was measurable both in mortality rate differences, and mortality ratio measures. Figure 2 shows that the annual decline in under-5 mortality between surveys was, on average, greatest among the poorest. The average annual decline in under-5 mortality was 2.06 per 1000 live births among the least poor (95% confidence interval [CI] 1.06 to 3.07), 3.36 points among the middle tertile (95% CI 1.81 to 4.91), and 4.36 (95% CI 2.78 to 5.94) among the poorest. A Kruskal-Wallis analysis of variance suggests that these declines are meaningfully different from one another (P = .031). Overall, the mortality ratio in the 58 surveys has been declining gradually (Supplemental Appendix 5). The ratio of under-5 mortality between the poorest and least poor was 1.68 (95% CI 1.47 to 1.88) in the first wave and 1.48 (95% CI 1.30 to 1.66) in the second wave. Regression analysis also suggests that, within countries, the ratio has been declining by 0.04 per year (95% CI 0.01 to 0.07, P = .006).

Within-Survey Longitudinal Convergence

Examining the longitudinal trends generated from all 85 surveys in the 54 study countries provides additional support for convergence. Figure 1 shows the distribution of under-5 mortality estimates from the 85 surveys along with a smoothed (median spline) fit curve for each wealth stratum from 1995 to 2011. Overall, under-5 mortality declined in the study countries from a median of 146 per 1000 live births in 1995 to 75 per 1000 live births in 2011. Table 2 and Supplemental Appendix 5 demonstrate that the difference in under-5 mortality between the poorest and least poor has been shrinking along with the overall mortality declines. Table 2 also shows that between 1995 and 2011, the median under-5 mortality declined by 106.5 per 1000 live births among the poorest (194.4 to 87.9) and 37.5 per 1000 live births among the least poor (104.7 to 67.2).

Regression analysis supports the convergence of under-5 mortality across wealth tertiles in the 54-country sample. In a linear model, regressing under-5 mortality on an interaction between the year and wealth tertile indicators with country fixed effects to examine within-survey trends and robust SEs

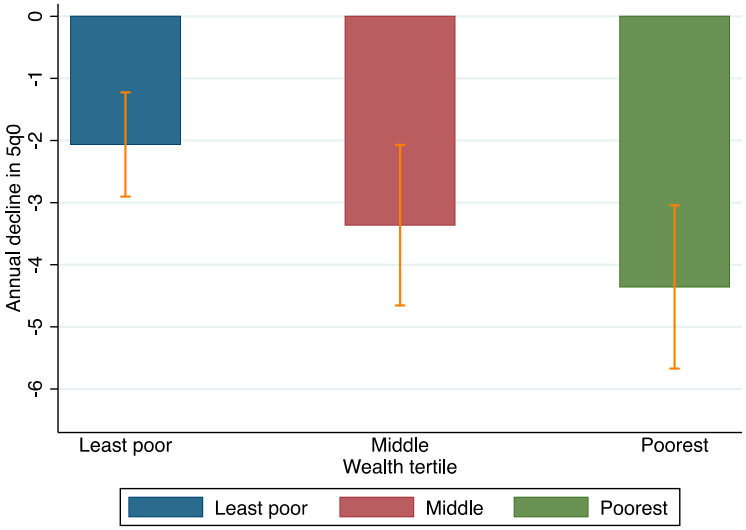

FIGURE 2
Average annual decline of under-5 mortality (5q0) by wealth tertile in 29 countries with repeated DHS surveys (and 95% CI bars). Only the first and most recent surveys of countries with repeat surveys were used in this analysis. The absolute annual declines in 5q0 were greatest in the poorest tertile and smallest in the least poor.

TABLE 2 Temporal Trends in Under-5 Mortality by Wealth in 85 Surveys Between 1995 and 2011

Year	Median 5q0 (IQR)		
	Among the Poorest Tertile	Among the Middle Tertile	Among the Least Poor Tertile
1995	194.4 (129.0–254.4)	147.8 (83.1–236.1)	104.7 (44.9–158.5)
1997	175.8 (107.7–269.2)	139.6 (75.0–238.5)	97.9 (43.7–165.6)
1999	163.2 (85.4–250.1)	131.3 (58.8–229.1)	83.9 (40.6–149.3)
2001	156.5 (80.0–241.9)	130.7 (65.0–215.3)	86.5 (44.5–142.5)
2003	132.8 (81.1–191.8)	112.0 (61.4–179.5)	86.0 (38.2–130.1)
2005	113.1 (68.6–160.9)	96.1 (50.5–146.1)	69.4 (34.4–115.7)
2007	98.4 (46.8–153.0)	89.8 (33.1–145.4)	68.3 (30.7–104.7)
2009	94.5 (67.3–123.4)	83.9 (46.1–122.0)	67.5 (31.9–93.9)
2011	87.9 (62.2–101.1)	79.7 (49.5–91.6)	67.2 (35.2–79.5)

The data for this table use the longitudinal measurements of under-5 mortality within each survey from all 85 surveys between 1995 and 2011. Where multiple surveys provided point estimates for the same country and year (for example, the Armenia 2005 and 2010 surveys both provide estimates for under-5 mortality for 2000 to 2005), the data with the shorter retrospective period were retained. IQR, interquartile range.

clustered by survey (to account for serial correlation), under-5 mortality declined among the poorest by 4.04 per 1000 live births faster than the least poor ($P < .001$) annually, and among the middle tertile by 2.46 per 1000 live births faster than the least poor ($P < .001$) annually over the period from 1995 to 2011 (Supplemental Appendix 2).

Heterogeneity in Convergence

The mortality rate ratio, however, has not declined across all surveys. Among the 85 surveys used in this study, the mortality rate ratio decreased between the first and last years of measurement in 64 surveys, from 2.11 to 1.55 on average; in 21 surveys, however, the ratio has increased from 1.58 to 1.88 (Fig 3). Supplemental appendix 3 shows the under-5 mortality for each survey by wealth tertile. Colombia (2009 survey), Ghana (2008), and Nepal (2011) experienced large convergence, whereas, at the other end, Cambodia (2005), Congo (2005), Haiti (2005), and Ukraine (2007) experienced large divergence. Divergence was more common in surveys that were completed before 2008, suggesting that convergence was greater in more recent years.

Regression analyses were used to identify correlates of mortality convergence. In univariate regressions, the difference between the mortality rate ratio in the first and last years of measurement was significantly associated with 4 governance indicators (Government Effectiveness, Rule of Law, Control of Corruption, and Regulatory Quality; $P \leq .03$ for all 4), and positively related to all governance indicators (ie, better governance scores were related to greater convergence). Declining mortality ratio was not significantly related to GDPpc, TFR, urbanization, HIV prevalence, or public health spending as a percentage of gross domestic product (Table 3). Multivariate regressions of each governance indicator, adjusted for the other health and development indicators (GDPpc, TFR, urbanization, HIV prevalence, or public health spending as a percentage of gross domestic product), are consistent with the relationship between governance quality and mortality convergence.

Supplemental Appendix 4 also shows that using the DHS's 5-quintile wealth index is associated with a similar gradient of under-5 mortality declines, greatest among the poorest and smallest among the least poor.

DISCUSSION

This analysis of under-5 mortality trends presents evidence for a grand convergence of mortality across the wealth spectrum in low- and middle-income countries. These findings may be surprising given the large and, according to some measures, growing differences in mortality between wealthy and poor nations and between the rich and poor within nations.[9,22] This convergence is consistent with the theory that the intensive efforts to reduce the burden of communicable diseases resulted in

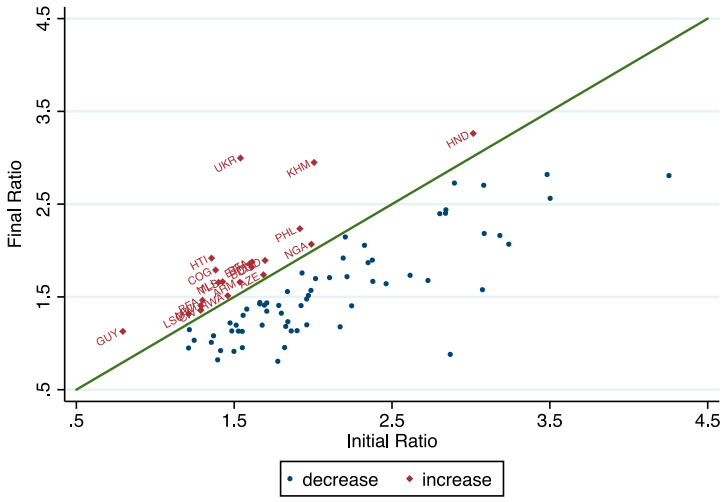

FIGURE 3

Heterogeneity in convergence. The ratio between the poorest and least poor in the earliest (Initial) and most recent (Final) year of measurement within each survey shows that the mortality ratio has been diverging in 21 of the 85 surveys. Three-letter country codes identify the countries with divergence of mortality across the wealth gradient, measured as increasing mortality rate ratios over time (ARM, Armenia; AZE, Azerbaijan; BDI, Burundi; BFA, Burkina Faso; COD, Democratic Republic of the Congo; COG, Congo; ETH, Ethiopia; GUY, Guyana; HND, Honduras; HTI, Haiti; KHM, Cambodia; LSO, Lesotho; MLI, Mali; MWI, Malawi; NGA, Nigeria; PHL, Philippines; RWA, Rwanda; TLS, Timor; UKR, Ukraine).

preferential declines of under-5 mortality among the poorest. The global epidemiologic trends of communicable diseases support this position: the relative burden of 4 dominant communicable diseases that preferentially afflict the poorest in LMICs (lower respiratory illnesses, diarrhea, malaria, and measles) has declined from a total of 40% of all disability-adjusted life years lost in 1995 to 32% in 2010 among children in developing countries.[23] Over the same period, the share of disability-adjusted life years lost due to neonatal causes and noncommunicable diseases among under-5 children residing in developing countries has increased from 36% to 43%.[23]

Several possibilities could explain why this convergence is occurring now, whereas an analysis of household survey data up to 2001 failed to find convergence.[10] Development assistance for health increased nearly threefold between 2000 and 2010, and the rise in investments was directed mostly toward the control of communicable diseases through large organizations, such as The Global Fund to Fight AIDS, Tuberculosis, and Malaria and the GAVI Alliance (formerly the Global Alliance for Vaccines and Immunization).[13] The extent to which these investments have effectively reduced the burden of communicable diseases is an active debate.[24,25] However, recent evidence suggests that under-5 mortality among the poor declined preferentially where greater development assistance investments have been made, particularly for malaria control.[26]

Although improving mortality equity among under-5 children across the wealth spectrum may be welcome news, this analysis also shows that this pattern was not universal. Equity in under-5 mortality decreased over time in nearly a fourth of surveys examined, a relationship associated with poor governance. Several studies suggest that governance matters for child survival through provision of public goods, including public health interventions.[27,28] This analysis adds to that literature by showing that better governance may be important for improving equity in child mortality, at least in LMICs.

This finding raises questions about the role of health aid institutions in supporting programs in poorly governed countries. On the one hand, the poorest in countries with poor governance may be most in need of public health programs, as the evidence in this study shows they may be falling behind relative to less-poor populations. On the other hand, supporting public health programs in well-governed countries may promote equity in child mortality in addition to providing health benefits. The Global Fund to Fight AIDS, Tuberculosis, and Malaria has been operating in fragile states, although not always successfully.[29] One approach may be to condition health aid on meeting governance standards. This approach has been shown to promote governance reforms with possible evidence of improved management of foreign aid funds.[30]

An important consideration in this analysis is that the primary determinant under scrutiny is relative wealth, not absolute wealth. Several of the countries in this study witnessed rapid economic growth over the study period, and it is likely that the wealth of many households increased even as they remained in the same relative wealth tertile. Absolute wealth may be a critical determinant if under-5 mortality is proportional to absolute wealth, and wealth gradients also have been converging. Alternatively, absolute wealth may be a critical determinant if increasing absolute wealth led to greater (or more efficient) investments in health among the poorest compared with the least poor. This analysis does not examine the independent role of absolute wealth changes in reducing mortality inequity; although, in high-income countries, increasing absolute wealth has not been associated with mortality convergence, which some speculate may be related to increasing income inequality.[31]

A related concern may be that wealth is measured at the time of the survey. This

TABLE 3 Univariate and Multivariate Associations of Mortality Ratio Changes

	Mortality Ratio Decline, Univariate Associations (*P* Value)[a]	Mortality Ratio Decline, Multivariate Associations (*P* Value)[b]	Mean (95% CI) Among Surveys With Lower Ratio (64 Surveys)[c]	Mean (95% CI) Among Surveys With Higher Ratio (21 Surveys)[c]
Factor				
GDPpc, constant 2005 USD[d]	0.05 (.26)	NA	1283 (931 to 1635)	838 (543 to 1132)
TFR	−0.05 (.18)	NA	4.07 (3.71 to 4.42)	4.55 (3.76 to 5.34)
Urbanization, %	0.12 (.54)	NA	40.8 (36.2 to 45.4)	35.6 (27.7 to 43.5)
HIV prevalence, % of adult population	0.02 (.11)	NA	3.96 (2.47 to 5.46)	3.45 (0.88 to 6.01)
Public health spending, % of GDP	−0.02 (.57)	NA	2.66 (2.31 to 3.02)	2.96 (2.14 to 3.78)
Worldwide Governance Indicators[e]				
Government Effectiveness	0.35 (.006)*	0.43 (.01)*	−0.56 (−0.66 to −0.45)	−0.80 (−1.01 to −0.60)
Rule of Law	0.27 (.02)*	0.38 (.01)*	−0.62 (−0.74 to −0.50)	−0.88 (−1.11 to −0.65)
Control of Corruption	0.31 (.02)*	0.46 (.007)*	−0.63 (−0.74 to −0.52)	−0.81 (−0.99 to −0.62)
Regulatory Quality	0.25 (.03)*	0.38 (.03)*	−0.49 (−0.61 to −0.36)	−0.71 (−0.90 to −0.51)
Voice and Accountability	0.12 (.27)	0.17 (.17)	−0.47 (−0.60 to −0.35)	−0.62 (−0.86 to −0.37)
Political Stability and Absence of Violence	0.03 (.67)	0.01 (.98)	−0.70 (−0.88 to −0.51)	−0.84 (−1.23 to −0.45)

[a] These estimates provide the univariate association from separate linear regression models where the dependent variable is the difference between the first and last years of measurement within each survey and the correlates are in the first column. A positive association indicates that higher levels of the correlate were associated with greater convergence of the mortality ratio. The year of each correlate is the year of the survey, although the findings were similar when using the average value over the period of measurement or the first year of measurement for each survey.

[b] In multivariate analysis, the dependent variable remained the difference between the first and last years of measurement within each survey; the independent variables included the governance indicators and 5 covariates shown at the top of the table (GDP per capita, total fertility rate, urbanization, HIV prevalence, and public health spending as a percentage of GDP). Each governance indicator was analyzed separately. The effect size and significance of the governance indicators is generally similar, or slightly larger, than in the univariate associations, suggesting a stable relationship between governance quality and convergence of mortality across wealth gradients.

[c] These columns indicate the mean of the correlates in 2 groups of surveys: those surveys in which the mortality ratio declined (64 surveys), and those in which it climbed (divergence of mortality, observed in 21 surveys).

[d] GDPpc measurements in 1000s of constant 2005 USD were used for the univariate association.

[e] The Worldwide Governance Indicators summarize surveys, private sector, and public sector data into a score on 6 dimensions of governance. Complete descriptions of each indicator are available through the Worldwide Governance Indicators portal.[34] The composite scores for each indicator are normalized and range from approximately −2.5 to 2.5, with higher values corresponding to better governance. The mean score for all indicators is <0 for the study countries, although the scores were consistently higher in those surveys in which convergence was observed compared with surveys with diverging under-5 mortality.

* $P < .05$.

concern raises doubts about misclassification of relative wealth status in the retrospective within-survey analyses. Reducing the number of wealth quantiles was done for that reason, so that households could experience substantial changes in wealth without changing their relative wealth rank. In addition, the wealth index was constructed by using durable household possessions, such as floor material and roof material. Possession of such goods changes slowly over time relative to income or consumption, conferring additional stability to the wealth index.[16]

The household mortality and wealth data used in this analysis come with uncertainty. The DHS methodologists developed a sophisticated approach for estimating standard errors by using block jackknife to account for the complexity in the statistics and study designs.[18,32] The uncertainty in the monthly estimates may bias trend measurements. However, an analysis of DHS surveys suggests that differences >15% in under-5 mortality between consecutive surveys signals true trends (the threshold is lower in bigger surveys).[19] Among the 29 countries with repeat surveys, the median reduction in under-5 mortality is 25.2%, and it is <15% in all 3 wealth tertiles in only 1 country (Zimbabwe). Thus, although this analysis relies on the uncertain mortality point estimates, the large changes in under-5 mortality during the study period relax some concerns over uncertainty in the trends.

Across much of the developing world, the recent declines in under-5 mortality have been fastest among the poorest, suggesting a widespread convergence of child mortality. This convergence was not shared across all countries, however. Although the drivers of this convergence remain a topic of investigation, this article presents evidence that good governance was related to this convergence. These findings have important implications for prioritization of global health investments and for future research on global health improvements.[33]

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