Neonatal, 1–59 month, and under-5 mortality in 597 Indian districts, 2001 to 2012: estimates from national demographic and mortality surveys

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Summary

Background India has the largest number of child deaths of any country in the world, and has wide local variation in under-5 mortality. Worldwide achievement of the UN 2015 Millennium Development Goal for under-5 mortality (MDG 4) will depend on progress in the subregions of India. We aimed to estimate neonatal, 1–59 months, and overall under-5 mortality by sex for 597 Indian districts and to assess whether India is on track to achieve MDG 4.

Methods We divided the 2012 UN sex-specific birth and mortality totals for India into state totals using relative birth rates and mortality from recent demographic surveys of 24 million people, and divided state totals into totals for the 597 districts using 3 million birth histories. We then split the results into neonatal mortality and 1–59 month mortality using data for 109 000 deaths in children younger than 5 years from six national surveys. We compared results with the 2001 census for each district.

Findings Under-5 mortality fell at a mean rate of 3·7% (IQR 3·2–4·9) per year between 2001 and 2012. 222 (37%) of 597 districts are on track to achieve the MDG 4 of 38 deaths in children younger than 5 years per 1000 livebirths by 2015, but an equal number (222 [37%]) will achieve MDG 4 only after 2020. These 222 lagging districts are home to 41% of India's livebirths and 56% of all deaths in children younger than 5 years. More districts lag behind the relevant goal for neonatal mortality (251 [42%]) than for 1–59 month mortality (197 [33%]). Just 81 (14%) districts account for 37% of deaths in children younger than 5 years nationally. Female mortality at ages 1–59 months exceeded male mortality by 25% in 303 districts in nearly all states of India, totalling about 74 000 excess deaths in girls.

Interpretation At current rates of progress, MDG 4 will be met by India around 2020—by the richer states around 2015 and by the poorer states around 2023. Accelerated progress to reduce mortality during the neonatal period and at ages 1–59 months is needed in most Indian districts.

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Introduction

Deaths in children younger than 5 years fell in India from about 2·5 million in 2001 to 1·5 million in 2012,[1] yet India still has the largest number of deaths in children younger than 5 years of any country in the world. India's large population and its enormous variation in social circumstances, access to health services, and other correlates of under-5 mortality mean that national statistics mask large local variation in sex-specific under-5 mortality and how this changes over time. Achievement of the UN 2015 Millennium Development Goal to reduce under-5 mortality (MDG 4) worldwide will depend in large part on progress in reduction of death in children younger than 5 years in the subregions of India, and in particular reductions during the neonatal period (first month of life) as well as at ages 1–59 months.[2] India's MDG for under-5 mortality is 38 deaths per 1000 livebirths by 2015. Programmatic attention has shifted to India's districts—small administrative areas each with about 2 million people—that now control the programme priorities within the National Rural Health Mission,[3,4] launched by the Indian Government in 2005, and the more recently launched National Urban Health Mission.[5] The Indian Government places special focus on the nine poorer states of Assam, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Orissa, Rajasthan, Uttar Pradesh, and Uttarakhand.

Reliable estimation of district-based under-5 mortality is a key obstacle to rational planning and assessment of services. We aimed to combine demographic totals of national and state deaths in children younger than 5 years with nationally representative demographic and mortality surveys to estimate neonatal, 1–59 month, and overall under-5 mortality by sex for 597 Indian districts in 2001 and 2012, and to assess whether India is on target to achieve MDG 4 in 2015.

Methods

Data sources

In this study, we make use of data from several surveys to calculate under-5 mortality across India. We divided the 2012 UN sex-specific birth and mortality totals for India[1] into state totals using the weighted average of relative birth rates and mortality for 2009–11 from the Registrar

See Online for appendix

General of India's yearly Sample Registration System (SRS)[6] and the third National Family Health Survey of 2005–06 (NFHS3).[7] We further divided state totals into totals for the 597 districts (as defined in the 2011 census) using birth histories from two rounds of the District Level Household Surveys of 2002–04 (DLHS2)[8] and 2007–08 (DLHS3).[9] We divided the resulting under-5 mortality into neonatal mortality and 1–59 month mortality from the ratios reported in six national mortality surveys: DLHS1 (1998–99);[10] DLHS2 (2002–04);[8] DLHS2 3 (2007–08);[9] the Special Fertility and Mortality Survey (1998);[11] SRS mortality data (1998–2003);[11] and the first phase of the ongoing Million Death Study (2001–03).[12] The chief benefit of this method is to produce internally consistent estimates—ie, district totals to equal state totals, and state totals to equal the 2012 UN estimates for India for each sex and age group (neonatal and 1–59 months). All surveys are nationally representative and together include 24 million people, 4 million households, 3 million birth histories, and 109 000 deaths in children younger than 5 years. Detailed methodology and brief descriptions of each survey are presented in the appendix (pp 1–4).

	Under-5 mortality	Neonatal mortality	1–59 month mortality
MDG 4			
2015 (end year)	38·0	20·0	18·0
2001	81·1	37·9	43·1
1990 (base year)	115·0	47·4	67·6
MDG-4 progress			
2012			
On track	47·2	24·9	22·3
Lag up to 5 years	47·3–62·6	25·0–31·5	22·4–31·0
Lag by >5 years	≥62·7	≥31·6	≥31·1
2001			
On track	81·1	..	..
Lag up to 5 years	81·2–96·5	..	..
Lag by >5 years	≥96·6	..	..

Data are the maximum number of deaths per 1000 livebirths allowed to fulfil each MDG 4. MDG 4=Millennium Development Goal to reduce under-5 mortality.

Table 1: **Expected levels of under-5 mortality, neonatal mortality, and 1–59 month mortality, 1990–2015**

	Poorer states	Richer states	All India
Population (×1 000 000)	596·5 (48·5%)	633·0 (51·5%)	1229·5 (100%)
Livebirths (×1 000 000)	14·9 (58·3%)	10·7 (41·7%)	27·2 (100%)
Deaths (×1000)			
Under 5 years old	1046·8 (71·2%)	423·1 (28·8%)	1469·9 (100%)
0–28 days old	537·6 (68·3%)	249·2 (31·7%)	786·9 (100%)
1–59 months old	683·1 (74·5%)	174·0 (25·5%)	683·1 (100%)
Mortality per 1000 livebirths			
Under 5 years old	70·1	39·5	57·3
0–28 days old	36·0	23·3	30·7
1–59 months old	34·1	16·3	26·6
Girls	40·7	17·1	30·8
Boys	29·9	14·6	23·5
Female-to-male mortality ratio	1·36	1·17	1·31

Data are number (%) and number per 1000 livebirths, unless otherwise stated.

Table 2: **Population, births, and deaths in the poorer states, richer states, and all India, 2012**

Estimation of national, state, and district totals

To estimate under-5 mortality state totals, we derived the crude birth rate (CBR), neonatal mortality, and under-5 mortality from weighted averages of data in SRS (2009–11) and NFHS3 (2005–06) to estimate livebirths, neonatal deaths, and 1–59 month deaths for each of India's 35 states and union territories, based on the 2011 census population. We applied the proportion of state totals out of national totals to the 2012 UN national totals for each sex, and adjusted them (by no more than 0·5%) to ensure that the sum of states matched the sex-specific national totals. We derived CBRs from the DLHS2 (2002–04) and DLHS3 (2007–08) and applied them to the 2011 census population for each district. We adjusted district births (by a mean of 1·1% [SD 0·03]) to ensure that the district totals matched each sex-specific state total for 2012. We derived district mortality totals in three steps. First, we estimated infant (first year of life) and under-5 mortality for each sex using the open source module QFIVE from the UN mortality estimation software MORTPAK4.3.[13] The software used pooled birth histories from DLHS2 and DLHS3 for 3·2 million children ever born and 2·9 million surviving children tabulated by age of the mother and the UN's south Asian mortality model life table. We derived neonatal mortality by using the proportion of neonatal deaths out of all infant deaths from the pooled data in the six national mortality surveys. Second, we calculated each district's under-5 and neonatal death totals by combining the census 2011 population, the DLHS2 and DLHS3 CBRs, and the aforementioned under-5 and neonatal mortality. We adjusted the proportion of deaths in each district out of state death totals (by a mean of 1·0% [SD 0·05]) so that the sum of the district totals matched state totals for 2012. Subtracting neonatal deaths from deaths in children younger than 5 years yielded the number of deaths of children aged 1–59 months. Between 1997 and 2008, the six national mortality surveys recorded 108 837 deaths in children younger than 5 years (56 653 boys; 52 184 girls) of which 52 139 (47·9%) were neonatal deaths (29 325 boys; 22 814 girls) and the remaining 56 698 (52·1%) were deaths in children aged 1–59 months (27 329 boys; 29 369 girls).

We stratified all rates by the 304 districts in the nine poorer states and 293 districts in the rest of India (appendix p 5). The six smaller northeastern states and the six union territories (consisting of only 1·3% of India's total population) are presented as equivalent to districts. To achieve the 2015 MDG 4, under-5 mortality

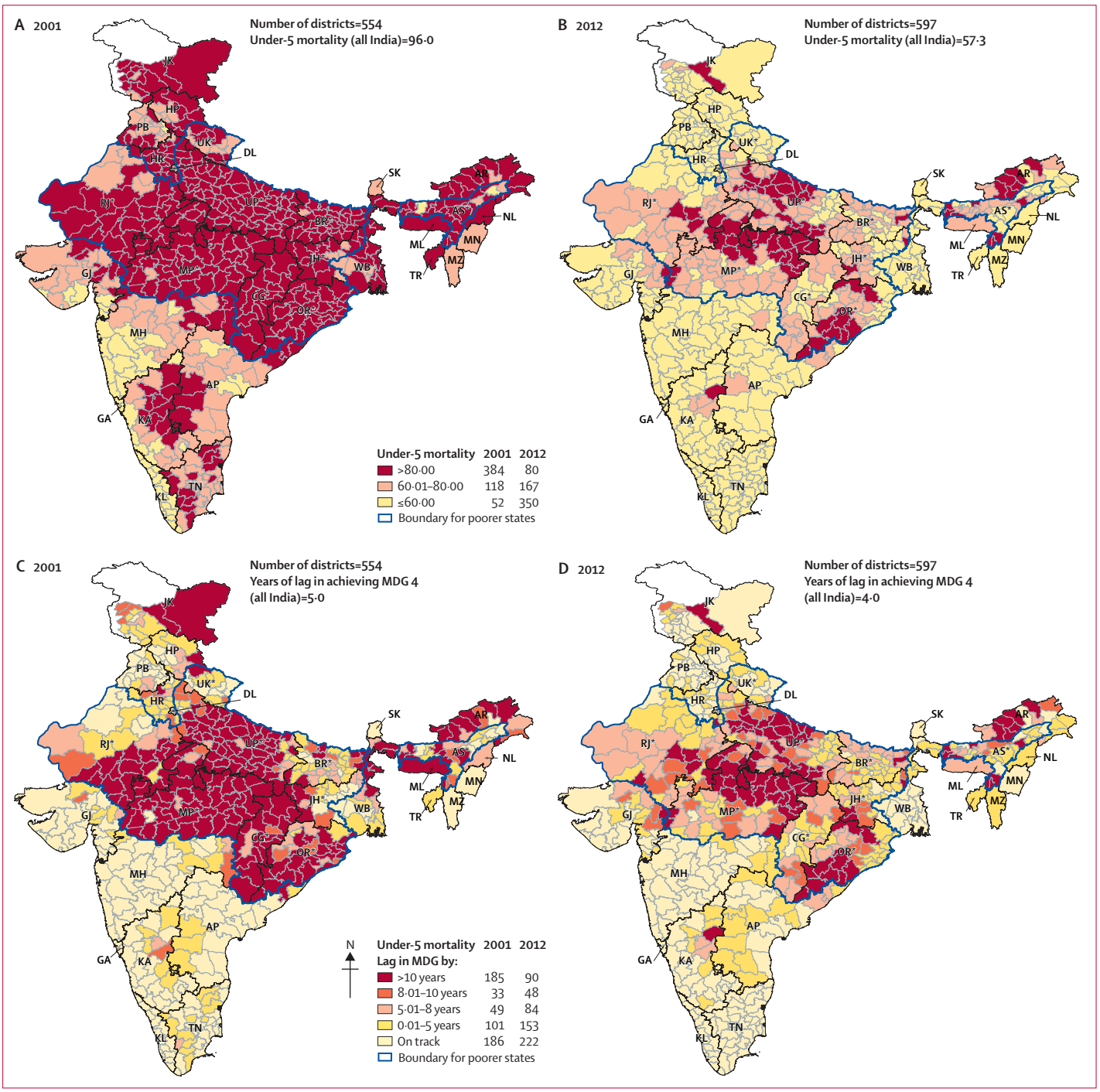

Figure 1: **Indian districts, according to under-5 mortality and MDG-4 progress, 2001 and 2012**

Under-5 mortality (number of deaths in children younger than 5 years per 1000 livebirths) per district in 2001 (A) and 2012 (B), and MDG-4 progress per district in 2001 (C) and 2012 (D), assessed by the number of years a district lagged behind the MDG of 38 per 1000 livebirths by 2015 according to current trends. Data for 2001 are from the 2001 census; data for 2012 are from the Centre for Global Health Research. Richer states are the 20 states of Andhra Pradesh (AP), Arunachal Pradesh (AR), Delhi (DL), Goa (GA), Gujarat (GJ), Haryana (HR), Himachal Pradesh (HP), Jammu and Kashmir (JK), Karnataka (KA), Kerala (KL), Maharashtra (MH), Manipur (MN), Meghalaya (ML), Mizoram (MZ), Nagaland (NG), Punjab (PB), Sikkim (SK), Tamil Nadu (TN), Tripura (TR), West Bengal (WB), and six small union territories. *Poorer states are the nine states of Assam (AS), Bihar (BR), Chhattisgarh (CG), Jharkhand (JH), Madhya Pradesh (MP), Orissa (OR), Rajasthan (RJ), Uttarakhand (UK), and Uttar Pradesh (UP). MDG 4=Millennium Development Goal to reduce under-5 mortality.

per 1000 livebirths in India has to decline by two-thirds in relative terms, from 115 to 38 over 25 years (1990–2015).[14] This reduction represents a 40% decline in relative terms between 2001 and 2012, assuming linear trends. Because no separate MDGs for neonatal mortality and mortality at 1–59 months exist, we

	Under-5 mortality (n per 1000 livebirths)	Under-5 deaths ×1000	Livebirths ×1000	Districts	MDG-4 progress					
					On track (under-5 mortality ≤47·2)		Lag up to 5 years (under-5 mortality 47·3–62·6)		Lag >5 years (under-5 mortality >62·7)	
					Districts (% state livebirths*)	Under-5 deaths ×1000	Districts (% state livebirths*)	Under-5 deaths ×1000	Districts (% state livebirths*)	Under-5 deaths ×1000
All India	57·3	1470	25 642	597	222 (32·3%)	269·9 (18·4%†)	153 (26·7%)	380·8 (25·9%†)	222 (41·0%)	819·2 (55·7%†)
Poorer states	70·1	1047 (71·2%†)	14 937 (58·3%‡)	304	19 (3·8% [2·2%‡])	23·5 (2·2%§; 1·6%†)	91 (31·0% [18·1%‡])	261·4 (25·0%§; 17·8%†)	194 (65·2% [38·0%‡])	761·8 (72·8%§; 51·8%†)
Uttar Pradesh	75·0	407	5433	71	0	0	15 (21·5%)	65·0	56 (78·5%)	342·2
Bihar	63·0	177	2809	38	2 (3·7%)	4·3	16 (43·1%)	69·3	20 (53·2%)	103·5
Madhya Pradesh	77·4	139	1792	50	1 (3·1%)	2·1	9 (16·6%)	17·5	40 (80·4%)	119·2
Rajasthan	65·7	116	1764	33	1 (2·6%)	2·1	10 (37·4%)	36·9	22 (60·0%)	76·9
Orissa	73·2	61	829	30	0	0	10 (42·6%)	20·0	20 (57·4%)	40·7
Assam	74·2	52	696	27	4 (10·2%)	2·9	9 (29·9%)	12·2	14 (60·0%)	36·6
Jharkhand	59·9	48	803	24	3 (15·8%)	5·4	12 (52·9%)	23·4	9 (31·3%)	19·3
Chhattisgarh	60·9	38	622	18	1 (12·7%)	3·6	6 (40·7%)	14·2	11 (46·6%)	20·1
Uttarakhand	51·5	10	188	13	7 (44·8%)	3·3	4 (29·6%)	3·0	2 (25·5%)	3·3
Richer states and rest of India¶	39·5	423 (28·8%†)	10 705 (41·7%‡)	293	203 (72·0% [30·0%‡])	246·3 (58·2%‖; 16·8%†)	62 (20·6% [8·6%‡])	119·4 (28·2%‖; 8·1%†)	28 (7·4% [3·1%‡])	57·4 (13·6%‖; 3·9%†)
Andhra Pradesh	47·2	69	1459	23	10 (45·4%)	24·7	11 (47·3%)	36·9	2 (7·3%)	7·3
Gujarat	52·2	66	1268	26	12 (47·2%)	21·8	8 (22·9%)	16·4	6 (30·0%)	27·9
Maharashtra	32·6	60	1854	35	31 (94·0%)	54·4	4 (6·0%)	6·0	0	0
West Bengal	39·6	58	1475	19	14 (77·5%)	40·7	5 (22·5%)	17·8	0	0
Karnataka	42·6	48	1128	30	21 (66·0%)	24·9	6 (22·1%)	13·5	3 (11·9%)	9·7
Tamil Nadu	27·3	30	1114	32	32 (100·0%)	30·4	0	0	0	0
Haryana	49·5	27	544	21	11 (48·9%)	10·9	9 (43·6%)	12·8	1 (7·5%)	3·2
Punjab	39·9	18	443	20	16 (81·3%)	13·5	4 (18·7%)	4·2	0	0
Jammu and Kashmir	44·1	10	220	22	14 (56·0%)	3·7	4 (25·8%)	3·0	4 (18·2%)	3·0
Kerala	13·2	6	479	14	14 (100·0%)	6·3	0	0	0	0
Himachal Pradesh	42·5	5	111	12	7 (54·0%)	1·8	5 (46·0%)	2·9	0	0
Rest of India¶	41·6	25	609	39	21 (67·8%)	13·3	6 (17·7%)	5·8	12 (14·5%)	6·2

Number might not always total because of rounding. MDG 4=Millennium Development Goal to reduce under-5 mortality. *Proportion of livebirths within those districts out of the total number of births within that state. †Proportion of under-5 deaths out of all national under-5 deaths. ‡Proportion of livebirths out of all national livebirths. §Proportion of under-5 deaths out of all under-5 deaths in the poorer states. ¶Rest of India includes nine smaller states and six union territories of India. ||Proportion of under-5 deaths out of all under-5 deaths in the richer states and the rest of India.

***Table 3*: Distribution of districts, under-5 mortality, livebirths, and MDG-4 progress in India by state, 2012**

estimated these numbers using UN data as 20 deaths per 1000 livebirths during the neonatal period and 18 deaths per 1000 livebirths at ages 1–59 months (table 1; appendix p 6). Each district was characterised in relation to its MDG-4 progress into: districts that have already achieved MDG 4 or are on track to do so by 2015, districts lagging behind MDG 4 by up to 5 years, and districts lagging behind MDG 4 by more than 5 years (ie, will achieve MDG 4 only after 2020). The excess female mortality at ages 1–59 months is the ratio of female to male mortality at these ages. During the neonatal period, female and male mortality is roughly equal[15] and thus is combined. We compared each district's under-5 mortality for 2012 with the 2001 census results (also derived using birth histories).[16] The 2001 census under-5 mortality was only slightly higher than the UN or SRS estimates for the same period.[17]

Uncertainty

The two main sources of statistical uncertainty arise from the district-specific inputs of children ever born or surviving and from the proportion of neonatal deaths out of all deaths in children younger than 5 years. For each district we provide 99% (a relative SE of 2·58) for lower and upper limits of the estimated under-5 mortality (appendix pp 7–17). The relative SE is defined as the inverse of the sum of the two square roots for the number of children ever born and the number of deaths in children younger than 5 years. These methods are similar to those used in the NFHS3.[18] The SRS does not publish uncertainty estimates for its state total; however, the 2001 and 2011 censuses are complete surveys and not samples and thus have little error. Census 2001 showed high completeness;[19] the 2011 census has yet to report completeness. Misclassification

between definitions of sex, or of neonatal and 1–59 month deaths, is small.

Role of the funding source

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

Results

The nine poorer states contained nearly half of all people in India in 2012 and just over half of all births, but 1·0 million (71%) of the 1·5 million deaths in children younger than 5 years (table 2). Compared with the richer states, the poorer states have notably higher mortality per 1000 livebirths in all three age categories (table 2). Girls had higher mortality at ages 1–59 months than did boys, meaning that nationally, for every 100 deaths of boys at these ages in 2012, 131 girls died.

India's under-5 mortality fell at a mean rate of 3·7% (IQR 3·2–4·9) per year from 96·0 per 1000 livebirths in 2001[17] to 57·3 per 1000 livebirths in 2012 (figure 1A and 1B; appendix). During the same period, the number of districts with under-5 mortality of more than 80 deaths per 1000 livebirths (>8% risk of newborn babies dying before age 5 years) fell from 384 (64%) of 597 districts to 80 (13%). In the districts with a child death risk of greater than 8%, the mean under-5 mortality fell from 114 to 94 per 1000 livebirths, and the proportion of livebirths in these districts out of national totals fell from 68% (18·3 million) to 15% (3·8 million).

Progress is less encouraging when examining the rate of decline needed to achieve the MDG 4 of 38 deaths in children younger than 5 years per 1000 livebirths by 2015 (figure 1C and 1D). In 2012, 222 (37%) of all 597 districts lagged behind this MDG 4 by more than 5 years, an improvement from the 267 (45%) districts that were similarly behind in 2001. In 2012, 90 (15%) districts lagged behind this MDG 4 by more than 10 years. 222 (37%) districts—the same number of districts as those that are lagging behind—are on track to achieve MDG 4, and this improvement is only slight compared with the 186 (31%) districts similarly on track in 2001. Notably, the number of districts lagging behind has increased in the richer states of Andhra Pradesh, Gujarat, and Karnataka. Only in the states of Kerala and Tamil Nadu have all districts achieved MDG 4. In 2012, average under-5 mortality was 79 per 1000 livebirths in the districts that lagged behind MDG 4 by more than 5 years and 33 per 1000 livebirths in those on track to reach MDG 4.

194 (87%) of the 222 districts lagging behind MDG 4 by more than 5 years are in the poorer states (table 3). Of the national totals, 12·6 million (41%) livebirths (and 0·8 million [56%] deaths in children younger than 5 years) took place in these 222 districts in 2012. By contrast, 203 (91%) of the 222 districts on track to reach MDG 4 are in the richer states. At current rates of progress, MDG 4 will be met by India around 2020, by the richer states around 2015, and by the poorer states around 2023. The appendix (pp 18–32) provides results for each district, including the exact number of years each is lagging behind MDG 4.

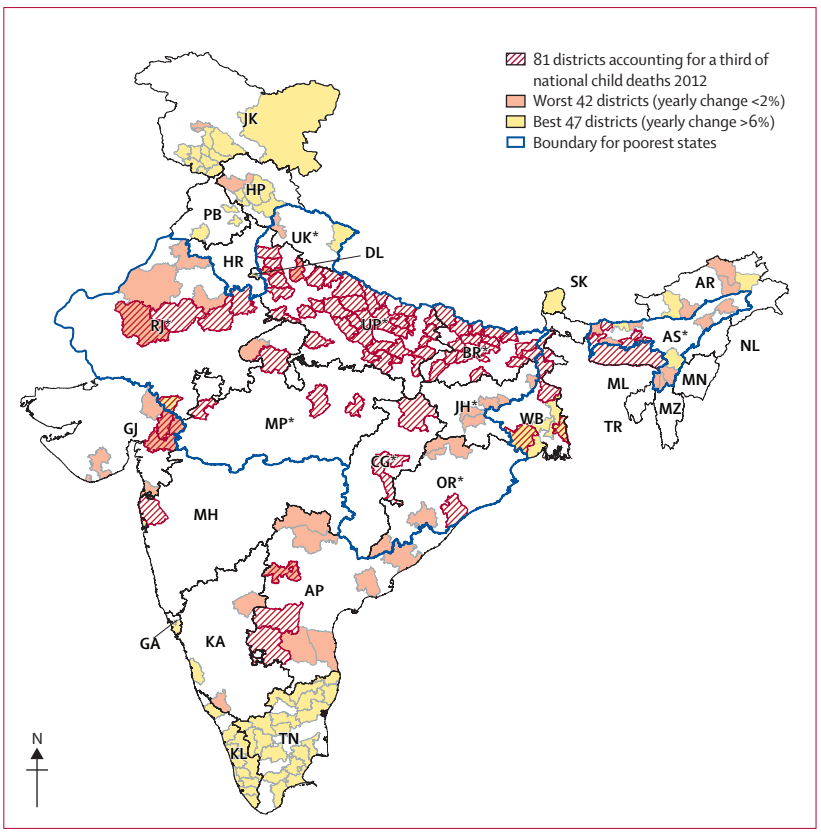

Figure 2: **Best and worst Indian districts according to change in under-5 mortality (2001–12), and districts with the highest third of under-5 mortality in 2012**

Map shows the best 47 districts and worst 42 districts according to change in the number of deaths in children younger than 5 years per 1000 livebirths between 2001 and 2012. The 81 districts containing a third of all deaths in children younger than 5 years in 2012 are shown. To calculate change in under-5 mortality we compared 2001 census results[17] with 2012 results for under-5 mortality. Richer states are the 20 states of Andhra Pradesh (AP), Arunachal Pradesh (AR), Delhi (DL), Goa (GA), Gujarat (GJ), Haryana (HR), Himachal Pradesh (HP), Jammu and Kashmir (JK), Karnataka (KA), Kerala (KL), Maharashtra (MH), Manipur (MN), Meghalaya (ML), Mizoram (MZ), Nagaland (NG), Punjab (PB), Sikkim (SK), Tamil Nadu (TN), Tripura (TR), West Bengal (WB), and six union territories. *Poorer states are the nine states of Assam (AS), Bihar (BR), Chhattisgarh (CG), Jharkhand (JH), Madhya Pradesh (MP), Orissa (OR), Rajasthan (RJ), Uttarakhand (UK), and Uttar Pradesh (UP).

The 2001 census did not provide mortality for neonates or children aged 1–59 months. Thus, only the 2012 results are presented. In 2012, 251 (42%) districts lagged more than 5 years behind the goal for neonatal deaths of 20 per 1000 livebirths (appendix pp 33–34). Of these, 155 (62%) districts lagged behind the neonatal goal by more than 10 years. None of the districts in Chhattisgarh, Orissa, Rajasthan, or Uttar Pradesh was on track to achieve the neonatal goal. Many districts in the richer states (Andhra Pradesh–18, Gujarat–16, Haryana–14, Karnataka–11, Maharashtra–14, Punjab–7, West Bengal–10) also lagged behind the neonatal goal. In 2012, 197 (33%) districts lagged more than 5 years behind the goal for children aged 1–59 months of 18 deaths

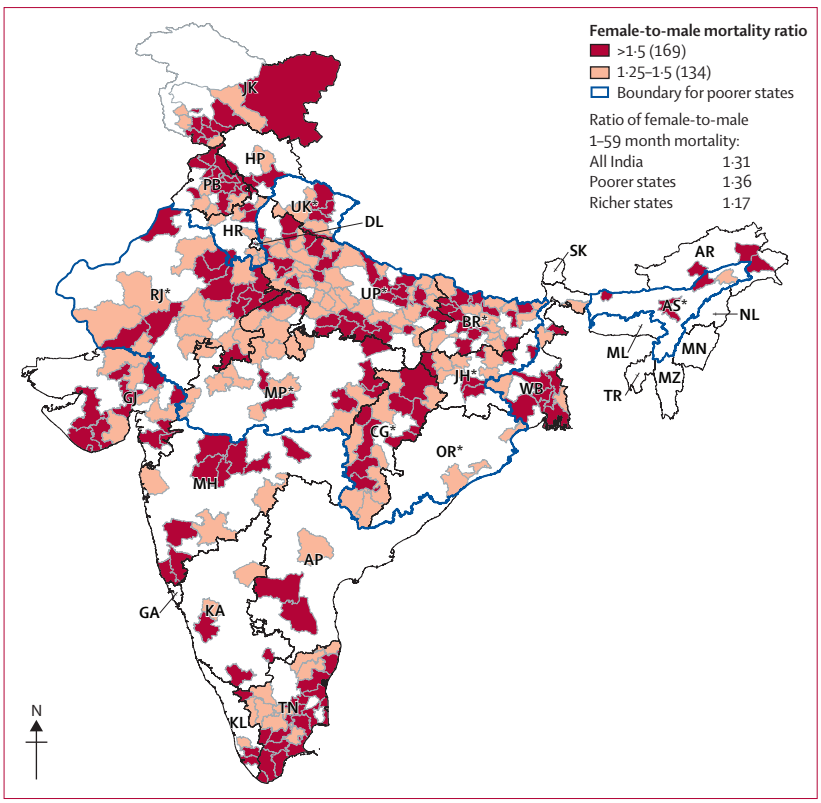

Figure 3: **Indian districts with high female-to-male mortality ratio at 1–59 months, 2012**
Female-to-male mortality ratio is the ratio of mortality in girls aged 1–59 months divided by mortality in boys aged 1–59 months. Richer states are the 20 states of Andhra Pradesh (AP), Arunachal Pradesh (AR), Delhi (DL), Goa (GA), Gujarat (GJ), Haryana (HR), Himachal Pradesh (HP), Jammu and Kashmir (JK), Karnataka (KA), Kerala (KL), Maharashtra (MH), Manipur (MN), Meghalaya (ML), Mizoram (MZ), Nagaland (NG), Punjab (PB), Sikkim (SK), Tamil Nadu (TN), Tripura (TR), West Bengal (WB), and six union territories. *Poorer states are the nine states of Assam (AS), Bihar (BR), Chhattisgarh (CG), Jharkhand (JH), Madhya Pradesh (MP), Orissa (OR), Rajasthan (RJ), Uttarakhand (UK), and Uttar Pradesh (UP).

per 1000 livebirths (appendix pp 34–35). Of these, 81 (41%) districts lagged behind the 1–59 month goal by more than 10 years (appendix p 34). Only in the state of Kerala have all districts achieved the goals for neonates and children aged 1–59 months.

The absolute decline in under-5 mortality is an appropriate measure to reduce geographic (and to some extent social) inequalities, because programmatic goals for each district are linked to the achievement of national goals. However, similar conclusions emerge with the use of relative declines from 2001 to 2012 in under-5 mortality (appendix p 36). Under-5 mortality fell at less than 3·75% per year (about the national average decline) in 236 districts, between 3·75% and 4·49% in 135 districts, and 4·50% or greater in 226 districts. Districts lagging in relative terms are more often seen in the richer states (except for Tamil Nadu and Kerala) than are districts lagging in absolute terms. 42 districts had yearly relative declines of 2% or less in under-5 mortality between 2001 and 2012 (figure 2); 18 of these 42 districts are in the richer states, including five in Andhra Pradesh and six in Gujarat (appendix pp 37–38). By contrast, yearly relative declines exceeded 6% per year in 47 districts, of which 21 are outside Kerala and Tamil Nadu, but only one in a poorer state. Districts lagging behind the goals, by any amount of time, for neonatal or 1–59 month mortality overlapped (correlation coefficient 0·66). 81 (14%) of the 597 districts in India (68 in poorer states) are home to 37% of the national deaths in children younger than 5 years (figure 2; appendix pp 39–40).

Female mortality at ages 1–59 months exceeds male mortality by more than 25% in 303 districts (appendix p 41) and by more than 50% in 169 districts (figure 3). Excess female mortality is seen in nearly all states, including Kerala and Tamil Nadu, which otherwise have relatively low under-5 mortality. Nationally, the 303 districts with excess female mortality are home to more than 58% of female livebirths and 68% of female deaths at 1–59 months, totalling about 74 000 excess deaths in girls (appendix p 41).

The Annual Health Surveys (AHS)[20] estimated under-5 mortality in 284 districts of the nine poorer states for 2012. At the state level, the means and the SDs of under-5 and neonatal mortality are similar between the AHS and our study (appendix p 42). The Spearman correlation was 0·57 for under-5 mortality and 0·46 for neonatal mortality with our district results. The numbers of districts lagging behind MDG 4 by more than 5 years were similar between the AHS and our results.

Discussion

We provide standardised estimates of neonatal, 1–59 month, and under-5 mortality for 597 districts of India and measure progress against the 2015 MDG 4 (appendix pp 18–32). Most Indian districts will only achieve the MDG for under-5 mortality well beyond 2015 and India as a whole will only achieve it by about 2020. Although under-5 mortality has fallen substantially in India,[1,21] an equal number of districts (222) are on track to achieve MDG 4 as those who will achieve it after 2020. The average under-5 mortality in the 222 lagging districts (71 per 1000 livebirths) is about the same as reported in Kenya in 2012.[2] Since more than 40% of India's livebirths occur in these lagging districts, much faster progress in reducing under-5 mortality is needed in these districts. Our estimates take into account the accelerations in yearly under-5 mortality declines from about 2008 onward, including in the poorer states.[6]

Excess female deaths at ages 1–59 months are seen across India, even in districts in south India with relatively low under-5 mortality. Selective abortions of girls are estimated to have totalled about 4–12 million between 1980 and 2010, and the practice has spread to most regions.[19] However, the correlation between excess female deaths and low girl-to-boy ratio in children younger than 6 years was weak (data not shown).

It would be cost effective to focus resources on the 81 districts accounting for about a third of all deaths in children younger than 5 years.[4] The Indian Government

has used similar targeting for 264 districts with low measles vaccination rates[22] and has recently defined 184 districts as top priority on the basis of DLHS3 and census data.[23] These definitions of priority districts overlap with our definition of the 222 lagging districts (data not shown).

Earlier results from the ongoing Million Death Study[15] have shown that the leading causes of death at ages 1–59 months are pneumonia and diarrhoea; together they contribute most to the female–male mortality gap at these ages. Effective interventions against these two diseases include introduction of *Haemophilus influenzae* type B, rotavirus, and conjugate pneumococcal vaccines and expansion of outreach programmes for case management of pneumonia and diarrhoea.[4] Our estimates take into account the increasing proportion of neonatal deaths out of all deaths in children younger than 5 years as overall under-5 mortality declines. A surprisingly high number of the districts in the richer states lag behind the neonatal goals. Nationally about 42% of neonatal deaths in 2005 occurred within the first 2 days of life and about 80% of all neonatal deaths were due to three disorders: birth asphyxia or birth trauma, low birthweight and prematurity, or infections.[15] These disorders are amenable to effective low-cost care, but the interventions rely on the availability of facilities.[4] More districts lag behind the neonatal goals than the 1–59 month mortality goals, and such districts are distributed among richer and poorer states, which suggests the necessity of renewed national attention on strategies to reduce neonatal deaths.[4,24] For example, the Indian Government's cash payment scheme introduced in 2006 has raised the proportion of births in hospitals,[23] but the scheme has few incentives to reduce early neonatal mortality.

Finally, all districts could benefit from better accountability and assessment of their performance,[4] including reporting on the causes of neonatal death and deaths at ages 1–59 months.[25] The AHS cover the nine poorer states from 2010 to 2012. As expected, under-5 mortality estimates vary across districts (and even between AHS and SRS results).[6] Understanding the variation in all-cause rates needs district-level estimates of the major causes of death, which are not yet available.

By necessity, our analysis is crude and several possible sources of error need to be considered. The main statistical uncertainties arise from the data extracted for children born and those who have died and the proportions of those that are neonatal or aged 1–59 months (appendix pp 7–17). The ratio of the number of children born to the number of those who died and the proportions of neonatal and infant deaths were generally stable over time for major states (data not shown). Our estimates showed similar results to the AHS (appendix p 42). Female births are underreported compared with male births.[16] Calibration to UN totals partly adjusts for the undercounts in death and birth rates in the SRS[26] and in the major surveys, particularly for missing girls and for neonatal deaths. District rates carry uncertainty from the input survey data, and we provide crude estimates of their error. Further direct district surveys, and a comparison with the birth histories from the 2011 census, are needed to improve the precision for each district and to reproduce our findings. Notwithstanding these statistical uncertainties, our estimates provide an important, replicable (appendix pp 1–4), and transparent method to drive local debate and decisions on allocation of resources by the National Rural Health Mission and major disease control programmes for child survival (panel).[4]

Much of the underlying variation in under-5 mortality across districts reflects not only differences in access to childhood prevention and treatment services, but also measurable differences in largely unknown causative factors and in some intermediate determinants of disease risk, such as the link between nutrition and infection.[27] Further aetiological studies of childhood mortality can build upon the wide variation in age-specific and sex-specific child mortality rates in India.

***Panel:* Research in context**

Systematic review

We used the search term ("child mortality"[MeSH Terms] OR ("child"[All Fields] AND "mortality"[All Fields]) OR ("child mortality"[All Fields]) AND district [All Fields] AND ("India"[MeSH Terms] OR "India"[All Fields])) and identified 188 studies published after 1970 in English. Only two studies[28,29] examined all-cause mortality in children younger than 5 years in the districts in selected states of India and 12 studies analysed child mortality in one or two districts. The remaining studies examined outbreak of selected diseases in children in a small area or causes of death in children from a specific disease in a small area, or reviewed the status of child health at the state or national level.

Interpretation

Our study is the first standardised estimate of district-specific neonatal, 1–59 month, and under-5 mortality by sex for 597 districts of India and measures the status of Indian districts with respect to Millennium Development Goal 4 (MDG 4). The study identifies the districts that are lagging behind MDG 4, which should help to identify and better target child survival strategies.

Contributors

PJ and UR conceived the study and analysed the data. All authors were involved with data interpretation, critical revisions of the paper, and approved the final version. PJ is the guarantor.

Conflicts of interest

We declare that we have no conflicts of interest.

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Accelerated progress to reduce under-5 mortality in India

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India has made steady progress in reducing deaths in children younger than 5 years, with total deaths declining from 2·5 million in 2001 to 1·5 million in 2012.[1] Achievement of the 2015 Millennium Development Goal for under-5 mortality (MDG4) for India—38 deaths or fewer in children younger than 5 years per 1000 live births—is important for the country's children and for reaching global targets.

Neonatal and 1–59 month mortality vary substantially between subregions of India as a result of the underlying differences in social and economic status, child nutrition status, health services, work culture, gender bias, and other factors that affect child mortality. The National Rural Health Mission recommends district-based planning for maternal child health programmes and, indeed, for other disease-specific initiatives. Availability of district-based mortality data and reliable information about barriers to achieving MDG targets in some of the districts is important for more effective local planning and action.

In *The Lancet Global Health*, Usha Ram and colleagues[2] report neonatal and 1–59 month mortality data for 597 districts in India in 2012 and compare these data with 2001 findings to assess progress towards achieving the 2015 MDG4. The key findings are that, from 2001 to 2012, under-5 mortality declined by an average of 3·7% (IQR 3·2–4·9) per year and that just over a third of all districts are on track to reach MDG4 by 2015. An important but not surprising message is that 222 districts are likely to achieve MDG4 only after 2020. These lagging districts account for over half of the total deaths in children younger than 5 years. Expectedly, the rate of decline in the lagging districts is slower for neonatal mortality than for 1–59 month mortality.

Insights into why many districts have a slow rate of decline in child mortality despite efforts of the National Rural Health Mission are beyond the scope of the article by Ram and colleagues.[2] District-level, cause-specific mortality data are not provided because they are not available. Further analyses are needed to identify barriers to progress that can be corrected as district plans and programmes are redesigned and reinforced.

Diarrhoea, pneumonia, and high rates of under-nutrition and micronutrient deficiencies are common causes and contributing factors to postneonatal deaths. Although use of oral rehydration solution has improved in most parts of India, use is substantially lower than in some neighbouring countries, and zinc treatment has been slow to pick up. The contribution of pneumonia to under-5 mortality is still high because of persistent difficulties in access to treatment and in navigation of referral pathways. This issue needs urgent attention.

Prevention works better wherever access to treatment is a challenge. Rotavirus and pneumococcal conjugate vaccines should be introduced when feasible, and use of pentavalent vaccines that also provide protection against *Haemophilus influenzae* infections needs scaling up. Interventions to improve water, sanitation, and hygiene are nearly as effective as these vaccines and should be prioritised.

With respect to acceleration in reduction of neonatal mortality, the progress made to increase the proportion of women giving birth in hospital has been impressive in many parts of India, and this progress needs a further push in areas where this achievement is less striking. Surveillance for adoption of best practice in health facilities would ensure progressive reduction in early neonatal mortality and linkage with community-based programmes after hospital discharge. The mortality and morbidity reduction as a result of improved newborn care practices has been repeatedly shown.[3–5] Home visitation programmes, supported by community mobilisation, should be scaled up. Much work needs to be done to support recognition, care seeking, and referral of sick neonates and young infants to appropriate facilities.

The districts that have the greatest challenges merely need stronger government and community efforts. Programme implementation can be supported by promotion of innovation in care delivery and strengthening of programme management. Financial incentives, where appropriate, should be considered to improve care seeking and access to treatment. In less well performing districts, not-for-profit institutions working in close synergy with local health systems can help to improve programme implementation and monitoring.

Overall, the steady decline in under-5 mortality in a large country like India is laudable; however, acceleration

through greater investment, focus, and innovation is needed in regions and districts that are doing less well. This goal can be achieved, as shown by some of India's neighbours.

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I declare that I have no conflicts of interest.

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