Causes of neonatal and child mortality in India: a nationally representative mortality survey

*The Million Death Study Collaborators**

Summary

Background More than 2·3 million children died in India in 2005; however, the major causes of death have not been measured in the country. We investigated the causes of neonatal and child mortality in India and their differences by sex and region.

Methods The Registrar General of India surveyed all deaths occurring in 2001–03 in 1·1 million nationally representative homes. Field staff interviewed household members and completed standard questions about events that preceded the death. Two of 130 physicians then independently assigned a cause to each death. Cause-specific mortality rates for 2005 were calculated nationally and for the six regions by combining the recorded proportions for each cause in the neonatal deaths and deaths at ages 1–59 months in the study with population and death totals from the United Nations.

Findings There were 10 892 deaths in neonates and 12 260 in children aged 1–59 months in the study. When these details were projected nationally, three causes accounted for 78% (0·79 million of 1·01 million) of all neonatal deaths: prematurity and low birthweight (0·33 million, 99% CI 0·31 million to 0·35 million), neonatal infections (0·27 million, 0·25 million to 0·29 million), and birth asphyxia and birth trauma (0·19 million, 0·18 million to 0·21 million). Two causes accounted for 50% (0·67 million of 1·34 million) of all deaths at 1–59 months: pneumonia (0·37 million, 0·35 million to 0·39 million) and diarrhoeal diseases (0·30 million, 0·28 million to 0·32 million). In children aged 1–59 months, girls in central India had a five-times higher mortality rate (per 1000 livebirths) from pneumonia (20·9, 19·4–22·6) than did boys in south India (4·1, 3·0–5·6) and four-times higher mortality rate from diarrhoeal disease (17·7, 16·2–19·3) than did boys in west India (4·1, 3·0–5·5).

Interpretation Five avoidable causes accounted for nearly 1·5 million child deaths in India in 2005, with substantial differences between regions and sexes. Expanded neonatal and intrapartum care, case management of diarrhoea and pneumonia, and addition of new vaccines to immunisation programmes could substantially reduce child deaths in India.

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Introduction

Yearly child mortality rates in India have fallen between 1·7%[1] and 2·3%[2] in the past two decades. Despite this decrease, the United Nations (UN) estimates that about 2·35 million children died in India in 2005. This figure corresponds to more than 20% of all deaths in children younger than 5 years worldwide, which is more than in any other country.[1,3] Large differences in overall child survival between India's diverse regions have been previously documented.[4,5] However, no direct and nationally representative measurement of the major causes of death in neonates (<1 month) and at ages 1–59 months has been done,[6] and how these causes of death vary across India's regions is unknown. Social preference for boys is strong, as noted by widespread selective abortion of female fetuses[7] and by lower immunisation rates in girls.[8] The consequences of boy preference on child mortality remain undocumented. Understanding of the causes of child death might, therefore, help to guide the use of widely practicable interventions for neonatal and child survival.[3,9]

Most deaths in India, including of children, are not medically certified since most occur at home, in rural areas, and without attention by a health-care worker.[10] Thus, other sources of information are needed to help to establish the probable underlying causes of death. During the past decade the Registrar General of India (RGI) has introduced an enhanced form of verbal autopsy called RHIME—or routine, reliable, representative, re-sampled household investigation of mortality with medical evaluation[11]—into its nationally representative sample registration system (SRS), which covered about 6·3 million people and monitored all deaths in 1·1 million homes.[5] This mortality survey is part of the Million Death Study, which seeks to assign causes to all deaths in the SRS areas during the 13 years from 2001 to 2013.[11–15] In this report we present the results of the causes of child deaths in India, separately for the neonatal period and at ages 1–59 months, for boys and girls, and for each of six major regions of India.

Methods

Study setting and procedures

Details of the design, methods, and preliminary results of the Million Death Study have been previously published.[11–15]

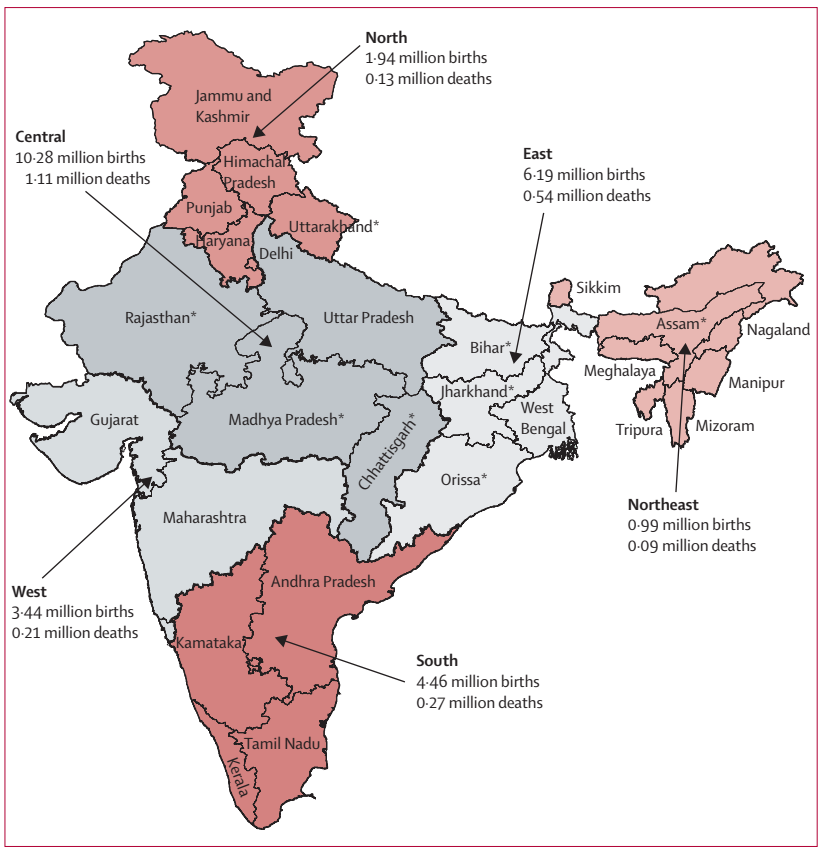

Figure 1: **Yearly number of livebirths and deaths in children aged 0–4 years in India, by region, 2005**
*These lower-income states are known as the Empowered Action Group plus Assam (EAGA) states.

See Online for webappendix

India was divided into about 1 million areas for the 1991 census, each with about 1000 inhabitants. The RGI chose 6671 of these areas randomly for the SRS in 1993; in each area all individuals and their household characteristics were documented and subsequent births and deaths (but not cause of death) were documented every month by a part-time enumerator resident in that area, and independently surveyed twice a year by one of 800 full-time RGI surveyors (trained non-medical graduates). Each of these RGI surveyors has visited, since 2002, each SRS area periodically to record from families (or other informants) a written narrative in the local language describing the events that preceded the death, in addition to answers to standard questions about key symptoms. Separate forms were used for neonatal deaths and deaths in children aged between 1 month and 14 years, on the basis of a WHO multicountry validation study of verbal autopsy for common causes of childhood deaths.[16] Forms were pretested in about 500 child deaths in India.[11] Random resampling and other fieldwork quality control methods were used.[11]

Central medical coding of causes of death

Each of the local language narratives and corresponding symptom data were electronically scanned and sent randomly, on the basis of the language of the narrative, to two of 130 collaborating physicians trained in disease coding who, working independently, assessed the probable underlying cause of death and assigned a three-character code from the International Classification of Diseases tenth revision (ICD-10)[17] with use of structured guidelines for each major disease group.[18] Disagreements about the ICD-10 codes assigned were resolved by anonymous reconciliation (ie, asking each physician to reconsider); persisting differences were adjudicated by a third physician. Separate classification systems were developed for the causes of neonatal deaths and at ages 1–59 months, based on input from the Child Health and Epidemiology Reference Group[9] (webappendix pp 2–5).

National and subnational mortality rates

The age-specific and sex-specific proportions of each cause of death were calculated (weighted according to the SRS sampling fractions in the rural and urban areas of each state[5]). We applied the proportions of each cause of death to the independent UN Population Division estimates of deaths (2·35 million) and livebirths (27·3 million) in India in 2005,[1] to calculate age-specific and sex-specific mortality rates (per 1000 livebirths) and absolute deaths by cause. The UN totals were used because the SRS slightly underestimates child mortality rates[19] and because about 12% of the SRS-enumerated deaths were not interviewed, mostly because of migration by the family. The UN totals for 2005 were used because these data were most complete, could be compared with the available Indian Census projections for 2006, and were collected before the implementation of a new national health programme to reduce child mortality.[9] Application of the 2001–03 proportions to the 2005 total deaths did not introduce major biases since there was little change in the yearly distribution of causes of deaths in our survey, or between 2001 and 2004 in an independent survey of medically certified causes of death from selected urban hospitals.[20]

To calculate subnational mortality rates, we partitioned the UN total births and child deaths into 140 strata (35 states, rural and urban areas, and both sexes) with the Census of India 2005 population,[21] relative SRS birth and death rates,[5] or smaller demographic surveys[4] when SRS data were not available (webappendix pp 1–2). Subnational results were produced for the six regions (north, south, west, central, northeast, and east),[12] and for the lower-income states with historically higher child mortality rates and poverty levels (Assam, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Orissa, Rajasthan, Uttarakhand, and Uttar Pradesh) and the remaining states (figure 1). 99% CIs for each cause of death proportion or mortality rate were calculated with Taylor linearisation[22] on the basis of the survey design and the observed sample deaths in the Million Death Study. All statistical analyses were done in Stata (version 10.1).

Role of the funding source

The sponsor of the study 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 the data in the study and had final responsibility for the decision to submit for publication

Results

Of the 24 841 child deaths surveyed, 93% (23 152) were double-coded by physicians and included in the study (table). Reasons for exclusion were missing information about age or sex (n=191), and non-legible forms, improper scanning of narrative, or incorrect language code (n=1498). Respondents for the 23 152 child deaths were the father (n=5117; 22%), mother (8103; 35%), siblings and other relatives (5047; 22%), grandparents (3612; 16%), or a neighbour or non-relative (1273; 5%). Most child deaths occurred in rural areas (table) irrespective of the cause of death. Only 17% (3877/23 152) of children died in a health facility, with large variations between rural and urban areas and between states (webappendix p 11). Physicians agreed on the cause of death initially for 62% (14 410/23 152) of all deaths.[23]

	Study deaths, 2001–03						All India, 2005					
	Boys	Girls	Total	Rural area	Died in a health facility	Two coders immediately agreed	Mortality rate per 1000 livebirths			Total deaths (thousands)		
							Boys	Girls	Total	Boys	Girls	Total (99%CI)*
Neonatal (<1 month)												
Prematurity and low birthweight†	2012	1619	3631	3265	988	2381	13·0	10·8	12·0	185	142	327 (309–345)
Neonatal infections‡	1544	1339	2883	2694	346	1804	10·3	9·4	9·9	145	123	268 (253–286)
Birth asphyxia and birth trauma	1219	854	2073	1869	631	946	8·0	5·9	7·0	113	77	190 (176–206)
Other non-communicable diseases	316	243	559	502	118	251	2·0	1·6	1·8	28	21	49 (42–58)
Congenital anomalies	213	146	359	304	139	202	1·4	1·0	1·2	20	13	33 (28–42)
Diarrhoeal diseases	175	162	337	318	26	227	1·2	1·2	1·2	17	15	32 (26–40)
Tetanus	149	115	264	255	14	180	1·3	1·0	1·2	18	14	32 (26–39)
Injuries	27	20	47	43	8	15	0·2	0·1	0·2	3	2	5 (3–8)
Other causes	414	325	739	665	147	329	2·7	2·5	2·4	39	33	72 (61–81)
All causes	6069	4823	10 892	9915 (91·0%)	2417 (22·2%)	6335 (58·2%)	40·1	33·5	36·9	568	440	1008
1–59 months												
Pneumonia	1542	1890	3432	3146	404	2546	11·2	16·0	13·5	159	210	369 (348–390)
Diarrhoeal diseases	1184	1532	2716	2480	293	2146	8·9	13·4	11·1	126	176	302 (283–323)
Measles	308	450	758	687	64	374	2·5	4·2	3·3	36	56	92 (79–104)
Other non-communicable diseases	418	433	851	772	142	490	3·0	3·5	3·2	42	46	88 (77–100)
Injuries	400	357	757	689	91	673	2·9	2·9	2·9	42	38	80 (68–92)
Malaria	262	325	587	562	43	354	1·7	2·4	2·0	24	32	56 (47–65)
Meningitis/encephalitis	232	209	441	396	94	183	1·9	1·9	1·9	27	25	52 (43–62)
Nutritional diseases	141	201	342	303	18	190	1·1	1·9	1·5	16	25	41 (34–51)
Acute bacterial sepsis and severe infections	147	213	360	324	50	117	1·1	1·8	1·4	15	23	38 (31–47)
Other infectious diseases	143	182	325	298	43	120	1·0	1·5	1·2	14	19	33 (27–41)
Other causes	847	844	1691	1490	218	882	6·4	7·2	6·9	91	95	186 (170–203)
All causes	5624	6636	12 260	11 147 (90·9%)	1460 (11·9%)	8075 (65·9%)	41·7	56·7	48·9	592	745	1337
0–4 years												
All causes	11 693	11 459	23 152	21 062 (91·0%)§	3877 (16·7%)§	14 410 (62·2%)	81·8	90·2	85·8	1160	1185	2345

Total livebirths (2005): 27·3 million; 14·2 million boys, 13·1 million girls. Mortality estimates exclude stillbirths, cancelled reports (ie, not coded), and children with missing information about sex or age. The percentage of deaths that could not be coded was 6·5% in boys, 5·6% in girls, 8·0% in urban areas, and 5·8% in rural areas. *99% CIs are provided for the causes of death but not for the UN totals for all-cause child deaths. †For prematurity: mortality rate for boys 9·5 (99% CI 8·9–10·1), estimated total deaths 135 000; for girls 7·4 (6·9–8·0), 97 000 deaths; and for both 8·5 (8·1–8·9), 232 000 deaths. Low birthweight: mortality rate for boys 3·5 (3·1–3·9), estimated total deaths 50 000; for girls 3·4 (3·0–3·9), 45 000 deaths; and for both 3·5 (3·2–3·8), 95 000 deaths. These two conditions are combined because of the difficulty in differentiating them in verbal autopsies. ‡Infections category includes neonatal pneumonia, sepsis, and CNS infections (about 2000 deaths every year). For neonatal pneumonia: mortality rate for boys 6·0 (99% CI 5·5–6·5), estimated total deaths 85 000; for girls 5·8 (5·3–6·3), 76 000 deaths; and for both 5·9 (5·5–6·3), 161 000 deaths. For sepsis: mortality rate for boys 4·2 (3·8–4·7), 60 000 deaths; for girls 3·6 (3·2–4·0), 47 000 deaths; and for both 3·9 (3·6–4·2), 107 000 deaths. These three conditions are combined because of the difficulty in differentiating them in verbal autopsies. §Sample-weighted percentage of deaths: 87·1% occurred in a rural area and 16·6% occurred in a health facility.

Table: **Causes of death in neonates and at ages 1–59 months in this study and estimated national totals**

The mortality rate in children younger than 5 years was 85·8 per 1000 livebirths (81·8 for boys and 90·2 for girls). Five causes accounted for 62% (1·46 million of 2·35 million) of all child deaths: pneumonia, prematurity and low birthweight, diarrhoeal diseases, neonatal infections, and birth asphyxia and birth trauma (table). The sex (figure 2) and regional (figure 3) distribution of the leading causes of child deaths varied in neonates (figure 4) and at ages 1–59 months (figure 5). Estimates of deaths and mortality rates for the leading causes of death for the major states of India are shown in webappendix pp 9–20.

Three causes accounted for 78% (0·79 million of 1·01 million) of all neonatal deaths in India: prematurity and low birthweight; neonatal infections, comprising

Figure 2: **Causes of death in children aged 0–4 years in India, by sex and by state income, 2005**
MR=mortality rate in children younger than 5 years. *Includes neonatal pneumonia, sepsis, and CNS infections. †Lower-income states are Assam, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Orissa, Rajasthan, Uttarakhand, and Uttar Pradesh; higher-income states are the remaining 26 states/union territories.

neonatal pneumonia, neonatal sepsis, and CNS infections; and birth asphyxia and birth trauma (figure 4). The proportion of neonatal deaths to total child deaths was higher in boys than in girls, and in higher-income than in lower-income states (table and figure 2). The proportion of neonatal deaths to total child deaths was greatest in areas with lowest mortality rates in children younger than 5 years (figure 3). The all-cause neonatal mortality rate was about 20% higher in boys (40·1) than in girls (33·5). Furthermore, neonatal mortality rates were higher for most causes in boys than in girls, although neonatal mortality rates were similar between sexes for diarrhoeal diseases (table). The proportion of total child deaths caused by neonatal infections was higher in the lower-income states than in

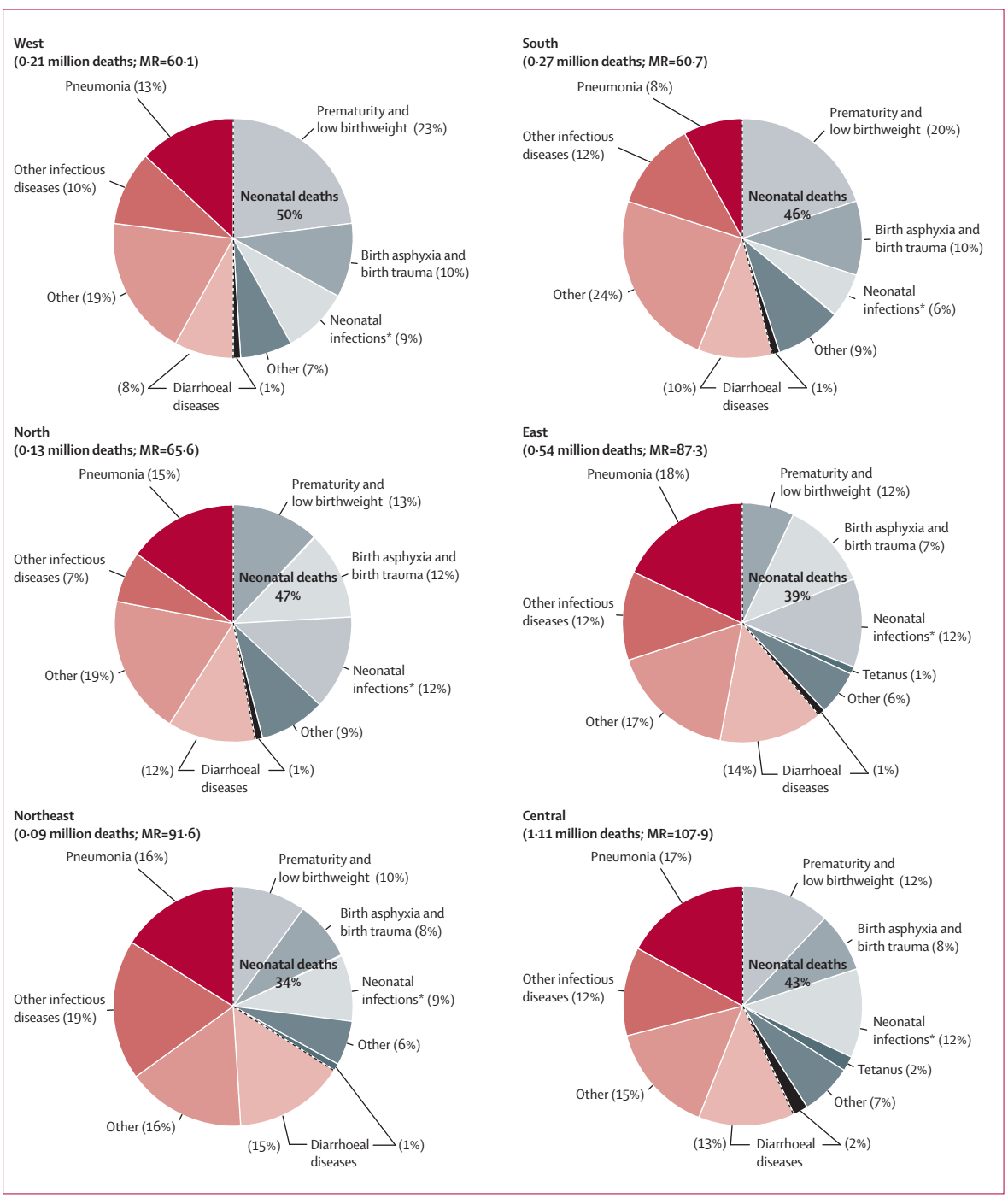

***Figure 3*: Causes of death in children aged 0–4 years in India, by region, 2001–03**
MR=mortality rate in children younger than 5 years. *Includes neonatal pneumonia, sepsis, and CNS infections.

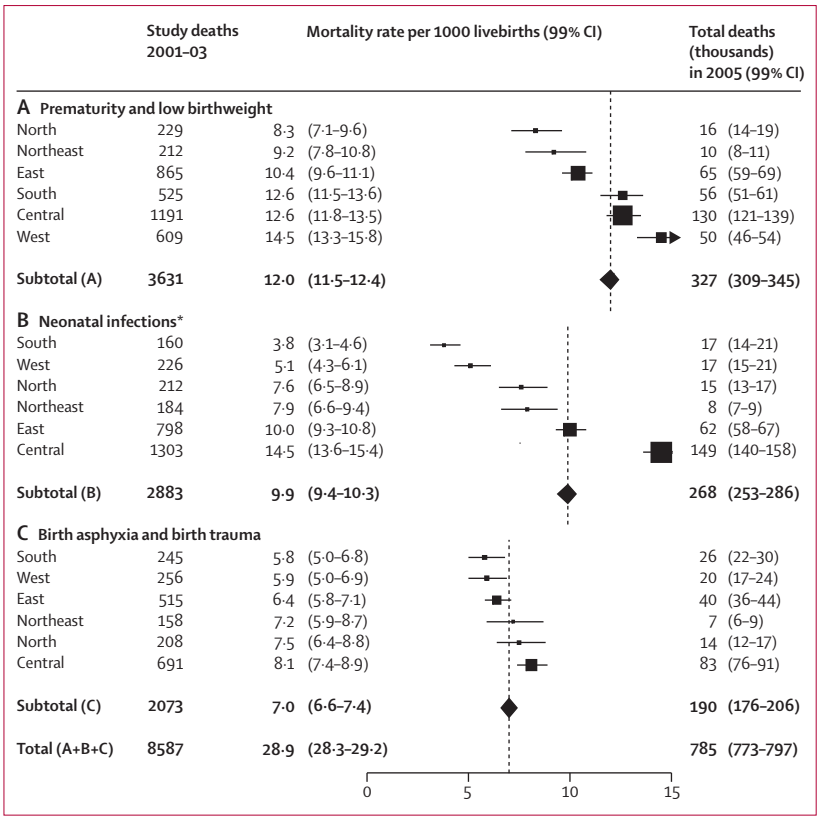

Figure 4: **Mortality rates for the three leading causes of neonatal death in India, by region, 2005**
*Includes neonatal pneumonia, sepsis, and CNS infections.

the higher-income states (figure 2). Prematurity and low birthweight formed a greater proportion of all child deaths in the west and south India than in other regions (figure 3). Tetanus was a notable cause of death in central and east India (figure 3).

We recorded substantial regional variation in mortality rates for the three leading causes of death in neonates (figure 4). The mortality rate for prematurity and low birthweight was highest in the west and lowest in the north (figure 4). The mortality rate for neonatal infections in central India was nearly four-times higher than that in south India, and mortality rates for birth asphyxia and birth trauma were highest in central India and lowest in the south (figure 4).

Pneumonia and diarrhoeal diseases accounted for 50% (0·67 million of 1·34 million) of all deaths in children aged 1–59 months (figure 5). All-cause mortality rate in children aged 1–59 months was about 36% higher in girls (56·7) than in boys (41·7) and most of the leading causes of death were between 12% and 72% higher in girls than in boys, with the exception of injuries and meningitis/encephalitis (table). Pneumonia and diarrhoeal diseases accounted for about two-thirds (0·10 million) of the 0·15 million more deaths from all causes in girls aged 1–59 months (table). Pneumonia and diarrhoeal diseases accounted for a greater proportion of total child deaths in lower-income than in higher-income states (figure 2), and their proportion of total child deaths decreased as rates of mortality in children younger than 5 years fell (figure 3).

The mortality rate from pneumonia in central India was four times that in the south, and the mortality rate from diarrhoeal diseases in central India was three times that in the west (figure 5). Differences were even greater when sex was taken into account. Girls in central India had a five-times higher mortality rate from pneumonia than did boys in south India, and had a four-times higher mortality rate from diarrhoeal disease than did boys in the west (figure 5).

Discussion

More than three-fifths of all 2·3 million child deaths in India in 2005 were from five causes: pneumonia, prematurity and low birthweight, diarrhoeal diseases, neonatal infections, and birth asphyxia and birth trauma. Each of the major causes of neonatal deaths can be prevented or treated with known, highly effective and widely practicable interventions such as improvements in prenatal care, intrapartum care (skilled attendance, emergency obstetric care, and simple immediate care for newborn babies), postnatal family-community care (preventive postnatal care, oral antibiotics, and management of pneumonia),[24] and tetanus toxoid immunisation.[25] Concern has been raised that neonatal death rates in India are not falling fast enough.[9] However, our results suggest that almost half of India's neonatal deaths are caused by birth asphyxia and birth trauma, sepsis, pneumonia, and tetanus—most of which can be avoided by increases in delivery and postnatal care.[26]

The substantial regional differences in cause-specific mortality, even in girls (webappendix p 12), could indicate the existence of some underlying social, behavioural, or biological risk factors for child deaths.[10] However, at ages 1–59 months, girls in every region die more commonly than do boys, and inequities in access to care, rather than biological or genetic factors, are a more plausible explanation for these recorded differences between sexes.[7,8] Household surveys[4,27] show little difference between sexes in the rate of respiratory symptoms and diarrhoeal disease, whereas our study and previous analyses[28] have shown substantial sex differences in mortality. Integrated management of child illnesses increases care seeking for illnesses,[29] and reduces child deaths,[30] but in India, boys use such programmes more than girls.[9] Fewer girls than boys are vaccinated in health facilities.[8] However, outreach programmes that visit households immunise a greater proportion of girls than do facility-based vaccination programmes.[9] Addition of vaccines against pneumonia (pneumococcal conjugate, *Haemophilus influenzae* type B) and diarrhoeal diseases (rotavirus) to outreach home-based immunisation programmes would reduce child deaths and narrow the gap in child mortality in India between sexes.[9,31]

Our study shows that boy social preference probably affects survival for girls. States with higher mortality rates in girls than in boys aged 1–59 months were also those with lower female-to-male sex ratio for second births after a boy (a measure of selective abortion of girls)[7] (Pearson's correlation coefficient –0·47, p=0·0004; data not shown). This finding implies that less frequent use of health services by girls than by boys occurs in the same states in which selective abortion of female fetuses is common. Moreover, a relative gap in mortality between girls and boys at ages 1–59 months is recorded in urban areas, in more educated groups, and in states with lower mortality rates (webappendix p 12).[4,32] However, the excess of 0·15 million deaths in girls aged 1–59 months is largely offset by the excess of 0·13 million deaths in male neonates. Thus, the most plausible explanation for the difference of 6 million between boys and girls in the 2001 census[21] (which recorded 76 million girls and 82 million boys aged 0–6 years) is probably selective abortion of female fetuses,[7] and less so the greater mortality in girls.

The main uncertainty in our estimates arises because verbal autopsy misclassifies some causes of death,[11,16,23] and because our estimates relied mostly on family reports of deaths occurring in rural homes. Previous studies comparing hospital-based deaths with home-based verbal autopsy (which formed the basis for the field instrument used in the Million Death Study) have reported reasonable agreement for the symptoms used to assign the five major causes of death that we report in this study.[16] Hospital deaths should not be regarded as a gold standard because there are probably important differences in the distribution of causes of child deaths, treatment patterns, and, for infectious causes, in their underlying pathogens,[33] between hospital deaths (mostly in urban areas) and rural, unattended deaths in the home.[13] Misclassification of causes can affect our estimates of the total number of deaths from each cause,[34] but misclassification is unlikely to be greatly different across sex, areas, and regions, and is unlikely to substantially affect our estimates of differences between sexes. The missing deaths or deaths that physicians were unable to code, although sizeable, are mostly random and unlikely to have affected the overall substantial variation by sex and region that we recorded. Similarly, there is also uncertainty in the UN total estimates of yearly child deaths (2·35 million deaths in 2005, ranging between 2·26 million and 2·46 million);[35] however, such uncertainty would probably raise or lower the overall mortality rates, but would not affect the recorded sex or regional variation in these mortality rates.

Our results correspond to deaths before the wide-scale introduction of India's National Rural Health Mission in 2006. That programme reports increases in institutional deliveries[9] and in coverage of existing vaccines, and therefore might have reduced child mortality in India. Our study also suggests that specific interventions might be priorities for different regions (eg, expanded case management and introduction of newer vaccines into immunisation programmes would be particularly needed in central India, especially for girls). The changes in the sex-specific and region-specific rates and causes of neonatal mortality and mortality at ages 1–59 months will continue to be monitored and reported by the RGI,[12] and should thus help to assess the effectiveness of the National Rural Health Mission and other efforts to reduce child mortality in India.

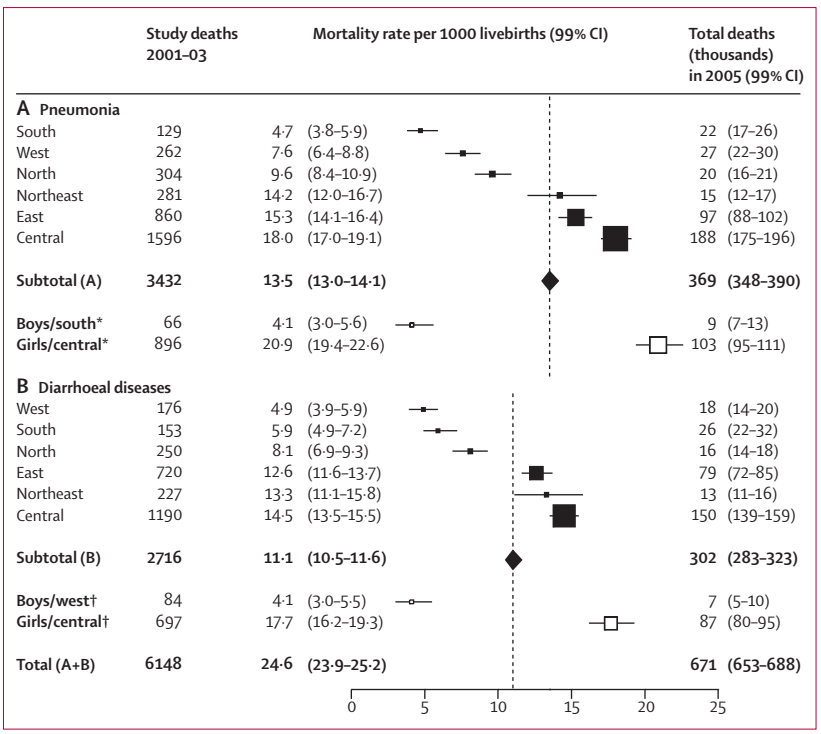

Figure 5: **Mortality rates for the two leading causes of death in children aged 1–59 months in India, by region, 2005**
*Boys from the south region have the lowest mortality rate for pneumonia by sex and region (at age 1–59 months), and girls from the central region have the highest. †Boys from the west region have the lowest mortality rate for diarrhoeal diseases by sex and region (at age 1–59 months), and girls from the central region have the highest.

Contributors

The academic partners in India (Million Death Study collaborators; webappendix p 7) planned the Million Death Study in close collaboration with the Office of the RGI. RK, SA, DGB, and PJ planned the child mortality study. DGB and PJ did the analyses. All authors were involved with data interpretation, critical revisions of the paper, and approved the final version. PJ is the guarantor of this report.

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Conflicts of interest

We declare that we have no conflicts of interest.

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