National Burden Estimates of healthy life lost in India, 2017: an analysis using direct mortality data and indirect disability data

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Summary

Background Many countries, including India, seek locally constructed disease burden estimates comprising mortality and loss of health to aid priority setting for the prevention and treatment of diseases. We created the National Burden Estimates (NBE) to provide transparent and understandable disease burdens at the national and subnational levels, and to identify gaps in knowledge.

Methods To calculate the NBE for India, we combined 2017 UN death totals with national and subnational mortality rates for 2010–17 and causes of death from 211 166 verbal autopsy interviews in the Indian Million Death Study for 2010–14. We calculated years of life lost (YLLs) and years lived with disability (YLDs) for 2017 using published YLD–YLL ratios from WHO Global Health Estimates. We grouped causes of death into 45 groups, including ill-defined deaths, and summed YLLs and YLDs to calculate disability-adjusted life-years (DALYs) for these causes in eight age groups covering rural and urban areas and 21 major states of India.

Findings In 2017, there were about 9·7 million deaths and 486 million DALYs in India. About three quarters of deaths and DALYs occurred in rural areas. More than a third of national DALYs arose from communicable, maternal, perinatal, and nutritional disorders. DALY rates in rural areas were at least twice those of urban areas for perinatal and nutritional conditions, chronic respiratory diseases, diarrhoea, and fever of unknown origin. DALY rates for ischaemic heart disease were greater in urban areas. Injuries caused 11·4% of DALYs nationally. The top 15 conditions that accounted for the most DALYs were mostly those causing mortality (ischaemic heart disease, perinatal conditions, chronic respiratory diseases, diarrhoea, respiratory infections, cancer, stroke, road traffic accidents, tuberculosis, and liver and alcohol-related conditions), with disability mostly due to a few conditions (nutritional deficiencies, neuropsychiatric conditions, vision and other sensory loss, musculoskeletal disorders, and genitourinary diseases). Every condition that was common in one part of India was uncommon elsewhere, suggesting state-specific priorities for disease control.

Interpretation The NBE method quantifies disease burden using transparent, intuitive, and reproducible methods. It provides a simple, locally operable tool to aid policy makers in priority setting in India and other low-income and middle-income countries. The NBE underlines the need for many more countries to collect nationally representative cause of death data, paired with focused surveys of disability.

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Introduction

In 1993, the World Bank proposed using burden of disease estimation paired with cost-effectiveness and economic analyses as quantitative tools to set priorities for disease control.[1] The Bank's measure of the global burden of disease drew upon three inputs: earlier work at WHO on consistent estimates of death by cause worldwide,[2] methodologies developed in the 1970s to combine fatal and non-fatal health events[3]—now known as disability-adjusted life-years (DALYs)—and an illustration of national burden in Ghana that combined non-fatal outcomes with cause of death estimates.[4,5] Many governments, especially of low-income and middle-income countries (LMICs), now conduct local cost-effectiveness studies.[5] By contrast, most LMICs lack nationally representative mortality data, and hence most burden of disease estimates are done by the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) secretariat in Seattle, USA.[5,6]

GBD is an important advance by ensuring consistent estimates of the global numbers of death by cause, and attempting to combine death and disability into a single metric.[1,6] At the national level, GBD estimates for LMICs of death by cause rely primarily on econometric models. Where no consistent and reliable national cause of death data are available, GBD or similar might be the only choice.[5,7,8] Where such data are available, however, they can be used for independent and locally relevant estimates, based on actual deaths. Here, we report a simple method

Research in context

Evidence before this study

We searched MEDLINE, Popline, CABI Global Health, and websites of WHO and the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) using the terms "burden of disease", "DALY", "India", and "causes of death" for national studies in people of all ages in India, from Jan 1, 2010, to March 1, 2019, with no language restrictions. From 795 articles screened, we found that GBD and WHO published modelled annual national estimates of disability-adjusted life-years (DALYs) for more than five diseases in 2013, 2015, 2016, and 2017. Ischaemic heart disease was consistently the leading cause of DALYs in GBD estimates, but the rank of other causes varied by year. It was difficult to separate changes in model specifications from changes in actual disease burdens. We were unable to reproduce the GBD method for burdens in India.

Added value of this study

We have developed and implemented an indigenous, simple, and intuitive method to calculate deaths and disability at national and state levels in India. The National Burden Estimates (NBE) establishes the plausible distribution of the major causes of death and disability across the major states of India. In 2017, there were about 9·7 million deaths and 486 million DALYs in India. Non-communicable diseases comprised 46·6% of national DALYs, but a notably higher 55·0% in urban areas. Injuries comprised 11·4% of DALYs. The conditions that accounted for the top 15 DALYs were led mainly by deaths in childhood and early adulthood. Together, these conditions accounted more than 70% of total DALYs—a proportion consistent with WHO and GBD results. The remarkable variation in years of life lost across India suggests that diseases common in one part of the country are relatively uncommon elsewhere, for reasons that are not well understood. Five conditions comprise much of the uncertainty in years lived with disability, and should be the focus of future research to derive better disability estimates. The NBE and GBD results for years of live lost and overall DALYs were moderately comparable, and the gaps identified in disability should help to improve future modelling and inform direct surveys of the major conditions causing disability.

Implications of all the available evidence

Much of Indian disease burden is avoidable. The NBE method is simple, locally operable, and widely replicable within India and in many other low-income and middle-income countries to track progress in human health.

to create a measure called National Burden Estimates (NBE), which combines nationally representative cause of death data from the Million Death Study (MDS) with UN demographic totals and WHO estimates of deaths and disability.[9,10] We provide details on the methodology to encourage replication in other LMICs.

About a fifth of all deaths worldwide occur in India.[10,11] The NBE was created in response to a request from India's Ministry of Health and Family Welfare to the Indian Council of Medical Research (ICMR) to provide transparent and understandable disease burdens at the national and subnational levels, and to identify gaps in knowledge, particularly from disability.[12]

Methods

Data sources

To calculate our estimates, we used national-level population and mortality data for 2017 from the UN Population Division[11] and state-level population and mortality data for 2010–17 from the Registrar General of India's Sample Registration System,[13,14] a continuous demographic surveillance system that reports state-level vital rates every year. For cause of death data, we used 2010–14 data from the MDS,[14] to which we applied the classifications of specific disease groups used in the WHO Global Health Estimates (GHE) for 2016.[10] We drew on the average of 2010–14 deaths, which are the latest available, for stability across age groups and cause of death categories.

See Online for appendix

Full details, including data limitations, of the UN demographic data, the Sample Registration System vital rates, and the WHO GHE have been published elsewhere.[9–11,13] The methods, strengths, and limitations of the MDS and key results for various diseases have also been extensively reviewed and published.[14–17] Briefly, in collaboration with the Registrar General of India, the MDS monitored approximately 14 million people in 2·4 million nationally representative households in India from 1998 to 2014.[18] About 900 non-medical surveyors recorded the details of each death that occurred in these households during the preceding 6 months using a well validated verbal autopsy instrument, which is based on the 2012 WHO instrument and includes a half-page local language narrative. Each record is converted to an electronic form and randomly assigned to two of 400 trained physicians, who assign a cause according to the International Classification of Diseases, 10th revision (ICD-10). Disagreements in assignment undergo anonymous reconciliation, and persisting differences undergo adjudication by a third physician.

Subnational analyses focused on the 21 major states of India, comprising the 20 most populous states as defined by the Registrar General of India plus seven northeastern states which we grouped as one state.[14] We included the recently created state of Telagana within Andhra Pradesh. These 21 states were home to more than 99% of India's total population in 2017.

Causes of death

We grouped ICD-10 codes into 44 overarching categories (appendix pp 5–7), informed by public health goals, in consultation with ICMR's Burden of Disease Technical

Advisory Group.[12] These 44 categories were further grouped into three main disease categories: communicable, maternal, perinatal, and nutritional diseases (13 causes); non-communicable diseases (NCDs; 24 causes); and injuries (seven causes). We retained ill-defined deaths as an additional category. By contrast, the GBD reassigns ill-defined deaths using unpublished algorithms whereas the GHE redistributes them to a published list of other specific causes.[6,9,10] Ill-defined deaths are a check on the quality of a cause of death system, with generally low levels before old age in the MDS.[15]

The NBE method

Calculation of the NBE involves seven steps (figure 1). First, we obtained UN age-specific and sex-specific country population and death counts for 2017 and deaths and population by state and for rural and urban strata for 2010–17. Second, we summed the subnational deaths and adjusted these (usually upwards by small amounts) to match the UN national total for each age and sex stratum.

In the third step, we applied the cause of death proportions from the MDS for 2010–14,[14] weighted by the sampling probability for rural and urban strata for each state, to these adjusted death totals to obtain age-specific and sex-specific numbers of deaths for each cause. We aggregated the death and population totals into eight age groups: 0–4 years, 5–14 years, 15–29 years, 30–49 years, 50–59 years, 60–69 years, 70–79 years, and 80 years or older. Fourth, we mapped the MDS classification of ICD-10 codes to the WHO GHE classification for India (appendix pp 5–7).[10] For each condition in the GHE, we derived the years lived with disability (YLDs) and years of life lost (YLLs) and calculated the YLD–YLL ratio for the specified age groups (appendix p 8). The GHE assigns no deaths to major depression; hence, to calculate YLDs for depression, we applied the GHE proportion of YLDs due to depression to the estimated overall YLDs from neuropsychiatric conditions.

Fifth, we calculated the median age at death for each cause from the MDS, subtracted this from the WHO standard life expectancy of 92 years, and multiplied this by the number of deaths from step 3 to obtain YLLs. Thus, the YLLs for cause i for age group j are given by

$$YLLs_{i,j} = (92 - \text{median age at death}_{i,j}) \times \text{adjusted UN deaths}_{i,j}$$

Sixth, we multiplied the YLLs by the GHE YLD–YLL ratios from step 4 to obtain YLDs. The final step summed YLLs and YLDs to obtain DALYs for each cause by age and sex. A worked example of the calculations for respiratory infection deaths at ages 5–14 years is shown in the appendix (p 4).

For subnational (rural or urban and state-specific) estimates, we used the same method, applying the national median age of deaths and 684 age-specific and sex-specific YLD–YLL ratios. We summed state-level vital rates to national totals in step 2, and applied the state-specific proportion of deaths in step 3. We compared state variation in DALY, YLL, and YLD rates after standardising for age using the World Standard Population 2000–25.[19]

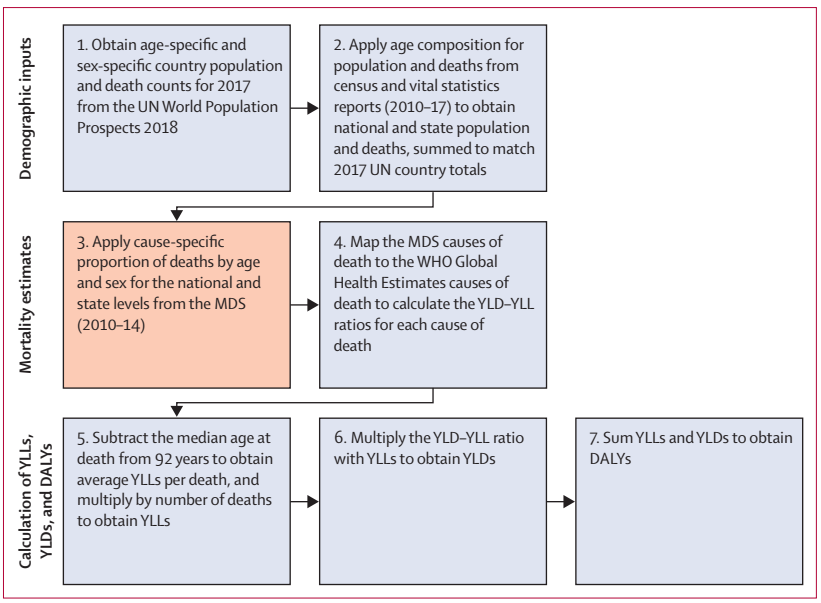

Figure 1: **Summary of the steps in the National Burden Estimates of combined death and disability**
The orange tinted box (ie, step 3) indicates the required input dataset on country-specific causes of death. All other steps use publicly accessible datasets from the UN Population Division[11] or the WHO Global Health Estimates.[10] MDS=Million Death Study. YLD=year lived with disability. YLL=year of life lost. DALY=disability-adjusted life-year.

Statistical analysis

We applied chance-corrected mortality fraction accuracy to calculate the population-level concordance between the NBE and GBD, taking into account chance agreement.[20] 100% concordance would mean identical cause of death distribution in the two comparisons. The major source of uncertainty in the NBE does not arise from random errors: the sample size for the MDS is very large and completeness of the sources of vital rates is high, as evaluated independently by the UN.[13,14,21] Rather, uncertainty arises mostly from the misclassification of causes of death. The appendix (p 114) presents the uncertainty bounds based on dual or single physician agreement on the underlying cause of death. We used Stata version 15.1 for statistical analyses. The ICMR has developed a user-friendly estimation and visualisation tool. The Stata code and tools are available on written request to the first author.

Role of the funding source

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

	Sex			Location	
	Both	Male	Female	Urban	Rural
Population, millions	1339	694	645	418	921
Deaths, thousands	9652	5298	4354	2397	7255
DALYs at all ages, millions	486	264	222	114	372
DALYs at age <70 years, millions	427	234	193	99	328
MDS deaths, 2010–14	211166	120912	90254	47695	163471
DALYs per 100 000 population*					
By age, years					
All ages	36300	38100	34400	27400	40400
0–4	84400	83800	85000	58100	93700
5–14	13300	14400	12100	9300	14800
15–29	17400	16800	18100	16100	18100
30–49	27900	31000	24600	20400	31900
50–59	52200	59200	44900	36800	60600
60–69	85000	94000	76000	66800	92500
70–79	127600	137900	118400	109700	135100
≥80	112900	120400	106800	99600	118600
By major cause groups					
Communicable, maternal, perinatal, and nutritional	13000	12900	13000	7600	15400
Non-communicable	16900	18000	15800	15100	17800
Injuries	4100	5100	3100	3100	4600
Ill-defined at age <70 years	1100	1000	1200	800	1200
By top 15 causes of DALYs					
Ischaemic heart disease	3500	4300	2500	4000	3200
Perinatal conditions	3100	3200	3000	1800	3700
Nutritional deficiencies	2200	2200	2200	1200	2600
Chronic respiratory diseases	2100	2300	1800	1200	2500
Neuropsychiatric conditions	2000	1800	2300	1500	2300
Diarrhoea	1700	1600	1800	900	2100
Vision and other sensory loss	1600	1500	1900	1300	1800
Respiratory infections	1600	1600	1600	1000	1900
Cancers	1400	1400	1500	1300	1500
Stroke	1300	1400	1200	1100	1400
Road traffic accidents	1200	1900	400	1100	1200
Tuberculosis	1100	1500	800	700	1300
Liver and alcohol-related conditions	1100	1500	600	1000	1100
Musculoskeletal disorders	1000	800	1200	1000	1000
Fever of unknown origin	900	800	1000	500	1100

DALYs=disability-adjusted life-years. MDS=Million Death Study. *Rounded to nearest 100. Totals might not sum due to rounding.

Table: **Burden of disease in India due to major causes in different age groups, by sex and location, 2017**

Results

We analysed 211166 deaths from 2010 to 2014 in the MDS covering the whole of India (table). The full results for deaths, DALYs, YLLs, and YLDs by sex and age for each major state, and for rural and urban areas nationally, are provided in the appendix (pp 9–112). For ease of understanding, we present these results in formats identical to WHO GHE tables, the only difference being the number of causes (45 major causes in NBE *vs* 136 major or subcauses in the GHE).

In 2017, India had about 9·7 million deaths and 486 million DALYs, so the ratio of DALYs to deaths was about 50 to one (table). More than three quarters of deaths and DALYs occurred in rural areas, and males accounted for 54·3% of all DALYs. At all ages, the DALY rate per 100 000 population was 36 300, but rates were higher among rural residents and among males (table). DALY rates in rural areas were at least twice those of urban areas for perinatal and nutritional conditions, chronic respiratory diseases, diarrhoea, and fever of unknown origin. By contrast, DALY rates for ischaemic heart disease were considerably greater in urban areas (table). DALY rates showed a U-shaped relationship with age, starting high at ages 0–4 years, dropping to their lowest among children aged 5–14 years, and rising again to highest levels at 70–79 years. 35·7% of total national DALYs arose from communicable, maternal, perinatal, and nutritional causes, and this proportion was greater among females and rural residents (appendix pp 89–90). NCDs comprised 46·6% of DALYs overall, which increased to 55·0% in urban areas. Injuries comprised 11·4% of DALYs. Ill-defined causes comprised 3·3% of all DALYs before age 70 years but a higher proportion (27·9%) above age 70 years (appendix pp 89, 113). NCD and injury DALY rates were higher in males than females (table).

The top 15 conditions that accounted for the most DALYs at all ages arose mostly from YLLs—namely, ischaemic heart disease (9·6% of all DALYs), perinatal conditions (8·5%), chronic respiratory diseases (5·7%), diarrhoea (4·7%), respiratory infections (4·5%), cancer (4·0%), stroke (3·6%), road traffic injuries (3·3%), tuberculosis (3·1%), and liver and alcohol-related conditions (3·0%). DALYs for five conditions arose mostly from YLDs as opposed to YLLs: neuropsychiatric conditions including epilepsy (6·2% of all DALYs), nutritional deficiencies (6·0%), vision and other sensory loss (4·5%), musculoskeletal disorders (2·7%), and genitourinary diseases excluding renal failure (0·8%).

More than 70% of DALYs at all ages resulted from YLLs (346 million of 486 million years; figure 2), with YLLs dominating DALYs among the communicable, perinatal, maternal, and nutritional disorders and among injuries. By contrast, YLDs constituted 86·8% of DALYs for nutritional deficiencies. YLLs also dominated most of the NCDs, including all cancers and vascular and respiratory diseases. Among the NCDs, YLDs contributed more than the YLLs for four conditions: genitourinary diseases (excluding renal failure), neuropsychiatric conditions (mostly major depression, but also including other psychiatric conditions and epilepsy), musculoskeletal disorders, and vision and other sensory loss. Collectively, these four NCDs plus nutritional deficiencies accounted for 62·8% of all YLDs and fewer than 18·1% of all DALYs (table; appendix p 65, 89).

YLLs continued to dominate DALYS when we restricted analyses to below age 70 years, and for ages 30–69 years

(corresponding to the ages for the UN Sustainable Development Goals for NCDs; appendix p 117), and ages 15–59 years (corresponding to the ages in the current World Bank Human Capital Index;[22] appendix p 118).

We observed a clear geographical distribution across states of YLLs and YLDs (appendix pp 11–14). We present differences in the age-standardised YLL rates per 100 000 population across the major states for selected causes that showed marked variation across states (figures 3, 4); we included smaller states and Union Territories in separate analyses of all remaining states (appendix pp 89–112). We defined the levels of each of the chosen diseases separately to highlight differences. Each is shown in descending order of YLL rates. Nearly every condition that is common in one state was far less common in another state, and hence must be mostly avoidable.

Among the infectious diseases, tuberculosis YLL rates were much higher in the north, particularly in Uttar Pradesh and Rajasthan, than in southern India (figure 3). Respiratory infection YLL rates were high in the northern and northeastern states. By contrast, diarrhoea YLL rates showed an east–west gradient, being much higher in Odisha, Jharkhand, Bihar, and Uttar Pradesh, and comparatively lower in western India. The high-burden states accounted for 52% of the absolute national total YLLs for tuberculosis, 41% for respiratory infections, and 15% for diarrhoea (figure 3).

Among NCDs, cancer YLLs were particularly high in northeastern states, Uttar Pradesh, Rajasthan, West Bengal, Haryana, Assam, Gujarat and Madhya Pradesh, and in the southern states of Kerala and Karnataka (figure 4), but the YLLs from specific causes of cancer varied even within those states with high cancer burden;[12] these high-burden states accounted for 44% of national YLLs from cancer. Chronic respiratory YLL rates were high in Rajasthan and Uttar Pradesh, accounting together for 7% of national YLL totals. Liver and alcohol-related YLL rates were high in the northeastern states, Assam, Bihar, Karnataka, and Maharashtra, accounting for 18% of national YLLs. Suicide YLL rates were highest in the southern states, accounting for 15% of national totals.[23] Road traffic injuries were high in the northern states of Uttar Pradesh, Punjab, Uttarakhand, Haryana and Himachel Pradesh, accounting for 33% of national totals. Drowning YLL rates were highest in the central states of Madhya Pradesh and Chhattisgarh and in Assam in the northeast, accounting for 11% of national totals.

GBD estimates, which we derived from GBD data,[6] and NBE DALY results correlated moderately (figure 5). Compared with the NBE, GBD underestimated absolute totals of nutritional conditions for males, overestimated most NCDs for both sexes, and, surprisingly, underestimated road traffic injury deaths among males. There were differences in both directions for specific conditions, with some overestimates and some underestimates when comparing NBE and GBD estimates. The contribution of

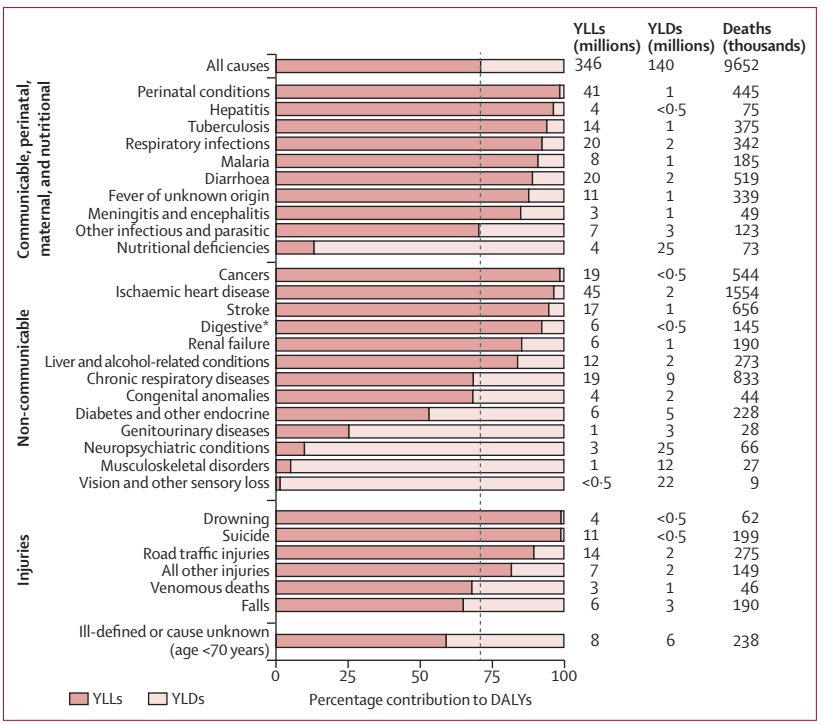

Figure 2: **Contribution of YLLs and YLDs for selected major causes of death in India at all ages, 2017**
Sexually transmitted infections, selected vaccine-preventable diseases, maternal conditions, epilepsy, rheumatic heart diseases, gastro-oesophageal diseases, and interpersonal violence resulted in a total of 181 000 deaths, with total DALYs comprised of 81% YLLs and 19% YLDs. YLLs=years of life lost. YLDs=years lived with disability. DALY=disability-adjusted life-year. *Digestive excludes gastro-oesophageal diseases and liver and alcohol-related conditions.

YLDs to overall DALYs in the NBE is similar to that in the GHE and GBD, at around 30% (appendix p 116). The most notable discrepancies between NBE, GHE, and GBD were for YLDs for just a few conditions (appendix pp 115–116).

There is no reference standard for disability, only the modelled estimates from the GBD, which WHO also uses.[24] We examined our NBE estimates of major depression, which causes much disability but little mortality. At ages 30–59 years, major depression caused 4·1 million YLDs, approximately 40% of all YLDs attributable to neuropsychiatric conditions. Based on GBD median disability weights,[24] this would constitute about 10 million people in India with prevalent depression. This prevalence is close to the estimate of 13 million adults of these ages reporting major depression in a recent multistate survey of mental health.[25]

If we take NBE to be the comparison standard, the GBD yields similar YLD rates for vision loss, underestimates YLD rates for nutritional and other genitourinary diseases, and overestimates YLD rates for neuropsychiatric conditions and musculoskeletal disorders. Had we substituted our NBE rates with the GBD rates, then the total from these conditions would have been 96 million YLDs versus 87 million YLDs in the NBE. This change would add less than 2% to total DALYs.

Discussion

We have developed and implemented an indigenous, transparent, and reproducible method to calculate deaths and disability at national and state levels in India, using a combination of the UN mortality totals for India,[11] disability–mortality ratios published by WHO for many years,[10] and, most importantly, nationally representative cause of death data from the MDS.[14–18] The NBE establishes the plausible distribution of the major causes of death and disability across the major states of India, showing that the largest burdens of disease occur in rural areas, especially from communicable, maternal, perinatal, and nutritional causes, and a large burden of NCDs exists in urban areas. Importantly, premature deaths, expressed as YLLs, account for more than 70% of the total DALYs.

The MDS mortality data have been incorporated recently into GBD analyses, but GBD data and the modelling techniques are not in the public domain and hence have not been reproduced in other studies. Unsurprisingly, this has led to discrepant results between GBD and country-led estimates, even for high-income countries with complete mortality data.[26–28] In India, for example, the availability of MDS data from 2001 onwards should have decreased GBD's reliance on modelled inputs. However, it is not possible to determine how these data were used because changes in model specifications and variable data inputs are not public,[7,9,29] leading to an inability to understand trends or to compare them with estimates using other methods, such as NBE. For example, in the GBD estimates for India, premature birth ranked as the second leading cause of death at all ages in 2015 but seventh in 2016 and fifth in 2017.[6]

The NBE method avoids so-called black boxes of complex econometric models that have uncertain validity,[7] even for countries with high-quality mortality data.[27,28] The NBE will allow the Indian Government to reliably monitor progress in the major states, including the impact on mortality of the new Ayushman Bharat national health insurance programme intended to cover about 500 million Indians.[30]

We observed remarkable variation in YLLs across India, showing that each disease that is common in one part of the country is relatively uncommon elsewhere. This disease variation contributes particularly to marked differences in adult mortality, where differences in life expectancy between districts can exceed a full decade.[31] This variation in disease rates across India indicates the existence of differences in underlying social, behavioural, or biological risk factors, suggesting important avoidable causes that await discovery. Much more remains to be understood about the novel genomic, proteomic, and other biochemical

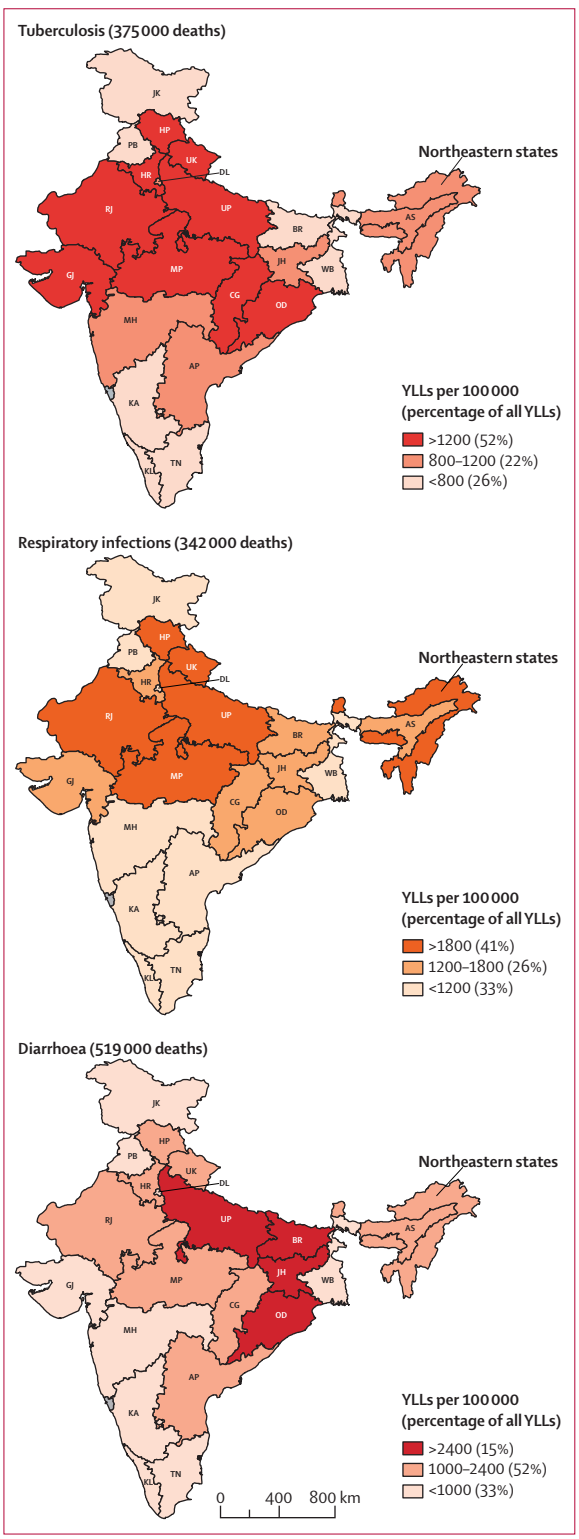

Figure 3: **Variation in YLLs using age-standardised rates for selected communicable causes of death across the major states of India, 2017**
Northeastern states include Tripura, Meghalaya, Manipur, Nagaland, Arunachal Pradesh, Mizoram, and Sikkim. YLLs=years of life lost. AP=Andhra Pradesh. AS=Assam. BR=Bihar. CG=Chhattisgarh. DL=Delhi. GJ=Gujarat. HP=Himachal Pradesh. HR=Haryana. JH=Jharkhand. JK=Jammu and Kashmir. KA=Karnataka. KL=Kerala. MH=Maharashtra. MP=Madhya Pradesh. OD=Odisha. PB=Punjab. RJ=Rajasthan. TN=Tamil Nadu. UK=Uttarakhand. UP=Uttar Pradesh. WB=West Bengal.

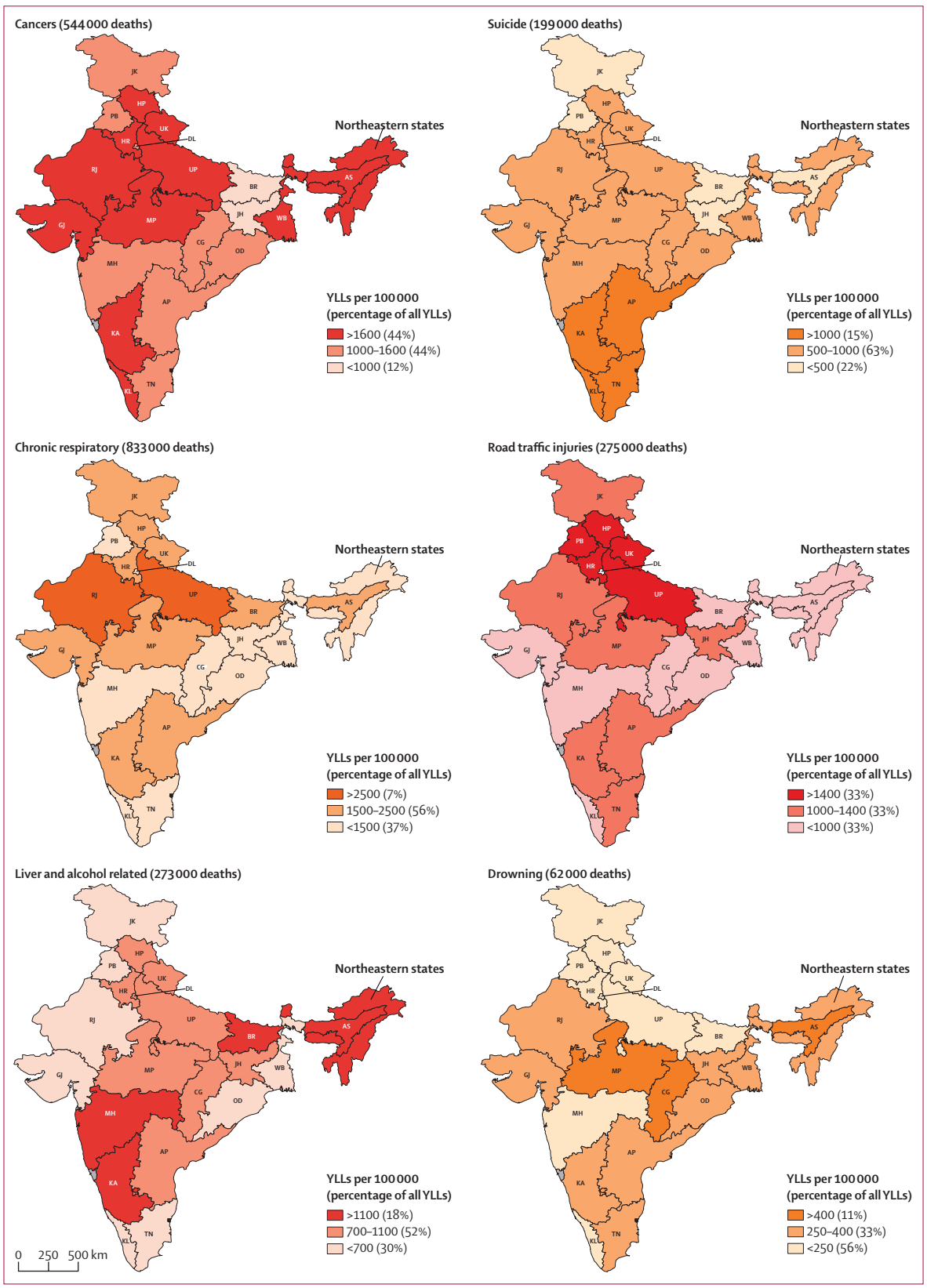

Figure 4: **Variation in YLLs using age-standardised rates for selected non-communicable diseases and injuries across the major states of India, 2017**
Northeastern states include Tripura, Meghalaya, Manipur, Nagaland, Arunachal Pradesh, Mizoram, and Sikkim. YLLs=years of life lost. AP=Andhra Pradesh. AS=Assam. BR=Bihar. CG=Chhattisgarh. DL=Delhi. GJ=Gujarat. HP=Himachal Pradesh. HR=Haryana. JH=Jharkhand. JK=Jammu and Kashmir. KA=Karnataka. KL=Kerala. MH=Maharashtra. MP=Madhya Pradesh. OD=Odisha. PB=Punjab. RJ=Rajasthan. TN=Tamil Nadu. UK=Uttarakhand. UP=Uttar Pradesh. WB=West Bengal.

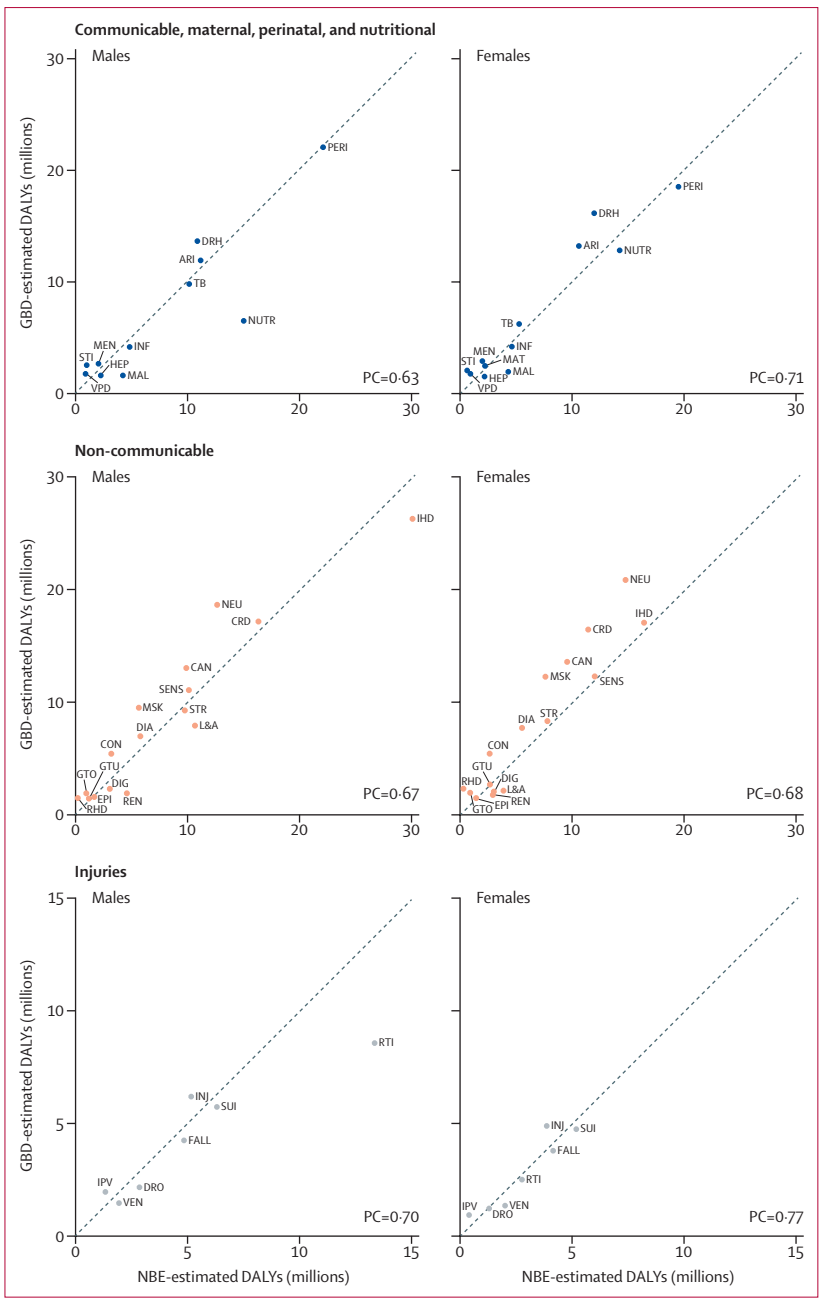

Figure 5: **Comparison of the absolute total of DALYs in India in the GBD model-based estimates to the NBE by condition, 2017**

To calculate concordance in cause of death distribution between NBE and GBD, we excluded the causes fever of unknown origin and ill-defined or cause unknown due to the lack of comparable categories between the NBE and GBD. DALYs=disability-adjusted life-years. GBD=Global Burden of Diseases, Injuries, and Risk Factors Study. NBE=National Burden Estimates. PC=population-level concordance. ARI=respiratory infections. DRH=diarrhoea. HEP=hepatitis. INF=other infectious and parasitic. MAL=malaria. MAT=maternal. MEN=meningitis and encephalitis. NUTR=nutritional deficiencies. PERI=perinatal conditions. STI=sexually transmitted infections. TB=tuberculosis. VPD=selected vaccine preventable. CAN=cancers. CON=congenital anomalies. CRD=chronic respiratory diseases. DIA=diabetes and other endocrine. DIG=digestive. EPI=epilepsy. GTO=gastro-oesophageal diseases. GTU=genitourinary diseases. IHD=ischaemic heart disease. L&A=liver and alcohol-related conditions. MSK=musculoskeletal disorders. NEU=neuropsychiatric conditions. REN=renal failure. RHD=rheumatic heart diseases. SENS=vision and other sensory loss. STR=stroke. DRO=drowning. FALL=falls. INJ=all other injuries. IPV=interpersonal violence. RTI=road traffic injuries. SUI=suicide. VEN=venomous deaths.

correlates of respiratory, intestinal, or other infections in general, and of the avoidable causes of chronic diseases such as cancer, heart attack, stroke, and respiratory disease that currently account for most of the adult mortality in India.[31,32] Even for infections such as tuberculosis, there might be biological causes that make particular infections, or progression from infection to disease, more probable in some people. Variation in secondary treatment and in smoking has already been identified as one explanation for the rising rates over the last 15 years in ischaemic heart disease mortality in rural areas.[33]

YLLs alone can be a robust measure to monitor disease burden, particularly trends over time.[34] Indeed, the inconsistent results between NBE and GBD for disability point to measurement error in disability. This error often exceeds any change in health outcomes that governments might want to monitor. For example, in seeking a 10% annual improvement in health outcomes in children, it is not possible to assess accurately the outcome of a child health programme if the measurement error exceeds 10%. As death is a discernible, objective outcome, focusing analyses of trends on mortality should reduce measurement error and allow reliable monitoring of the impact of disease control programmes.[7] An argument can be made that rather than a composite metric such as DALYs, priority setting could focus on the major causes of mortality for children and adolescents (eg, age ≤19 years) and for adults in middle and older age, and separately consider the major causes of disability at all ages. This would have the specific benefit of tying better survey methods to each of these three outcomes.

Nonetheless, governments commonly demand some reasonable measurement of disability. Most of the GBD and GHE disability data use disability weights that relate a preference of disability relative to mortality, and then apply these to estimated incidence and duration for various diseases.[24] These disability weights come from a multicountry (including India) but non-representative household survey that asked 18–65 year olds to self-report their health states.[35] Aside from the obvious biases in self-reporting, there are other limitations to such weights.[36] The YLDs in our analyses correlated poorly with those in the GBD. However, the uncertainties in disability probably had only a minor effect on overall DALY totals, rates, or the relative ranking of diseases. Verbal autopsies cannot capture all conditions, especially conditions leading mostly to disability.[7,8] We identify five conditions that contributed the most to YLDs but to a relatively small proportion of DALYs: nutritional deficiencies, genitourinary diseases, neuropsychiatric conditions, musculoskeletal disorders, and vision and other sensory loss. Improved estimates of YLDs from major depression can use a recent multistate survey.[25] Similar studies of the most common disabilities are lacking in India and most other countries.[24] Ideally, nationally representative disability surveys should accompany expanded cause of death studies.

Our results are subject to uncertainties in the key demographic inputs, such as the age-specific totals of deaths. The Indian census and Sample Registration System data provide a reasonably robust time series of death rates by age, sex, and location, and we grouped results for 5 years to reduce temporal fluctuations. We used 2010–14 cause of death rates, the latest available, applied to 2017 UN death totals, probably resulting in modest overestimates of the rapidly declining burden of some childhood and infectious conditions.[17] Earlier evaluations of the MDS have shown high comparability with relevant hospital or clinical data, strong reproducibility of the dual physician-coded verbal autopsies, and generally low rates of misclassification in children and young and middle-age adults.[15,16,20] Moreover, the uncertainty in diagnosis on verbal autopsy is not likely to affect the relative ranking of diseases.

The NBE method is replicable in other LMICs, as well as in the districts of India. A benefit of the method is that it draws mostly on well established and respected WHO and UN demographic inputs, which are available widely.[21] Although GBD estimates for India have drawn on MDS data in recent years, this is not the case for many other countries as they do not have nationally representative cause of death data.[7,29] Earlier assessments in Africa have found GBD results to be more plausible when local cause of death data were available.[8] As an interim solution, LMICs without nationally representative cause of death data could use results from similar settings (such as Mozambique's 2007 post-census mortality survey[37] in Africa, or from the MDS in Asia). Another option is to use pooled regional cause of death data from the INDEPTH network, despite these not being nationally representative.[8] However, the main priority for countries is to implement nationwide representative mortality studies.[7,16,29] Well validated cause of death data will decrease reliance on modelled data and improve burden estimates.[38]

Decentralised and improved burden estimates would complement the expanding use of local cost-effectiveness and poverty analyses.[5] The NBE could help countries to address data and reporting needs relevant to the WHO and UN goals for universal health coverage. Countries require open-source, locally operable, transparent, and believable data paired with simple, transparent and reproducible tools to track progress towards the 2030 UN Sustainable Development Goals.[1,29,39]

Contributors

GRM and PJ conceived the idea for the study and developed the study design. GRM, SAF, PSh PY, LKW, and WS contributed to the data analysis. SAF and GRM did the literature review. GRM and PJ wrote the initial draft, and all authors were involved in commenting on subsequent revisions.

Declaration of interests

We declare no competing interests.

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