Age-specific and sex-specific adult mortality risk in India in 2014: analysis of 0·27 million nationally surveyed deaths and demographic estimates from 597 districts

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Summary

Background As child mortality decreases rapidly worldwide, premature adult mortality is becoming an increasingly important contributor to global mortality. Any possible worldwide reduction of premature adult mortality before the age of 70 years will depend on progress in India. Indian districts increasingly have responsibility for implementing public health programmes. We aimed to assess age-specific and sex-specific adult mortality risks in India at the district level.

Methods We analysed data from five national surveys of 0·27 million adult deaths at an age of 15–69 years together with 2014 demographic data to estimate age-specific and sex-specific adult mortality risks for 597 districts. Cause of death data were drawn from the verbal autopsies in the Registrar General of India's ongoing Million Death Study.

Findings In 2014, about two-fifths of India's men aged 15–69 years lived in the 253 districts where the conditional probability of a man dying at these ages exceeded 50%, and more than a third of India's women aged 15–69 years lived in the 222 districts where the conditional probability of a woman dying exceeded 40%. The probabilities of a man or woman dying by the age of 70 years in high-mortality districts was 62% and 54%, respectively, whereas the probability of a man or woman dying by the age of 70 years in low-mortality districts was 40% and 30%, respectively. The roughly 10-year survival gap between high-mortality and low-mortality districts was nearly as extreme as the survival gap between the entire Indian population and people living in high-income countries. Adult mortality risks at ages 15–69 years was highest in east India and lowest in west India, by contrast with the north–south divide for child mortality. Vascular disease, tuberculosis, malaria and other infections, and respiratory diseases accounted for about 60% of the absolute gap in adult mortality risk at ages 15–69 years between high-mortality and low-mortality districts. Most of the variation in adult mortality could not be explained by known determinants or risk factors for premature mortality.

Interpretation India's large variation in adult mortality by district, notably the higher death rates in eastern India, requires further aetiological research, particularly to explore whether high levels of adult mortality risks from infections and non-communicable diseases are a result of historical childhood malnutrition and infection. Such research can be complemented by an expanded coverage of known effective interventions to reduce adult mortality, especially in high-mortality districts.

Funding National Institutes of Health, Canadian Institutes of Health Research, University of Toronto.

Lancet Glob Health 2015; 3: e767–75

This online publication has been corrected. The corrected version first appeared at thelancet.com/globalhealth on March 21, 2016

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Introduction

In 2014, about two-thirds of India's 10 million deaths per year occurred before age 70 years. About 1·4 million of these deaths were in children younger than 5 years of age, 0·6 million deaths were in young people aged 15–29 years, and 4·4 million were in adults aged 30–69 years.[1] As child death rates decrease[2] and the effects of smoking[3] and other major risk factors increase, adults will form a greater proportion of the overall decreasing death rates. If 2010 deaths rates were to persist, more than 9 million people in India could die prematurely before the age of 70 years annually by 2030, the most of any country[4] and most of whom would be adults. The Indian Government has committed to introducing universal health coverage and has endorsed WHO's call for a 25% reduction in the death rates of adults aged 30–69 years from selected non-communicable diseases between 2008 and 2025.[5]

As with global progress in the reduction of child mortality, any future global progress in the reduction of adult mortality will depend largely on progress in India. Indian districts (small administrative areas each with about 2 million people) increasingly bear responsibility for implementing public health programmes. We have earlier described the widespread variability in child mortality rates between Indian districts[2] and in the age-specific adult mortality risks from cancer and heart disease between Indian states.[6–8] Epidemiological and demographic studies of adult mortality at subnational levels in India are scarce. The absence of reliable evidence of the levels, variation, and trends in adult mortality in India's districts restricts the adoption of evidence-based policies and does not allow measurement of the effect of introducing universal health coverage or of specific disease-control programmes.

We have combined data from five national mortality surveys with 2014 demographic data to estimate adult mortality by sex and age for 597 districts. We focus in particular on the large geographical variation in adult mortality and the contribution of specific diseases or determinants of premature mortality to these differences.

Methods

Data sources

We derived estimates for all 640 districts in the 2011 census but classified 12 smaller states and union territories (containing 39 districts) as districts themselves, for a total of 597 districts. From the 2015 revision of the UN World Population Prospects,[1] we derived annual estimates for 2014 of the age-specific and sex-specific death totals for India (appendix). Each 5-year age group and sex-specific national mortality total was divided into state totals and further into district totals using ratios reported in five national mortality surveys done between 1996 and 2008: the District Level Household Surveys of 2002–04[9] and 2007–08,[10] and three surveys by the Registrar General of India (the Special Fertility and Mortality Survey [1998],[11] Sample Registration System data [1998–2003],[7] and the ongoing Million Death Study [2001–06]).[7,8] This method, similar to that already published for child mortality trends in India,[2] is transparent in that it relies only on demographic totals and survey proportions and produces internally consistent estimates—for each age and sex, district death totals sum to state totals, which in turn sum to the 2014 UN estimates for India. All surveys were nationally representative (providing a true snapshot) and totalled 20 million surveyed population, including 142 634 deaths at ages 0–14 years and 265 393 deaths at ages 15–69 years (157 742 men and 107 651 women). Comparison of the district proportional mortality for men and women aged 15–69 years in different surveys with a linear growth curve showed stable proportions, suggesting that the surveys were consistent in their measurement of proportional mortality (data not shown).

See Online for appendix

Estimation of national, state, and district totals

To estimate deaths for each of India's 35 states and union territories on the basis of the 2011 census, we derived age-specific and sex-specific death rates from the weighted averages of relative mortality rates from the Registrar General of India's 2011–13 annual Sample Registration System data.[12] We applied the state proportional mortality to the 2014 UN national death totals for each sex and adjusted them (by no more than 0·03%) to ensure that the sum of states matched the age-specific and sex-specific national totals. We derived district mortality totals by calculating each district's death totals for each of the 11 5-year age groups (15–19 years, 20–24 years, etc, until 65–69 years) from the five national mortality surveys. We then applied the age-specific and sex-specific proportions of district mortality to the 2014 state totals. We derived the age-specific and sex-specific district population by extrapolating the recorded annual growth rate for each district between the 2001 and 2011 censuses to the 2014 population; to these we applied the 2011 district–age distribution. Division of the district deaths by population yielded age-specific death rates. We used the 10·3 million total deaths estimated by the UN for 2014 to correct for the slight undercounts in the Sample Registration System death rates.[13,14]

Statistical analysis

We calculated the conditional probability that an individual aged 15 years would die before reaching the age of 70 years. This calculation assumed constant mortality within each of the 11 5-year age intervals from ages 15 to 69 years, or within the relevant intervals in each of the smaller age groupings (15–29 years, 30–69 years, etc).[15] Standard life-table methods were used to generate probabilities of dying from birth to age 100 years. Age-standardised rates were based on the WHO's standard world population.[16]

Geospatial maps for each district used smoothed interpolation or so-called kriging.[17] Data of causes of death, based on household collections of verbal autopsies,[18] were available for 2001–06 from the Million Death Study.[7,8] Causes of death were apportioned into the three district-level mortality categories after applying the survey weights.[19] We compared high-mortality to medium-mortality or low-mortality districts by logistic regression analysis of 47 possible district-level social, economic, demographic, and health indicators that were grouped into 22 variables from a principal components analysis (appendix). For all analyses, use of tertiles of conditional probability of dying at an age of 15–69 years yielded similar results to our deliberate classifications. The main source of statistical uncertainty arises from the district-specific inputs of deaths tabulated from five mortality surveys. Thus, for each district we summed deaths in the five surveys to provide a 99% CI (a relative SE of 2·58) for lower and upper limits of the conditional probability of dying at an age of 15–69 years. The male-to-female gap in conditional probability of dying at these ages is computed as the difference in conditional probability of men and women dying at these ages divided by the conditional probability for women.

Role of the funding source

The funder 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

In 2014, 428 million men and 408 million women in India were 15–69 years of age, and 3·0 million men and 2·1 million women died (table 1). Most deaths happened at an age of 30–69 years, and men aged 15–69 years had about a third greater mortality risk than women in that age group (table 1). On the basis of estimated conditional probabilities of dying at an age of 15–69 years, each of the 597 districts was classified as high-level, medium-level, and low-level mortality districts for men and women. We used different cutoffs for men and women because of persistently lower mortality among women. We used easily understandable groupings of 40% or 50%, but results were similar when using tertiles of mortality (data not shown). For men, the conditional probability of dying at an age of 15–69 years was less than 40% (low level) in 143 districts, 40·0–49·9% (medium level) in 201 districts, and 50% or greater (high level) in 253 districts. For women, the conditional probability of dying at this age was less than 30% (low level) in 138 districts, 30·0–39·9% (medium level) in 237 districts, and 40% or greater (high level) in 222 districts. About one third of India's men lived in the 253 districts where the conditional probability of a man dying at an age of 15–69 years exceeded 50%, and nearly a third of India's women lived in the 222 districts where the conditional probability of a woman dying at this age exceeded 40%. In absolute terms, about 1·3 million men and 0·8 million women died at an age of 15–69 years in the high-mortality districts. The distribution of districts with high mortality, medium mortality, and low mortality varied markedly between states (appendix). Each district's population, deaths, crude and age-standardised death rates, and conditional probability of dying at an age of 15–69 years, along with their upper and lower limits, are shown in the appendix.

These death rates enabled us to calculate the probability of dying between birth and the age of 100 years (figure 1). Our analysis revealed that the mortality risks for men by the age of 70 years was 62% in high-mortality districts versus 40% in low-mortality districts, whereas for women, the mortality risk by the age 70 years was 54% in high-mortality districts versus 30% in low-mortality districts (figure 1). This difference in mortality rates

	Men				Women				Both sexes (men CpoD ≥50·0%; women CpoD ≥40·0%)
	Low-mortality district (CpoD <40·0%)	Medium-mortality districts (CpoD=40·0–49·9%)	High-mortality district (CpoD ≥50·0%)	All India	Low-mortality district CpoD <30·0%	Medium-mortality districts CpoD=30·0–39·9%	High-mortality district CpoD ≥40·0%	All India	
Number of districts	143	201	253	597	138	237	222	597	172
Population									
All ages	207 million	225 million	221 million	653 million	176 million	265 million	176 million	618 million	279 million
15–69 years	137 million	148 million	143 million	428 million	121 million	175 million	112 million	408 million	179 million
Deaths									
All ages	1·3 million	1·9 million	2·4 million	5·6 million	1·0 million	2·0 million	1·7 million	4·7 million	3·0 million
0–14 years	0·2 million	0·3 million	0·4 million	0·8 million	0·1 million	0·3 million	0·3 million	0·8 million	0·5 million
15–29 years	0·1 million	0·1 million	0·1 million	0·3 million	0·1 million	0·1 million	0·1 million	0·3 million	0·2 million
30–69 years	0·6 million	0·9 million	1·2 million	2·7 million	0·3 million	0·8 million	0·7 million	1·8 million	1·4 million
≥70 years	0·5 million	0·6 million	0·7 million	1·8 million	0·5 million	0·8 million	0·6 million	1·8 million	0·9 million
Age-standardised mortality rate (per 1000 population)*									
0–14 years	3·4	4·2	5·6	4·5	3·1	4·7	6·0	4·7	6·1
15–29 years	1·3	1·8	2·5	1·9	1·1	1·6	2·3	1·6	2·4
30–69 years	7·8	11·0	15·7	11·5	5·0	7·5	11·1	7·7	14·1
15–69 years	5·5	7·7	11·0	8·1	3·6	5·4	8·0	5·6	10·0
Conditional probability of dying at age (%)									
0–14 years	4·9%	6·1%	8·0%	6·4%	4·5%	6·7%	8·5%	6·7%	8·7%
15–29 years	2·0%	2·6%	3·6%	2·8%	1·6%	2·4%	3·3%	2·4%	3·6%
30–69 years	33·6%	43·5%	55·8%	45·0%	24·1%	33·6%	45·3%	34·2%	52·6%
15–69 years	35·0%	45·0%	57·4%	46·5%	25·3%	35·2%	47·1%	35·8%	54·3%

CpoD=conditional probability of dying at an age of 15–69 years. *Age-standardised mortality rate, with rate standardised to the world population.

***Table 1*: Population, death, age-standardised mortality rates, and district-level conditional probability of dying at an age of 15–69 years, India, 2014**

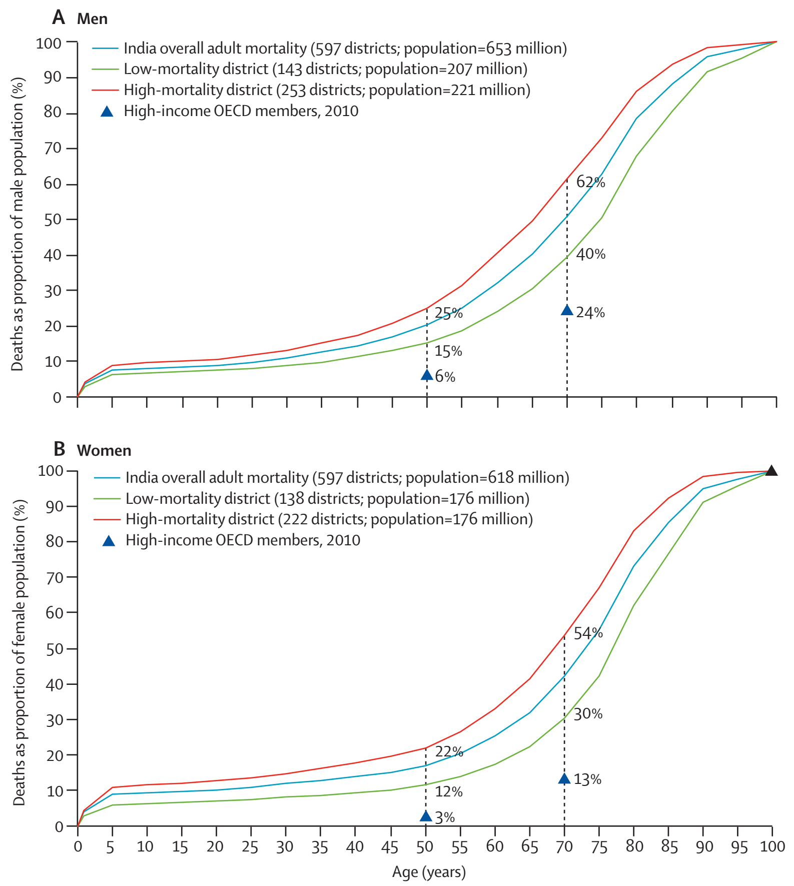

Figure 1: **Probability of men and women dying versus age by district mortality levels for India (2014) and high-income OECD countries (2010)**
We extended the probability of dying at an age of 85–100 years by multiplying mortality rates in the previous age interval to the ratio of mortality at the age of 80–85 years to 75–80 years. Thus, the estimates at the oldest ages are less certain than are those at younger ages. OECD=Organisation for Economic Co-operation and Development.

between districts with high mortality and low mortality corresponds to a survival gap of 22% for men and 24% for women. These marked differences appeared early in middle-age, such that by the age of 50 years, men living in districts with high mortality had a 25% risk of death and women living in districts with high mortality had a 22% risk of death, compared with a 15% risk of death for men and a 12% risk of death for women living in districts with low mortality. The mortality risks of a 55-year-old typical person living in a high-mortality district were similar to that of a 70-year-old typical person living in a district with low mortality, corresponding to a survival gap of about 10 years. For both sexes, mortality at an age of 0–4 years accounted for less than 3% of the gap in mortality risks by the age of 70 years between districts with high mortality and low mortality (data not shown). At the rate of deaths in 2014, about 50% of all Indian men and 40% of all Indian women could expect to die by the age of 70 years, compared with 24% of men and 13% of women in high-income countries.[4] Thus the 22% gap in male mortality risks and 24% gap in female mortality risks by the age of 70 years between some districts of India are nearly as extreme as the 26–27% gap in mortality risk for this age group between India as a whole and high-income countries.

The conditional probability of dying at an age of 15–69 years varied spatially across Indian districts (figure 2). Unlike the conditional probability of dying at an age of 0–14 years, which is much higher in northern Indian districts than in southern Indian districts (figure 2), the conditional probability of dying at an age of 15–69 years suggested an east–west divide (figure 2), particularly in women. We found no evidence of a north–south divide for adult mortality risks. Notable geographical pockets of districts with high adult mortality were found in the states of Orissa and Andhra Pradesh in eastern India, in north India near Delhi, and in northeast India. Districts with a high conditional probability of dying at an age of 0–14 years did not have a high conditional probability of dying at an age of 15–69 years (correlation coefficients 0·42 for men and 0·48 for women). Eastern India had a noticeably lower male-to-female survival at an age of 15–69 years (figure 2) owing to a higher mortality risk among adult women. The districts with highest conditional probability of dying at this age were generally the same for men and women (correlation coefficient 0·77). In 172 districts, with 179 million inhabitants, the conditional probability of dying at an age of 15–69 years exceeded 50% for men and 40% for women (table 1; appendix). These 172 high-mortality districts were mostly in eastern India, but also in Karnataka and Tamil Nadu. Six of the nine poorest states (Assam, Uttar Pradesh, Chhattisgarh, Orissa, Jharkhand, Madhya Pradesh) and Himachal Pradesh had a third or more districts with high conditional probability of dying for both women and men in this age group (appendix).

Men and women aged 15–69 years living in high-mortality districts had relatively higher mortality risks from most of the 16 major causes of death than did people living in districts with low mortality (table 2). For both sexes, the risk of vascular disease (particularly stroke), respiratory disease, tuberculosis, malaria, and other infections was higher in districts with high mortality than in districts with low mortality. These causes of death constituted about 60% of the absolute survival gap between high-mortality and low-mortality districts. Whereas child deaths contributed little to the overall survival gaps until 70 years of age between high-mortality and low-mortality districts, child deaths remain important. About 60% of the 172 districts in which the conditional probability of men and women dying at an age of 15–69 years is high (above 50% and 40%, respectively) also lagged behind in reaching the 2015 Millennium Child Development Goals by 5 years or more.[2]

District levels of poverty, education, public health access, urban location, smoking, and other selected correlates of mortality seemed to account for no more than about a fifth

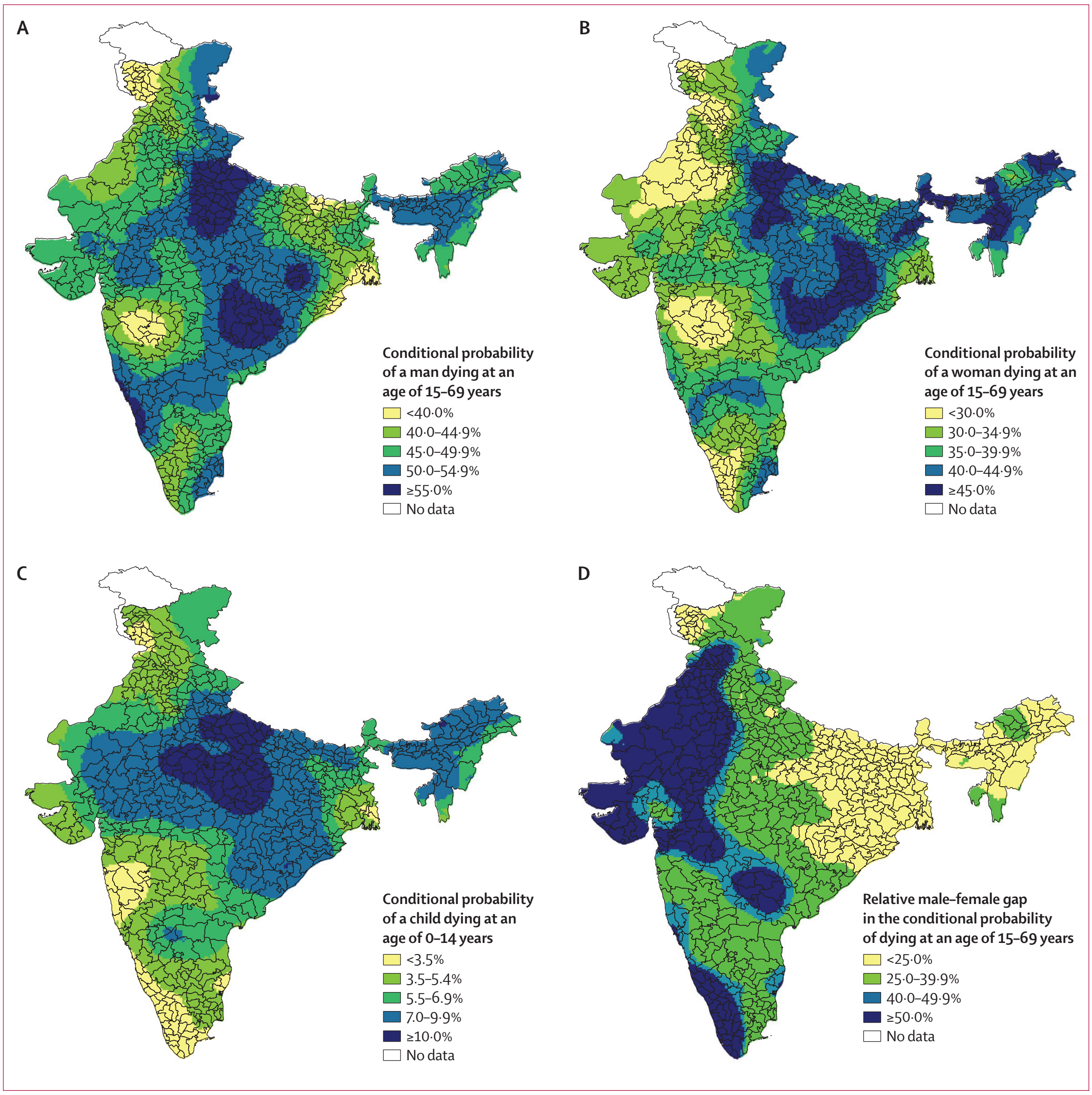

***Figure 2*: Geographical distribution (kriging interpolation estimates) of conditional probability of dying, by age group, in India, 2014**
Heat maps (kriging interpolation) show the conditional probability of dying at an age of 15–69 years for (A) men and (B) women. (C) Conditional probability of dying at an age of 0–15 years. (D) Male-to-female gap in conditional probability of dying at an age of 15–69 years.

of the differences in the age-standardised mortality rates at ages 15–69 years for men and about a third of the differences in the age-standardised mortality rates at these ages for women. By contrast, these factors explained about three-fifths of the child mortality differences (appendix).

Discussion

Premature adult mortality is of increasing importance in India and other low-income and middle-income countries.[4–5,20] We found strikingly large differences in adult mortality between Indian districts, nearly approaching the survival gap between India as a whole country and high-income countries. Within India, gaps in survival until the age of 70 years between districts are as wide as 10 years, mostly due to adult mortality rather than childhood mortality. As far as we can determine, our study is the first to document that adult mortality risks are highest in east India and lowest in west India, quite unlike India's well-established north–south differences in child mortality.[2,21] Several infectious diseases and selected non-communicable diseases account for about 60% of the gap in mortality risks at ages 15–69 years between districts with high mortality and low mortality. By contrast, the established predictors of premature mortality account for little of the variation in adult mortality. Genetic differences are unlikely to explain these marked differences; most Indian populations in east

	Number of deaths (district mortality) at ages 15–69 years (%)*				Ratio of deaths of high-mortality districts to low-mortality districts	Difference in district mortality between high-mortality districts and low-mortality districts	Contribution to absolute difference in mortality between high-mortality and low-mortality districts (%)
	Low-mortality districts	Medium-mortality districts	High-mortality districts	All India			
Men							
Vascular diseases	182 000 (10%)	256 000 (12%)	308 000 (13%)	746 000 (12%)	1·4	3·6	16%
Tuberculosis	59 000 (3%)	103 000 (5%)	156 000 (7%)	318 000 (5%)	2·1	3·6	16%
Chronic respiratory diseases	50 000 (3%)	88 000 (4%)	130 000 (6%)	268 000 (4%)	2·1	3·0	13%
Other infections	50 000 (3%)	78 000 (4%)	128 000 (6%)	256 000 (4%)	2·1	2·8	13%
Non-road-traffic accidents	46 000 (2%)	70 000 (3%)	95 000 (4%)	211 000 (3%)	1·7	1·7	7%
Cancer	57 000 (3%)	74 000 (3%)	95 000 (4%)	226 000 (4%)	1·4	1·1	5%
Malaria	10 000 (<1%)	20 000 (1%)	37 000 (2%)	67 000 (1%)	3·1	1·1	5%
Digestive	19 000 (1%)	31 000 (1%)	49 000 (2%)	99 000 (2%)	2·0	1·1	5%
Suicide	28 000 (1%)	37 000 (2%)	58 000 (3%)	123 000 (2%)	1·7	1·0	5%
Other NCD	47 000 (3%)	67 000 (3%)	82 000 (4%)	196 000 (3%)	1·4	1·0	5%
Cirrhosis	38 000 (2%)	54 000 (2%)	59 000 (3%)	151 000 (2%)	1·3	0·5	2%
Road traffic accidents	40 000 (2%)	50 000 (2%)	58 000 (3%)	148 000 (2%)	1·2	0·4	2%
HIV	7000 (<1%)	12 000 (1%)	13 000 (1%)	32 000 (1%)	1·6	0·2	1%
Nutritional deficiencies	2000 (<1%)	3000 (<1%)	4000 (<1%)	9000 (<1%)	1·8	0·1	0%
Ill-defined	25 000 (1%)	46 000 (2%)	62 000 (3%)	133 000 (2%)	2·0	1·4	6%
All causes	660 000 (35%)	989 000 (45%)	1 334 000 (57%)	2 983 000 (47%)	1·6	22·4	100%
Women							
Other infections	36 000 (2%)	102 000 (4%)	109 000 (7%)	247 000 (4%)	2·9	4·3	20%
Tuberculosis	26 000 (2%)	66 000 (3%)	74 000 (4%)	166 000 (3%)	2·7	2·8	13%
Chronic respiratory diseases	31 000 (2%)	77 000 (3%)	73 000 (4%)	181 000 (3%)	2·2	2·4	11%
Vascular diseases	103 000 (6%)	177 000 (7%)	146 000 (9%)	426 000 (8%)	1·3	2·2	10%
Malaria	8000 (<1%)	24 000 (1%)	34 000 (2%)	66 000 (1%)	4·0	1·5	7%
Digestive	11 000 (1%)	34 000 (1%)	33 000 (2%)	78 000 (1%)	3·0	1·3	6%
Maternal	7000 (<1%)	21 000 (1%)	27 000 (2%)	55 000 (1%)	3·8	1·2	5%
Non-road-traffic accidents	22 000 (1%)	52 000 (2%)	42 000 (3%)	116 000 (2%)	1·8	1·1	5%
Cancer	55 000 (3%)	91 000 (4%)	75 000 (4%)	221 000 (4%)	1·3	1·0	5%
Other NCD	36 000 (2%)	60 000 (3%)	51 000 (3%)	147 000 (3%)	1·3	0·8	3%
Cirrhosis	9000 (1%)	19 000 (1%)	18 000 (1%)	46 000 (1%)	2·0	0·6	3%
Nutritional deficiencies	3000 (<1%)	8000 (<1%)	8000 (1%)	19 000 (<1%)	2·7	0·3	1%
Suicide	22 000 (1%)	39 000 (2%)	28 000 (2%)	89 000 (2%)	1·2	0·3	1%
HIV	3000 (<1%)	5000 (<1%)	3000 (<1%)	11 000 (<1%)	1·1	0·0	0%
Road traffic accidents	7000 (<1%)	10 000 (<1%)	7000 (<1%)	24 000 (<1%)	1·0	0·0	0%
Ill-defined	24 000 (2%)	59 000 (2%)	58 000 (3%)	141 000 (2%)	2·3	2·0	9%
All causes	403 000 (25%)	844 000 (35%)	786 000 (47%)	2 033 000 (36%)	1·9	21·8	100%

NCD=non-communicable disease. *See table 1 for definitions of low-mortality, medium-mortality, and high-mortality districts. Results are sorted by contribution to absolute gap in mortality risk between high-mortality and low-mortality districts.

***Table 2*: Cause-specific mortality risks for men and women aged 15–69 years on the basis of deaths in 2001–06, by level of district mortality, in India, 2014**

and west India are composites of two prehistorical, genetically divergent groups.[22] Linguistic variation, which is a crude proxy for genetic differences, accounted for little of the variation in adult mortality (appendix).

The large mortality excesses from not just infections but also selected non-communicable diseases in otherwise similar districts suggests measurable differences in largely unknown causative factors and in some intermediate determinants of disease risk. One important, albeit still speculative, hypothesis for these patterns of high adult mortality risks in parts of India could be chronic infection or malnutrition in childhood

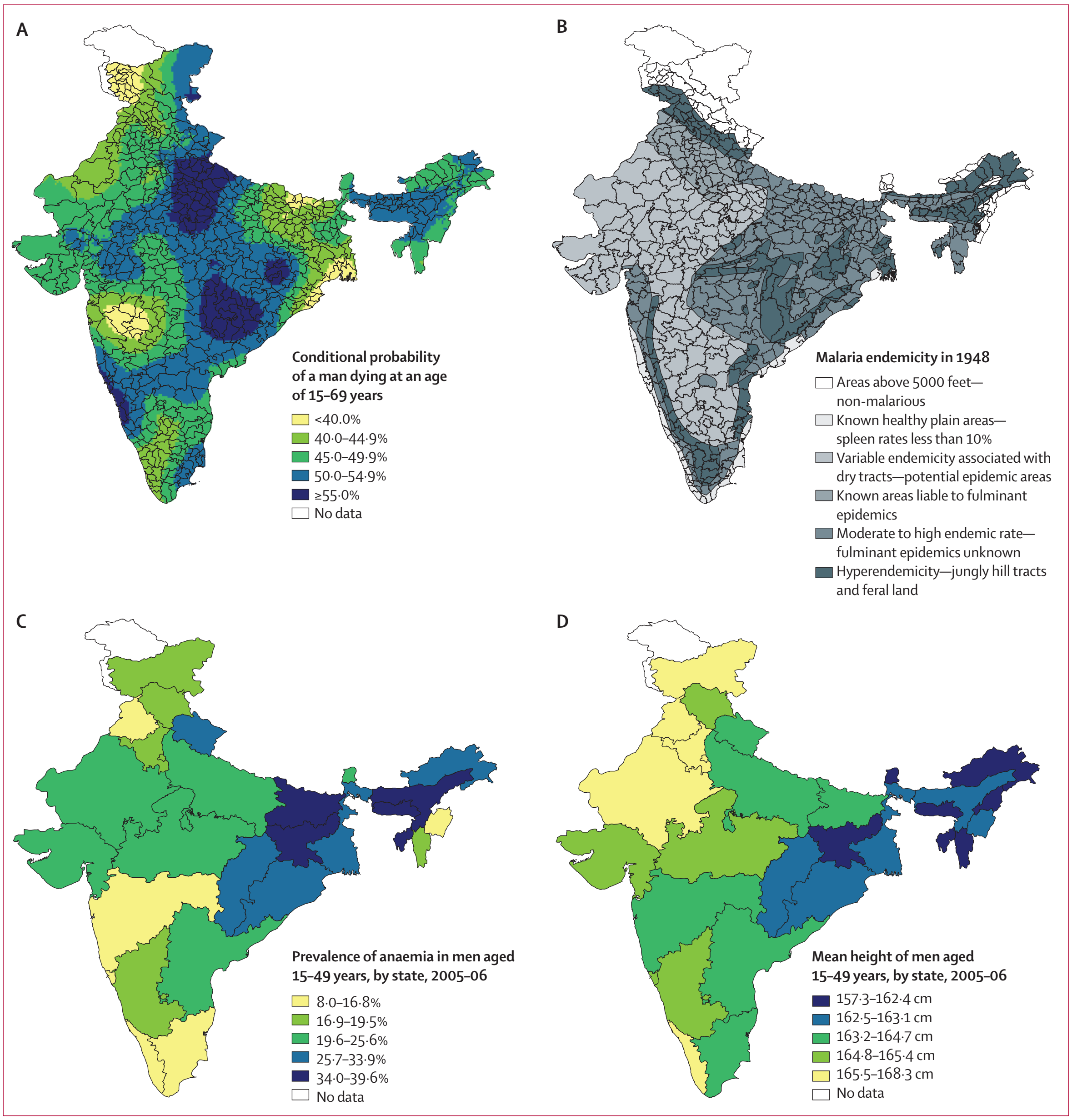

***Figure 3*: Conditional probability of a man dying at an age of 15–69 years in 2014 compared with malaria endemicity in 1948, state-level anaemia prevalence, and mean height of men aged 15–49 years (2005–06) in India**

leading to reduced adult height attainment and high anaemia levels. The mean year of birth of the people who died in 2014 was about 1960, about a decade after Indian independence. Malaria prevalence patterns in 1948[23] (but not available to us for 1960) closely resemble the geographical patterns of conditional probability of dying at an age of 15–69 years in 2014 (figure 3). At the state level, adult height appears to be lower and adult anaemia levels higher in east India than in west India,[24] but such data are not yet available at the district level. In a prospective cohort study in Mumbai (in west India),[25] the risks of death for people with a body-mass index of less than 18·5 kg/m² were significant for all causes and various specific causes, such as tuberculosis, cancer, and vascular, respiratory, or digestive diseases. Blood-based investigations of the genetic and environmental factors,[26] with special attention to lipids and the role of different patterns of adiposity and early childhood infection and malnutrition, are required.

Our study methods are crude, and ecological comparisons have predictable limitations. However, there should be few systematic biases that would alter our observation of high adult mortality risks in various districts. The undercounts for adults in the Sample

Panel: Research in context

Systematic review

We searched PubMed, ScienceDirect, SCOPUS, and the International Institute for Population Sciences Library with the terms ("adult"[MeSH Terms] OR "adult"[All Fields]) AND ("mortality"[Subheading] OR "mortality"[All Fields] OR "mortality"[MeSH Terms]) AND district [All Fields] AND ("India"[MeSH Terms] OR "India"[All Fields]) for articles published between Jan 1, 2000, and June 14, 2015, without any language restrictions. We identified 230 studies, of which 167 were published in 2000 or later. No study had examined all-cause mortality rates of adults in the districts of India. 139 of these studies analysed incidence or prevalence or mortality or both of a particular cause in one district (131 studies) or two or more districts (eight studies). Prevalence of cardiovascular risk factors was lower in three east Indian cities than in eight other cities.[30] Other studies examined the outbreak of selected diseases in adults living in a small area, causes of death in adults (eg, tuberculosis, malaria, cancer, maternal conditions, homicide, and snakebite) from a specific disease in a small area, or reviewed status of adult health.

Interpretation

Our study is the first standardised comparison of district-specific adult mortality by gender for 597 districts of India. The marked variation in adult death rates, especially between east and west India, suggest the need to address specific diseases, most notably infections and vascular, respiratory, and digestive diseases, and the need for more aetiological research of these large differences in adult mortality.

Registration System are not greater in west India than they are in east India,[13,14] and therefore do not account for the lower death rates in western India. Two of the national mortality surveys were designed to sample at the district level (although all were nationally or state representative). Comparison of district proportional mortality for men and women at ages 15–69 years across surveys suggested that the surveys were consistent in measurement of district proportional mortality. Additionally, restriction of analyses to these two district-representative surveys[9,10] yielded similar results (data not shown). The 2001–06 causes of death estimates might well have changed over the past few years, particularly from reductions in infectious disease. More contemporary estimates from 2010 onward from the Registrar General of India[7,8] should be available soon and will help to further quantify the contribution of specific diseases to the large gaps in adult mortality risks.

Ecological analyses such as ours can only explain some of the differences in mortality risk. Epidemiological studies of individuals have already confirmed the large excess in adult deaths among India's 120 million smokers (causing more than 1 million deaths each year).[3] Increased blood pressure[25] and poor access to effective secondary treatments for vascular disease[27] are strong risk factors for adult mortality. More generally, India, like many other countries in Asia and Africa, has large gaps in reliable estimation of adult mortality.[28] To monitor the UN's 2030 global goals for a one-third reduction in the rates of mortality from non-communicable disease,[4] India's districts and other countries will need much better data collection of mortality, causes of death, and risk factors for mortality (panel).[28,29]

Fuller investigation of the reasons for excess adult mortality in otherwise similar parts of India need not delay the expansion of coverage of powerful interventions already proven to reduce adult mortality. These interventions include tobacco control and higher tobacco taxation,[31] secondary treatments for vascular disease,[27] combination drug therapies for malaria and tuberculosis, screening and treatment for cervical, breast, and oral cancers, and other selected interventions.[32] As a practical strategy, these effective interventions could be expanded to cover the 172 districts we have identified with high adult mortality in men and women.

Contributors

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

Declaration of interests

We declare no competing interests.

Acknowledgment

This study is supported by grants from the US National Institutes of Health (R01-TW05991–01 and TW007939-01), Canadian Institutes of Health Research (CIHR HOPE Fellowship to UR), the Centre for Global Health Research, and the University of Toronto (Endowed Chair and Canada Research Chair to PJ). The opinions expressed in this Article are those of the authors and do not necessarily represent those of the institutions with which they are affiliated or of the Government of India.

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