

# Mortality by cause for eight regions of the world: Global Burden of Disease Study

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## Summary

**Background** Reliable information on causes of death is essential to the development of national and international health policies for prevention and control of disease and injury. Medically certified information is available for less than 30% of the estimated 50.5 million deaths that occur each year worldwide. However, other data sources can be used to develop cause-of-death estimates for populations. To be useful, estimates must be internally consistent, plausible, and reflect epidemiological characteristics suggested by community-level data. The Global Burden of Disease Study (GBD) used various data sources and made corrections for miscoding of important diseases (eg, ischaemic heart disease) to estimate worldwide and regional cause-of-death patterns in 1990 for 14 age-sex groups in eight regions, for 107 causes.

**Methods** Preliminary estimates were developed with available vital-registration data, sample-registration data for India and China, and small-scale population-study data sources. Registration data were corrected for miscoding, and Lorenz-curve analysis was used to estimate cause-of-death patterns in areas without registration. Preliminary estimates were modified to reflect the epidemiology of selected diseases and injuries. Final estimates were checked to ensure that numbers of deaths in specific age-sex groups did not exceed estimates suggested by independent demographic methods.

**Findings** 98% of all deaths in children younger than 15 years are in the developing world. 83% and 59% of deaths at 15–59 and 70 years, respectively, are in the developing world. The probability of death between birth and 15 years ranges from 22.0% in sub-Saharan Africa to 1.1% in the established market economies. Probabilities of death between 15 and 60 years range from 7.2% for women in established market economies to 39.1% for men in sub-Saharan Africa. The probability of a man or woman dying from a non-communicable disease is higher in sub-Saharan Africa and other developing regions than in established market economies. Worldwide in 1990, communicable, maternal, perinatal, and nutritional disorders accounted for 17.2 million deaths, non-communicable diseases for 28.1 million deaths and injuries for 5.1 million deaths. The

leading causes of death in 1990 were ischaemic heart disease (6.3 million deaths), cerebrovascular accidents (4.4 million deaths), lower respiratory infections (4.3 million), diarrhoeal diseases (2.9 million), perinatal disorders (2.4 million), chronic obstructive pulmonary disease (2.2 million), tuberculosis (2.0 million), measles (1.1 million), road-traffic accidents (1.0 million), and lung cancer (0.9 million).

**Interpretation** Five of the ten leading killers are communicable, perinatal, and nutritional disorders largely affecting children. Non-communicable diseases are, however, already major public health challenges in all regions. Injuries, which account for 10% of global mortality, are often ignored as a major cause of death and may require innovative strategies to reduce their toll. The estimates by cause have wide CIs, but provide a foundation for a more informed debate on public-health priorities.

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## Introduction

This paper, the first of a series of four, reports on the 5-year Global Burden of Disease Study (GBD). (The other three papers will follow in the next three issues of *The Lancet*.) The study was initiated in 1992 at the request of the World Bank and was done in collaboration with WHO. Preliminary results were used by the World Bank<sup>1</sup> and published by WHO.<sup>2</sup> The GBD was designed to address three primary goals: to provide information on non-fatal health outcomes for debates on international health policy, which are generally focused on mortality; to develop unbiased epidemiological assessments for major disorders; and to quantify the burden of disease with a measure that could also be used for cost-effectiveness analysis. There were four specific objectives:

- To develop internally consistent estimates of mortality for 107 causes of death by age, sex, and geographic region.
- To develop internally consistent estimates of incidence, prevalence, duration, and case-fatality for 483 disabling sequelae of the 107 causes.
- To estimate the fraction of mortality and disability attributable to ten major risk factors.
- To develop various projection scenarios of mortality and disability estimates by cause, age, sex, and region.

Final results, including chapters on each major condition by the investigators who contributed to this study are available.<sup>3,4</sup> The results published here supersede the preliminary results.<sup>2,3</sup> This paper reports on regional and global patterns of mortality by cause.

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## Methods

### Design

The GBD can be divided into five components, which were all studied simultaneously and are interlinked: causes of death, descriptive epidemiology of disabling sequelae, burden attributable to selected risk factors, projections of burden from 1990 to 2020, and sensitivity analysis. In the cause-of-death component, data from vital registration and sample registration systems were combined with the results of population-monitoring laboratories and disease-specific epidemiological studies and models to develop regional estimates of mortality for different age-sex groups according to a clear set of algorithms.

For each of the 107 disorders, the number of disabling sequelae selected to be investigated in depth was limited. For example, diabetes mellitus was restricted to five sequelae—diabetes itself, retinopathy, neuropathy, diabetic foot, and amputation. In total, 483 sequelae were selected for direct assessment. For each sequela, average age at onset, duration, incidence, prevalence, and case-fatality rates by age, sex, and region were estimated by an iterative process. In 1992, disease specialists for each condition were identified. Based on a review of published and unpublished studies and surveys, the specialists developed first-round estimates of duration, incidence, remission, case-fatality, prevalence, and death rates. Estimates were critically reviewed, and their internal consistency was ascertained with a computer program (DISMOD) that modelled disease or injury process. Major inconsistencies were identified and epidemiological estimates revised to correct them. Throughout the study, four complete cycles of international review, revision, and internal-consistency analysis were done to generate the final set of estimates.<sup>4</sup>

To assist identification and modification of inconsistent estimates of incidence, prevalence, duration, and case-fatality, a simple model that formalised the relation between incidence, remission, case-fatality, and prevalence was developed. Susceptible people in the population were assumed to be at risk of incurring a disease or disability at rate  $i$ , from which they could die at general mortality rate  $m$ . Patients' diseases remit at rate  $r$ , or they die from general causes at the same rate as the susceptibles ( $m$ ) or die from cause-specific mortality at rate  $f$ . If these rates can be assumed to be constant in the short term, for example for a year, a set of ordinary differential equations can be defined to characterise movement between susceptible, diseased, recovered, and dead. DISMOD uses the finite difference method to solve these equations.<sup>3</sup>

We assessed the burden of disease and injury attributable to ten major risk factors—malnutrition, poor water, sanitation and hygiene, unsafe sex, alcohol, occupation, tobacco use, hypertension, physical inactivity, illicit use of drugs, and air pollution. For most risk factors, estimates of attributable death and disability were made from estimates for prevalence of exposure by age, sex, and region, relative risks for the exposed from several previously published studies, and the regional pattern of burden.

Three alternative projection scenarios of the burden of disease were developed for each region. Simple models related cause-specific mortality and disability to a limited set of major socioeconomic factors. The methods, which included several steps to incorporate other information, such as the spread of HIV, are detailed in the fourth paper of this series.

### Indicators of burden of disease

The results of the GBD were analysed by means of various epidemiological and demographic indicators, including incidence and prevalence rates, life expectancy, probabilities of death in different age-groups, disability-adjusted life expectancy, years of life lost because of premature death, years of life lived with disability (adjusted for the severity of disability), and disability-adjusted life years (DALYs), calculated as the sum of years of life lost and years of life lived with disability. DALYs, which were developed specifically for the GBD, are time-based health-outcome measures, similar to quality-adjusted life years, that include weights for time spent in less-than-perfect health. Such composite measures of the burden of disease allowed us to compare the burden of premature mortality with non-fatal health outcomes, such as disability. All measures of health outcome implicitly or explicitly include social values. Four key areas in which social values were important in the construction of a health-outcome indicator were years of life lost because of death in each age group; time lost because of premature death compared with time lived in a health state worse than perfect health; the discounting of future health; and the value of a year of life lived in the different age-groups. The choice of values incorporated into DALYs and their selection have been extensively debated and discussed.<sup>3,5-7</sup> Severity weights on a scale of 0 (perfect health) to 1 (death) were assigned to each of the 483 disabling sequelae. How these disability severity weights were developed is described in more detail in the second paper of this series. An extensive sensitivity analysis of the GBD results to changes in various social values showed that the main findings are largely unaffected by changes in the discount rate, age weights, or health-state preferences.<sup>3</sup>

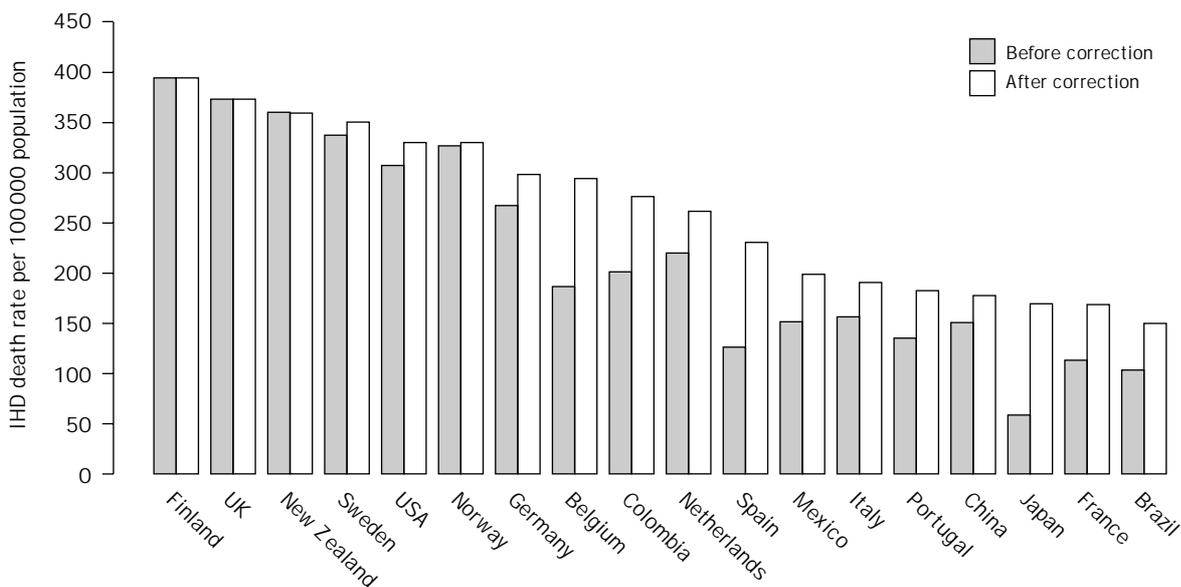


Figure 1: Mortality rates by country for ischaemic heart disease (IHD) before and after adjustment for miscoding. Age-standardised rates for men and women aged  $\geq 30$ , about 1990.

### GBD regions

We made assessments for eight geographic regions that were delineated by the World Bank.<sup>1</sup> These regions were: the established market economies, mainly consisting of high-income Organisation for Economic Cooperation and Development members; the formerly socialist economies of Europe, which stretched from Czechoslovakia to Siberia; Latin America and the Caribbean; China; India; the middle eastern crescent, which included North Africa, the Middle East, Pakistan, and the Central Asian Republics of the former Soviet Union; other Asia and islands, which covered the rest of Asia and the Pacific; and sub-Saharan Africa.

### GBD classification system

For the GBD we used a tree structure to show rankings of causes of death and disability.<sup>8</sup> At the first level were three groups of causes of mortality.

*Group 1* consisted of communicable diseases, maternal, perinatal, and nutritional disorders.

*Group 2* consisted of non-communicable diseases.

*Group 3* consisted of all intentional or unintentional injuries.

Group 1 causes of death included disorders, the specific mortality of which typically declines faster than all-cause mortality during epidemiological transition. In the theory of the epidemiological transition, as total mortality decreases, the cause-of-death structure should shift from group 1 to group 2 causes.<sup>9</sup> As a result, group 1 causes account for only a small proportion of deaths in low-mortality populations (and, conversely, dominate the cause-of-death pattern in high-mortality populations). The non-communicable diseases in group 2 are, therefore, the most important health problems for populations that have undergone the epidemiological transition.

Each of the three groups contained several major subcategories that were mutually exclusive and exhaustive. Specifically, group 1 was divided into infectious and parasitic causes, respiratory infections, maternal causes, perinatal disorders, and nutritional deficiencies. Group 2 contained 14 categories of non-communicable diseases. Group 3 was subdivided into unintentional and intentional injuries. Third and fourth levels of branching were used to identify all the 107 specific causes of death.

### Regional demographic estimates

Many sources provide much information about the basic demography of each region in the world. The database for estimating rates of child mortality in all regions is more developed than that for adult mortality.<sup>10,11</sup> Indeed, demographers disagree about rates of adult mortality in some developing regions without good vital registration systems, where mortality is estimated indirectly from census and survey data.<sup>12</sup> For example, estimates of adult mortality by age and sex from the World Bank and the United Nations Population Division can differ by as much as 50%; but, in general, the discrepancies are less extreme. Demographic estimates of deaths and population in 1990 by age and sex<sup>1</sup> form the basis of the GBD.

### Detailed methods for estimation of causes of death

Mortality rates specific for age, sex, and cause for each region were estimated in four steps: preparation of preliminary estimates, largely from vital registration and sample registration data; correction of estimates for selected causes by specific methods; adjustment of cause-specific mortality rates for selected causes based on epidemiological analyses; and final adjustments to ensure that the sum of cause-specific mortality rates was identical to total age-specific mortality rates estimated from demographic methods.

### Correction of ICD-9 miscoding in areas with good vital registration data

For those study areas with good vital registration data available, adjustments were made to correct for problems related to the

	Vital registration (% coverage)		
	Under 5	≥5	Total
EME	99	99	99
FSE	99	99	99
IND*	..	..	..
CHN*	..	..	..
OAI	2.1	13.6	10.2
SSA	0.4	1.7	1.1
LAC	27.6	47.2	42.6
MEC	12.3	27.1	21.8

\*See text.

EME=established market economies; FSE=formerly socialist economies of Europe; IND=India; CHN=China; OAI=other Asia and islands; SSA=sub-Saharan Africa; LAC=Latin America and the Caribbean; MEC=middle eastern crescent.

Table 1: Sources and methods used to estimate mortality by cause for each region in 1990

coding of causes of death. The rules of the International Classification of Diseases (ICD) specify that the underlying cause of death should be given as the primary cause of death. The various ICD conventions are arbitrary methods to deal with the multicausal nature of mortality. For example, liver cancer, in a patient known to have hepatitis B, is coded as the cause of death. By contrast, in ICD-10, deaths from lymphoma among HIV patients are coded to HIV and not to lymphoma. In our study we followed the principles of the ICD to give only a single cause of death for the primary tabulations. We estimated the proportion of deaths associated with each cause. In some cases, in which ambiguous ICD-9 rules and conventions were followed, we used an arbitrary convention to estimate rates for the underlying cause of death for the primary tabulations.<sup>3</sup>

Although medically certified causes of death are generally a reliable source of information on the broad causes-of-death pattern in a community, correction algorithms were necessary for three specific situations. First, based on statistical evidence<sup>8,13</sup> ICD-9 Chapter XVI deaths in the age-group 0-4 years were proportionately distributed across all group 1 causes within that age-sex group. For each age-group older than 5 years, chapter XVI deaths were proportionately distributed across group 2 causes. Second, for deaths from injuries that could not be classified as intentional or unintentional, deaths were proportionately redistributed across all other (known) injuries. Third, deaths from unspecified environmental and accidental causes (E928, including E929.9) were redistributed across all causes of unintentional injury.

Coding of cardiovascular disease across communities and within the same community over time has been notoriously variable.<sup>14-16</sup> Large proportions of deaths from heart failure (ICD-9 428), ventricular arrhythmias (ICD-9 427.1, 427.4, 427.5), general atherosclerosis (ICD-9 440.9), and ill-defined descriptions and complications of heart disease (ICD-9 429.0, 429.1, 429.2 and 429.9) are likely to be actually deaths from ischaemic heart disease. We developed a correction algorithm to redistribute a proportion of these deaths to ischaemic heart disease.<sup>17</sup> Before correction, the ratio of the highest ischaemic heart disease mortality rate in people over 30 years of age (Finland) to the lowest (Japan) was 6.3 to 1.0 (figure 1). After correction, the ratio was 2.3 to 1.0.

### Preliminary estimates for each region

For the established market economies and formerly socialist economies of Europe, preliminary estimates were derived solely from vital registration data (which covered virtually all deaths in both regions) after correction for miscoding (table 1). For China, preliminary estimates (rural and urban) were calculated from data from the 1991 disease surveillance points—a sample registration system that covered a representative sample of 10 million people, and included 52 734 deaths adjusted to match the total deaths in each age-group and sex-group in China. For India, cause-of-death patterns in urban areas were based on the nearly complete urban registration system in Maharashtra State.<sup>18</sup> Estimates of mortality by cause for rural areas were based on the survey of causes of death (rural), a system that currently includes

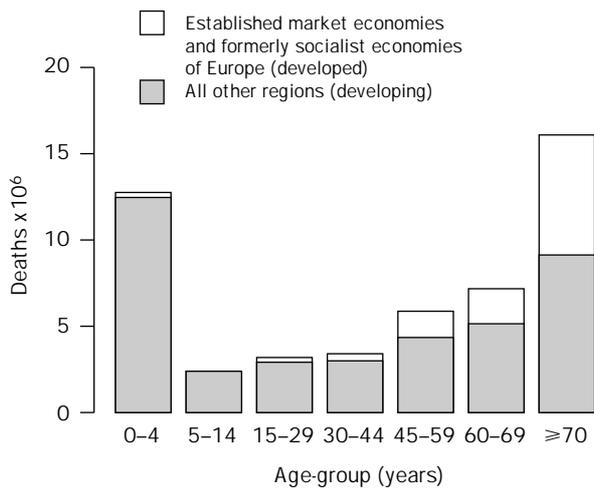


Figure 2: Distribution by age-group in study regions

over 1300 primary-health centres<sup>19</sup> and provides useful information on causes of mortality in rural areas. However, since the cause of death is assigned by non-medical personnel, the returns from this system are likely to be useful only for estimating broad cause-of-death patterns and not for specific causes. Detailed rates of specific causes were based on the extensive analysis and follow-up studies done as part of the Andhra Pradesh Burden of Disease Study (P Mahapatra and G N V Ramana, personal communication).

In Latin America and the Caribbean, other Asia and islands, the middle eastern crescent, and sub-Saharan Africa, some vital registration data are available, but most deaths are not recorded on the existing systems (table 1). Moreover, the deaths that are recorded are not representative of mortality for the entire region. Therefore, we divided each of these regions into a registration area, for which vital registration data were available, and a residual area. To develop plausible estimates of mortality by cause in the residual areas, we used a new method based on the geographical inequality of death distribution to estimate mortality rates specific for age and sex from all causes combined.<sup>3</sup> For both registration areas we then compared the percentage distribution of recorded deaths in each age-group assigned to groups 1, 2, and 3 with the percentage predicted by cause-of-death models. Building on substantial previous experience with cause-of-death models,<sup>8, 13, 20-22</sup> we developed a new set from a dataset of 103 observations from 67 countries, from the years 1950 to 1991. Separate models were developed for both sexes in each of the seven GBD age-groups: 0-4, 5-14, 15-29, 30-44, 45-59, 60-69, and 70 years or older. The number of SD above or below the predicted value for each group showed how much the registration areas in the region deviated from the cause-of-death patterns reflected in the models. To estimate the division of all-cause mortality into groups 1, 2, and 3 in the residual areas, the pattern of deviation of the cause-of-death structure as compared with the cause-of-death models was assumed to be similar to that of the registration areas.

In sub-Saharan Africa, a slightly different method was used because registration data were available only for South Africa. The region was divided into southern Africa (South Africa, Botswana, Namibia, Mozambique, Zimbabwe, Swaziland, Zambia, and Malawi) and Northern Africa (all other countries in sub-Saharan Africa). The inequality-of-death distribution method was then used to estimate the all-cause mortality for Southern Africa, based on the vital registration data from South Africa. The distribution of deaths across groups 1, 2, and 3 for registered deaths in South Africa was within one SD of that predicted by the models. For northern Africa, we applied the same pattern of deviation as suggested by the registration areas of South Africa because the observed patterns were consistent with evidence from various population-monitoring laboratories (eg, Senegal,<sup>23</sup> The Gambia,<sup>24</sup> Ghana,<sup>25</sup> Kenya,<sup>26</sup> and Tanzania.<sup>27</sup>)

For preliminary estimates for the more detailed causes within each group in the developing regions, the proportionate distribution for a given age-sex group was assumed to be the same as in the registration areas.

#### Specific corrections

For a number of disease categories specific corrections were also applied. To estimate the total cancer-death rates for each age-sex group, the preliminary estimates described earlier were used. For regions with vital registration data (table 1), those were used to estimate the distribution of total cancer deaths by site. In India, the distribution by site of cancer in the urban areas was based on the vital registration data from Maharashtra, and in the rural areas, based on the Andhra Pradesh Burden of Disease Study (P Mahapatra and G N V Ramana, personal communication). For other regions and the population in Latin America and the Caribbean, site-specific distributions were estimated from a set of published estimates of site-specific mortality based on the International Agency for Cancer Research network of registries for 1985.<sup>28</sup> However, in these estimates, the proportion of total cancer deaths that were attributed to "other and unknown" primary sites, was very small compared with areas that have better vital registration. The site distribution of cancer deaths in these estimates was based on the assumption that the low proportion of cancer deaths estimated for other and unknown cancers by Parkin and colleagues<sup>31</sup> is due to misdiagnosis of metastatic cancers or other coding errors.

#### Epidemiological estimates

Epidemiological assessments were used to adjust preliminary-round mortality estimates for selected causes. Because of the greater emphasis on study of infectious-disease epidemiology in most developing countries, there are epidemiologically based estimates of mortality for many more diseases in group 1 than group 2. Since epidemiological assessments tend to yield monitoring rates that are higher than those based on vital registration, the final results are often biased towards group 1 diseases and away from group 2 diseases.

Epidemiological estimates of war deaths, because of their sporadic but intense nature, were incorporated in a slightly different way. We chose to classify war deaths as additional to deaths estimated from the basic demographic analyses used to calculate the number of deaths in each age-sex group in each region. The epidemiological estimates of war deaths were not, therefore, subject to the internal consistency algorithm.

#### Internal consistency algorithms

To ensure that the sum of cause-specific deaths equalled the number of deaths from all causes in any given age-sex group, two additional adjustment algorithms were applied separately, one for neonatal causes<sup>6</sup> and one for all other age-groups. To assess the extent of overestimation of mortality in each of the age-sex groups and in each region we compared the number of SD above or below the proportionate mortality for a group, as predicted by the cause-of-death models, with the number of SD above or below the preliminary estimates. If preliminary estimates for group 1 or group 2 based on vital registration or sample registration data were already more than 2.5 SD above or below the expected value, we did not allow epidemiological assessments to increase the degree of deviation. If the preliminary assessment for group 1 was less than 2.5 SD greater than expected, or if that for group 2 was less than 2.5 SD below the expected value, the results from epidemiological assessments were permitted to change the proportion in either group by 2.0 SD. If a change of 2.0 SD would increase the percentage of deaths due to group 1 to be more than 2.5 SD above the mean, or decrease the percentage of deaths due to group 2 to be more than 2.5 SD below the mean, the percentage of deaths due to group 1 was set equal to a value 2.5 SD above the mean and the percentage of deaths due to group 2 was set equal to 2.5 SD below the mean.

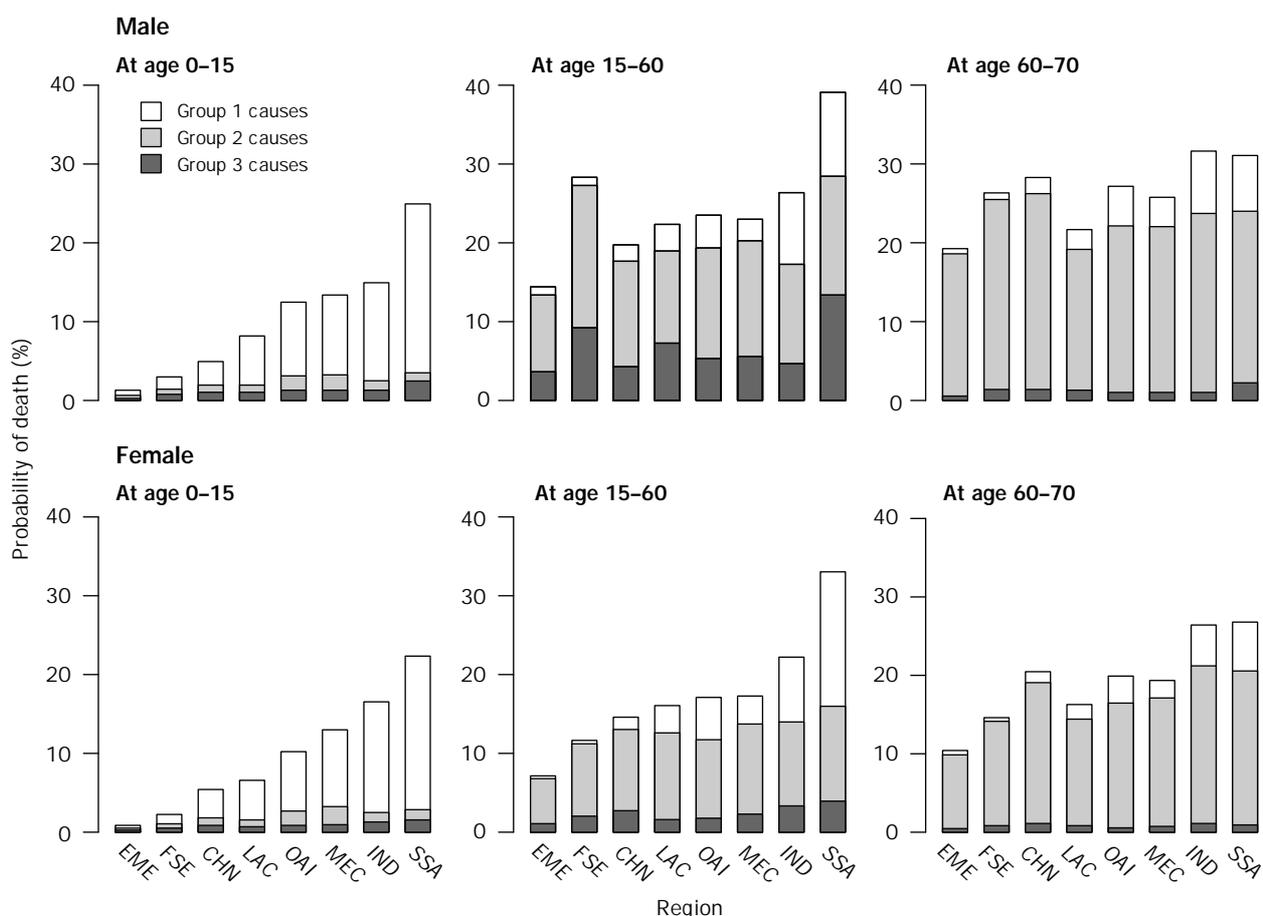


Figure 3: Probability of dying during three periods of life by broad-cause, group, sex, and region, 1990  
Abbreviations for regions given as footnote to table 1.

## Results

Figure 2 illustrates the distribution of all deaths worldwide by age and region. Because of a much younger population age distribution and higher mortality rates in children, 98% of deaths in children were in the developing world (all study regions except established market economies and formerly socialist economies of Europe). 32% of all deaths in the developing world occurred in children younger than 5 years, and 63% occurred by the age of 60 years. Within developing regions, the age structure of death varied widely: 53% of all deaths in sub-Saharan Africa occurred between ages 0 and 4 years, compared with 11% in China. Interestingly, 83% of all adult deaths between 15 and 59 years occurred in developing countries. Even at 70 years or older, 59% of deaths worldwide were in the developing world. In established market economies, 4.6 million deaths occur each year at 70 years or older, as do 3.6 million in China alone. This emphasises that by 1990 the demographic transition was sufficiently advanced that only a handful of causes led to more deaths in established market economies and formerly socialist economies of Europe than in the developing world—several sites of cancer, dementias, Parkinson's disease, and a few others.

A useful way to summarise the results of this study is in probabilities of death (figure 3). Probabilities are shown for death from group 1, group 2, or group 3 causes. As expected, for girls the highest probability of death between birth and age 14 (22.0%) was in sub-Saharan Africa and the lowest (1.1%) in established market

economies. At these ages, most of the regional difference was due to differences in the probability of a group 1 death. The regional rankings of probabilities for women aged 14–60 were the same as for child and adolescent death. For adult women, however, a large part of the regional difference was the higher probability of group 1 death, but the probability of non-communicable disease (group 2) death was higher in developing regions than in established market or formerly socialist economies of Europe. Figure 3 shows the unusually high probability of injury death among adult women in China, which is due mainly to high suicide rates in rural areas.

The regional rankings and prominence of group 1 causes in explaining regional differences in the probability of death between birth and 14 years are the same for boys and girls. Regional differences in the probability of death for men between 15 and 60 years are surprisingly different from that for children and women. Formerly socialist economies of Europe had a higher probability of death (28.4%) than any other region except sub-Saharan Africa (39.1%). Differences in adult risks of death were due to substantial variation in the probability of death from all three groups. Sub-Saharan Africa and India had higher risks of death among men, largely because of group 1 causes, such as tuberculosis and HIV. The remarkable excess mortality in men from the formerly socialist economies of Europe region was attributable to much higher risks of group 2 death and higher probabilities of group 3 death than in established market economies. The probability of death from group 3 injuries varied widely

	Deaths in region ( $\times 10^3$ )										
	EME	FSE	IND	CHN	OAI	SSA	LAC	MEC	Developed	Developing	World
<b>All causes</b>	7121	3791	9371	8885	5534	8202	3009	4553	10 912	39 554	50 467
<b>Group 1</b>											
Total group 1	453	214	4775	1405	2190	5316	943	1945	667	16 573	17 241
Infectious and parasitic diseases	111	52	2647	544	1176	3456	473	871	163	9166	9329
Respiratory infections	275	114	1229	474	552	1023	180	534	389	3992	4380
Maternal disorders	1	2	115	30	52	186	19	48	3	451	454
Perinatal disorders	46	36	660	276	331	503	196	395	82	2361	2443
Nutritional deficiencies	21	9	124	80	79	148	76	96	30	604	634
<b>Group 2</b>											
Total group 2	6223	3188	3788	6460	2785	1864	1676	2156	9411	18 730	28 141
Malignant neoplasms	1762	650	505	1464	640	429	345	228	2413	3611	6024
Other neoplasms	36	8	5	21	10	10	9	6	44	62	106
Diabetes mellitus	145	30	104	60	59	23	89	61	176	396	571
Endocrine disorders	46	4	2	14	9	23	27	17	50	93	143
Neuropsychiatric disorders	205	70	106	98	69	41	50	61	274	426	700
Sense-organ disorders	0	0	0	18	0	0	1	0	0	19	20
Cardiovascular disorders	3175	2071	2266	2568	1349	815	789	1295	5245	9082	14 327
Respiratory disorders	343	158	267	1530	148	210	116	163	500	2435	2935
Digestive disorders	305	120	255	411	315	153	140	152	424	1426	1851
Genitourinary disorders	123	45	104	124	98	96	53	92	167	568	735
Skin disorders	12	2	2	12	2	7	3	2	14	29	43
Musculoskeletal disorders	32	5	3	36	9	1	9	2	37	60	97
Congenital anomalies	39	27	170	105	75	55	43	76	66	523	589
Oral disorders	0	0	0	0	0	0	0	0	0	2	2
<b>Group 3</b>											
Total group 3	445	389	808	1020	559	1022	389	452	834	4251	5084
Unintentional injuries	303	249	650	626	426	534	248	198	552	2682	3233
Intentional injuries	143	140	158	394	133	488	141	254	282	1569	1851

Abbreviations for regions as in table 1: developed=EME+FSE; developing=all other regions.

Table 2: Distribution of deaths for specific causes (level-two categories) in 1990

among regions from 3.4% in established market economies to 13.3% in sub-Saharan Africa.

50 467 000 people died in 1990; 53% of them were male. Worldwide, one death in three is from a group 1 cause (table 2). One death in ten was from an injury, and slightly more than one death in two was from group 2 causes. Because of differences in population-age structure, mortality rates, and epidemiological patterns, there was a dramatic difference between established market and formerly socialist economies of Europe and

the developing regions in the distribution of deaths. For the developing regions as a whole, group 1 conditions accounted for four of ten deaths, group 2 causes one death in two, and injuries one death in ten. For countries in the established market economies and formerly socialist economies of Europe, only one in 16 was due to group 1 causes, whereas group 2 accounted for more than 85% of all deaths. In sub-Saharan Africa, group 1 disorders accounted for 65% of all deaths, whereas in China these causes accounted for only 16% of deaths.

Table 3 gives the 30 leading causes of global mortality in 1990. Ischaemic heart disease was the leading cause of death worldwide, accounting for 6.26 million deaths (2.7 million in established market economies and formerly socialist economies of Europe; 3.6 million in the developing regions). Stroke was the next most common cause of death (4.38 million deaths, almost 3 million in developing countries), closely followed by acute respiratory infections (4.3 million, 3.9 million in developing countries). Other leading causes include diarrhoeal diseases (virtually all in developing countries), chronic obstructive pulmonary disease, tuberculosis, measles, low birthweight, road-traffic accidents, and lung cancer. Worldwide these top ten causes account for 52% of all deaths.

The leading causes of death for women and men in the age-group 15–44 are of great interest. In 1990, an estimated 2.7 million women in this age-group died. Maternal disorders were the leading causes of death, accounting for about 433 000 deaths (15.8% of deaths in this age-group). Tuberculosis remains a major cause of death among women in this age-group and causes about 10% of deaths. Suicide (7.0%), war (4.4%), road-traffic accidents (3.7%), HIV (3.4%), and stroke (2.7%) are also significant causes of death, more so in some regions than in others (eg, in China, suicide is estimated to be the cause of almost one in four deaths for women in this age-group).

Rank	Cause of deaths	Number of deaths ( $\times 10^3$ )
	All causes	50 467
1	Ischaemic heart disease	6260
2	Cerebrovascular disease	4381
3	Lower respiratory infections	4299
4	Diarrhoeal diseases	2946
5	Perinatal disorders	2443
6	Chronic obstructive pulmonary disease	2211
7	Tuberculosis (HIV seropositive excluded)	1960
8	Measles	1058
9	Road-traffic accidents	999
10	Trachea, bronchus, and lung cancers	945
11	Malaria	856
12	Self-inflicted injuries	786
13	Cirrhosis of the liver	779
14	Stomach cancer	752
15	Congenital anomalies	589
16	Diabetes mellitus	571
17	Violence	563
18	Tetanus	542
19	Nephritis and nephrosis	536
20	Drowning	504
21	War injuries	502
22	Liver cancer	501
23	Inflammatory heart diseases	495
24	Colon and rectum cancers	472
25	Protein-energy malnutrition	372
26	Oesophagus cancer	358
27	Pertussis	347
28	Rheumatic heart disease	340
29	Breast cancer	322
30	HIV	312

Table 3: 30 leading causes of death worldwide in 1990

Cancer caused about 6 million deaths in 1990, 3.4 million in men. About 2.4 million cancer deaths occurred in established market economies and formerly socialist economies of Europe. By 1990, therefore, there were already 50% more cancer deaths in less developed countries than in developed countries. Lung cancer, trachea, bronchus, and lung) is the leading site of worldwide cancer deaths (table 3). Stomach cancer is the next most important site of cancer mortality, followed by liver, colon and rectum, oesophagus, and breast. Lung cancer caused almost twice as many male deaths in 1990 as the next most important site for men (stomach cancer). Other leading sites of male cancer mortality worldwide included liver (357 000 deaths), oesophagus (240 000), colon and rectum (237 000), prostate (193 000), and mouth and oropharynx (186 000). Breast cancer was the leading site of female cancer deaths in 1990, claiming about 50 000 more victims than the next most important site for mortality (stomach, with 282 000 deaths). Interestingly, lung cancer was already the third leading site of mortality from cancer in women in 1990, accounting for an estimated 237 000 deaths, slightly more than cervical cancer at 200 000.

Injuries, whether intentional or otherwise, were a major cause of death worldwide. In 1990, an estimated 5 million people died from group 3 causes (injuries). The risk of death from injury varied strongly by region, age, and sex. Worldwide, there were about two male deaths from violence for every female death (3.3 million compared with 1.7 million). Injuries accounted for about 12.5% of all male deaths, compared with 7.4% of female deaths. Equally striking was the regional variation in mortality from violent causes. In established market economies, for example, injuries from violence caused about 6% of all deaths in 1990, compared with 9–11% in other regions, rising to 12–13% in sub-Saharan Africa and Latin America and the Caribbean, where violence is a major cause of male deaths, accounting for about one in six deaths. Remarkably, 56% of all female suicides in the world occurred in China, whereas 40% of male homicides were in sub-Saharan Africa and a further 20% were in Latin America and the Caribbean.

For some diseases, the numbers of deaths estimated in the primary tabulations according to the rule of underlying cause greatly underestimated the real public-health importance of the disorder. For example, diabetes mellitus not only causes direct mortality but also increases an individual's risk of death from cardiovascular diseases. As part of the GBD, the burden attributable to diabetes, hepatitis B, Chagas' disease, tuberculosis, unipolar major depression, sexually transmitted diseases, and disorders causing blindness were calculated by a standard attributable risk method. In the primary tabulations diabetes mellitus accounted for 580 000 deaths in 1990, with adjustment for the heightened risk of death from other causes, 2.8 million deaths in 1990 were attributable to diabetes. Similarly, deaths directly attributable to hepatitis B and C in 1990 (about 105 000) represent only a fraction of the larger number of deaths attributable to cirrhosis and liver cancer, probably caused by hepatitis B. In total, hepatitis B and C caused about 820 000 deaths. Analyses of disorders such as trachoma, onchocerciasis, cataract, and glaucoma also suggest that large numbers of deaths are attributable to these disorders.

## Discussion

Despite decades of sustained progress through development and targeted health interventions in all regions of the world in the reduction of child mortality due to group 1 causes, five of the ten leading causes of death are still communicable or perinatal disorders. With the exception of tuberculosis, these major causes largely affect children younger than 5 years. Seven disorders (lower respiratory infections, diarrhoeal diseases, perinatal disorders, tuberculosis, measles, malaria, and hepatitis B and C, including deaths from cirrhosis and liver cancer attributable to hepatitis C) accounted for 14.4 million deaths per year or 28.5% of worldwide mortality. Further reduction of mortality from these and other communicable diseases must remain one of the principal priorities for global public-health action.

One major finding from this study is the importance of non-communicable diseases in worldwide and regional patterns of death in all regions of the world. The probability of death from a non-communicable disease is higher in low-income regions such as sub-Saharan Africa than in high-income regions such as established market economies. This finding is at odds with the popular perception that many risk factors for non-communicable diseases are more prevalent in high-income than low-income populations, and that, consequently, the rates of these "diseases of affluence" must also be higher in the better-off populations. The apparent paradox of higher non-communicable death rates in the adults of the developing world must be attributable to the other major determinants of non-communicable disease mortality that are more common in these regions. Leading possibilities include the possible role of group 1 conditions in children as determinants of subsequent non-communicable diseases as adults.<sup>29</sup> There is clear evidence that, in aggregate, non-communicable disease rates drop as an area develops but the proportion of deaths due to non-communicable diseases is higher in established market economies and formerly socialist economies of Europe than in sub-Saharan Africa. Because of declines in fertility that accompany mortality decline, the populations of the developed regions have higher proportions of older people, and, therefore, the proportion of deaths due to non-communicable diseases is increased. The ratio of group 2 deaths to group 1 deaths has been proposed as a crude but useful indicator of the epidemiological transition.<sup>30</sup> These ratios range from more than 13 in established market economies and formerly socialist economies of Europe to 0.4 in sub-Saharan Africa. According to this criterion, China, followed distantly by Latin America and the Caribbean and other Asia and islands, are all further along the path of the combined demographic and epidemiological transitions than was thought to be the case, which may affect the potential demand for health services in these countries.

Injuries account for 10% of worldwide mortality, but they are often ignored. Five of the 25 leading causes of mortality (road-traffic accidents, self-inflicted injuries, violence, drownings, and war) are injuries. The regional patterns raise important epidemiological questions, such as: why suicide rates among women in China, other Asia and islands, and South India are so high; why women in India are 2.3 times more likely to die from a burn, whereas in all other regions combined, men are more likely to die from burns; and why is homicide so

common? Much new descriptive epidemiology is urgently needed to reveal further the patterns and determinants of mortality from injury in different countries and regions of the world.

Many of our estimates are likely to have wide CIs. Since we integrated various estimation processes, used by several sources, into an internally consistent epidemiological profile, a precise 95% CI cannot be defined. The degree of uncertainty of the estimates does, however, vary from disease to disease, across age-groups, and between regions. For example, the estimates that are most uncertain are those for sub-Saharan Africa, particularly for the exact composition of group 2 and group 3 mortality. How should the degree of uncertainty associated with an estimate alter the way in which decision-makers interpret results? According to economic theory, when making decisions about programmes and policies, decision-makers should treat estimates that are certain or uncertain all in the same way. If there are wide CIs, decision-makers may invest resources to acquire more information to narrow the uncertainty. Disorders for which further information is gathered should be those that are major public-health concerns (eg, tobacco-related disease in developing countries).

Much more research is required on the application and adaptation of promising methods for epidemiological surveillance in poorer populations. The disease surveillance points system in China seems to be the most useful alternative to complete vital registration, but much more research is required on how this approach might be adapted for different sociopolitical environments. Applied research on the cost-effectiveness of different systems for data collection is also needed. The system of collecting cause of death data via "verbal autopsies" needs to be assessed and improved to provide reliable data on broad categories of causes of death at low cost. What is also clear from this attempt at appraisal of worldwide mortality patterns is that even the levels of mortality rates among adults are not well known, especially in large parts of sub-Saharan Africa. As more and more regions undergo the epidemiological transition, death, particularly premature death, among adults will increasingly become a major public-health concern. Surveillance systems and research methods to reliably measure and monitor adult mortality must anticipate this trend.

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