

ganizations would provide the basic municipal grid information, the core of the effort. Information volunteers and public safety agencies would update the system once a disaster strikes.

Unlike the 911 system, the 711 system would not be a one-way, top-down commu-

nications system, but rather a genuine interactive and horizontal communications medium connecting affected citizens, their loved ones, and rescue efforts. The technology is available and affordable; the user base is strong and growing; and the time is here and now.

Evidence-Based Health Policy—Lessons from the Global Burden of Disease Study

Christopher J. L. Murray and Alan D. Lopez

It is both extraordinary and unfortunate that at the end of the 20th century, the international public health community does not routinely quantify or project the health problems of populations. There are no standardized compilations of comparable information on the extent of morbidity, disability, or death in different populations of the world. Information at a global or regional level on behaviors and exposures that are important risk factors for death and disability is also extremely limited. Although the demographic community routinely publishes projections of fertility and population, future trends have been projected for only a very limited number of causes of death [such as the human immunodeficiency virus (HIV)] in select populations.

All too often, health statistics are provided to decision-makers, the scientific community, and the public by advocates. These advocates, although well intentioned, have specific agendas, and the information they provide is often filtered or biased. Health problems without vocal advocates are frequently ignored until someone or some group “discovers” or “rediscovers” a problem or when policy neglect leads to crises in which the public demands action. The rediscovery of the global tuberculosis problem is a classic example (1). Poor information on a health problem is often interpreted in policy debates to mean that a problem is unimportant, which generates a self-perpetuating phenomenon. In this environment, it is hardly surprising that a number of health programs at international organizations employ their own media consultants or full-

time “advocacy officers.” Public health policy formulation desperately needs independent, objective information on the magnitude of health problems and their likely trends, based on standard units of measurement and comparable methods. (In this case, we are defining health problems broadly to include diseases, injuries, and exposures to important risk factors.)

The Global Burden of Disease Study

A major effort to foster an independent, evidence-based approach to public health policy formulation is the Global Burden of Disease Study (GBD). This study was initiated in 1992 at the request of the World Bank; over the past 4.5 years, the work has been undertaken with the full collaboration and participation of the World Health Organization (WHO) (2). Final results are now available. The study had four specific objectives: (i) to develop internally consistent estimates of mortality from 107 major causes of death, disaggregated by age and sex, for the world and eight geographic regions; (ii) to develop internally consistent estimates of the incidence, prevalence, duration, and case-fatality for 483 disabling sequelae resulting from the above causes, disaggregated by age, sex, and region; (iii) to estimate the fraction of mortality and disability attributable to 10 major risk factors, disaggregated by age, sex, and region; and (iv) to develop projection scenarios of mortality and disability, disaggregated by cause, age, sex, and region. The study is based on the collaboration of over 100 scientists from more than 20 countries (3).

Just under 50.5 million individuals died in 1990 worldwide, and the results of medical certification of the cause of death were obtained for 13.8 million of these individuals (4). Even in cases where medically

certified causes of death are available, a series of analyses has been undertaken to adjust for miscoding of cardiovascular, injury, and other deaths. In some cases, these corrections for miscoding substantially alter the estimated death rates (for example, after correcting for coding of cardiovascular deaths in Japan that had been assigned to various ill-defined categories, the death rate from ischemic heart disease increased by a factor of 2.8). To ascertain the causes of death for the remaining 70 percent of deaths in the world, a variety of methods and sources has been used, including sample registration systems in China and rural India; small population laboratory studies in sub-Saharan Africa and Asia; estimates based on epidemiologic studies of the incidence, prevalence, and case-fatality rates of particular diseases; and, as a last resort, models relating cause-specific mortality for an age-sex group to mortality from all causes in that age group.

For each disease and its sequelae, epidemiological estimates based on a metasynthesis of published and unpublished studies have been developed. For example, estimates of incidence, prevalence, and duration for five sequelae of diabetes were developed: diabetes itself, retinopathy, neuropathy, amputation, and diabetic foot. Internally consistent estimates of incidence, prevalence, case-fatality, remission, and mortality rates and of duration were developed with the aid of computer models (5).

To foster comparisons across conditions and risk factors, a composite measure of the burden of each health problem has been developed: the Disability-Adjusted Life Year (DALY) (6). DALYs from a condition are the sum of years of life lost because of premature mortality and years of life lived with disability, adjusted for the severity of disability. Time lived with various short-, medium-, and long-term disabilities is weighted by a severity weight that is based on the measurement of social preferences for time lived in various health states (7).

Selected Findings of the GBD

Diseases and injuries in the GBD were divided into three clusters: Group I, consisting of communicable diseases, maternal causes, conditions arising in the perinatal period, and nutritional deficiencies; Group II, encompassing the noncommunicable diseases; and Group III, comprising all injuries, whether intentional or unintentional (Table 1). Group I causes of death consist of the cluster of conditions whose prevalence declines at a faster rate than mean mortality rates [most developed and a number of developing countries have undergone demographic and “epidemiological transitions” to

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lower fertility and mortality rates during this century (8)]. As a result, in low-mortality populations, these causes account for only a small proportion of deaths (and, conversely, dominate the cause-of-death pattern in high-mortality populations). The noncommunicable diseases listed together in Group II are the most important health problems in populations that have undergone or almost completed the epidemiological transition. Injuries are classified separately in Group III.

Globally, one-third of deaths arise from one of the diseases in Group I (Table 1). One death in 10 is caused by an injury, and just slightly more than 1 death in 2 is attributable to Group II, the noncommunicable diseases. Because of differences in population age-structure, mortality rates, and epidemiologic patterns, there is a dramatic difference in the distribution of deaths between established market economies (EMEs) and the formerly socialist economies of Europe (FSEs) and the developing regions. For the developing regions as a whole, Group I conditions account for 4 out of every 10 deaths, Group II conditions for 1 death in 2, and injuries (Group III) for 1 death in 10. For countries in EMEs and FSEs, only 1 death in 16 is due to Group I diseases, whereas Group II accounts for over 85% of all deaths. Variation in the extent of the demographic and epidemiological transitions in the developing regions is evident from Table 1. In sub-Saharan Africa, Group I diseases account for 65% of all deaths,

whereas in China these diseases account for only 16% of deaths.

The three leading causes of DALYs in 1990 were lower respiratory infections, diarrheal diseases, and conditions arising during the perinatal period (low birthweight and birth asphyxia or birth trauma) (Table 2). Tuberculosis, measles, and congenital anomalies are also among the 10 leading causes of DALYs worldwide. Perhaps more surprisingly, unipolar major depression, ischemic heart disease, and cerebrovascular disease are ranked fourth, fifth, and sixth, respectively. Road traffic accidents are also among the 10 leading causes of DALYs on the global list, accounting for 2.4% of all DALYs. Switching to a perspective that captures the effects of nonfatal health outcomes emphasizes the role of a number of neuropsychiatric conditions as contributors to the burden of disease. For example, alcohol dependence ranks 20th as a cause of global DALYs, bipolar disorder ranks 22nd, and schizophrenia ranks 26th.

To guide current investment decisions (including investments in health research, human resource development, and physical infrastructure), three different mortality and disability scenarios have been projected from 1990 to 2020 (4). The projection model is based on the observed relation between cause-specific mortality and socioeconomic

variables, including income per capita, average years of schooling, time, and tobacco use. Three sets of projections of these independent variables form the basis of the baseline, pessimistic, and optimistic scenarios presented in the GBD. The range defined by the pessimistic and optimistic projections is not a formal confidence interval but does provide some qualitative sense of the uncertainty associated with the projections of different conditions. From 1990 to 2020, the baseline projection scenario suggests that the following causes will rise in the rankings: ischemic heart disease, unipolar major depression, cerebrovascular disease, chronic obstructive pulmonary disease, HIV, war, violence, suicide, and lung cancer. These changes are largely due to demographic shifts and trends in age-specific mortality rates in a large part caused by the epidemic of tobacco-related diseases (9). Major declines in relative rank are expected for lower respiratory infections, diarrheal diseases, measles, malaria, anemia, and protein-energy malnutrition. In the pessimistic scenario, major Group I conditions such as lower respiratory infections and diarrheal diseases remain much larger causes in absolute terms but nonetheless still fall substantially in the relative rankings.

Some diseases or injuries occur without prior exposure to health hazards. Many cases, however, are attributable to one or more risk

Table 1. Distribution of deaths (in thousands) by broad-cause group and region in 1990. These regions and their abbreviations are as follows: established market economies (EMEs), the formerly socialist economies of Europe (FSEs), Latin America and the Caribbean (LAC), China (CHN), India (IND), other Asia and islands (OAI), Middle Eastern Crescent (which includes North Africa, the Middle East, Pakistan, and the Central Asian Republics of the former Soviet Union) (MEC), and sub-Saharan Africa (SSA). The criteria used to define these regions included the level of socioeconomic development, epidemiologic homogeneity, and geographic contiguity. "Developed" includes EMEs and FSEs; "developing" includes the other six regions.

Region	Group I	Group II	Group III	Total
EMEs	453	6,223	445	7,121
FSEs	214	3,188	389	3,791
IND	4,775	3,788	808	9,371
CHN	1,405	6,460	1,020	8,885
OAI	2,190	2,785	559	5,534
SSA	5,316	1,864	1,022	8,202
LAC	943	1,676	389	3,009
MEC	1,945	2,156	452	4,553
World	17,241	28,141	5,084	50,467
Developing	16,573	18,730	4,251	39,554
Developed	667	9,411	834	10,912

Table 2. The 17 leading causes of DALYs in the world in 1990 and 2020, plus those ranked 19th, 28th, and 33rd, according to the baseline scenario. The projections are based on a simple model that has been developed relating cause-specific mortality rates to income per capita, average years of schooling, time (serving as a proxy for technology change), and tobacco use. Cause-of-death data from 47 countries for the period 1950 to 1990 have been used to fit log-log regression equations. The projections from the former WHO Global Programme on AIDS were used for HIV. DALYs were projected with the use of simple relational models between death and disability.

Disease or injury	1990		2020 baseline scenario	
	Rank	Percent of total DALYs	Rank	Percent of total DALYs
Lower respiratory infections	1	8.2	6	3.1
Diarrheal diseases	2	7.2	9	2.7
Conditions arising during the perinatal period	3	6.7	11	2.5
Unipolar major depression	4	3.7	2	5.7
Ischemic heart disease	5	3.4	1	5.9
Cerebrovascular disease	6	2.8	4	4.4
Tuberculosis	7	2.8	7	3.1
Measles	8	2.6	25	1.1
Road traffic accidents	9	2.5	3	5.1
Congenital anomalies	10	2.4	13	2.2
Malaria	11	2.3	24	1.1
Chronic obstructive pulmonary disease	12	2.1	5	4.1
Falls	13	1.9	19	1.5
Iron-deficiency anemia	14	1.8	39	0.5
Protein-energy malnutrition	15	1.5	37	0.6
War	16	1.5	8	3.0
Self-inflicted injuries	17	1.4	14	1.9
Violence	19	1.3	12	2.3
HIV	28	0.8	10	2.6
Trachea, bronchus, and lung cancers	33	0.6	15	1.8

factors. Mortality and disability attributable to 10 major risk factors have been estimated in the GBD and are summarized in Table 3. Exposures that underlie the major infections of young children, such as malnutrition and poor water, sanitation, and hygiene, cause an estimated 20 to 25% of the total disease and injury burden. Their control remains a priority for global public health. Various exposures such as tobacco use, alcohol use, and occupation each account for approximately 3% of the burden, which is similar to that of measles, tuberculosis, and malaria. If these risk factor estimates of burden are correct, they would suggest that the prevention of occupation, tobacco, and alcohol-related illness and death are urgent priorities for public health policy. The estimates for alcohol allow for probable cardioprotective effects and indicate a higher percentage contribution to DALYs (3.5%) than deaths (1.5%), reflecting the importance of disability caused by alcohol and the much younger age distribution of deaths caused by alcohol than those from ischemic heart disease deaths avoided by its use. To many, it may be surprising that the global burden of disease attributable to physical inactivity is nearly equal to the burden of hypertension—for both, the burden attributable in EMEs is much higher than elsewhere (4.8 and 3.9%, respectively).

Figure 1 illustrates the projected trends in burden from diarrheal diseases, HIV, and tobacco in the baseline scenario. In this scenario, the dramatic rise of HIV as a cause of mortality and disability is clear. HIV, which in 1990 ranked 28th as a cause of burden, would become one of the 10 leading causes of DALYs early in the next decade, after which its incidence is projected to decline worldwide. The magnitude of the HIV epidemic is clearly highly uncertain, depending not only on current epidemiologic trends but on the individual, community, and government response to the epi-

dem in different countries. In the pessimistic scenario, the projected burden of HIV is 51 million DALYs, and in the optimistic scenario it is 23 million DALYs. Because of expected economic growth and aging populations in many regions, Group I conditions such as diarrhea are expected to decline in importance as causes of burden. In the pessimistic scenario, the burden of diarrhea will remain much higher, 70 million DALYs in 2020. The most dramatic feature of Fig. 1 is the unprecedented rise in the burden attributable to tobacco. This trend is a robust prediction because most of the tobacco-related mortality and disability in 2020 is due to smoking prevalence today. By 2020, tobacco is projected to account for 9% of the burden expected to occur in that year and is expected to be the leading cause of DALYs. Of the projected 8.4 million tobacco-related deaths, 6.0 million are projected to be in developing regions overall, including 2.2 million in China, 1.5 million in India, and 0.8 million in the Middle Eastern Crescent.

Policy Implications

A number of conclusions emerge from the results of the GBD. First, because of expected economic growth and demographic change, the epidemiological transition is well under way in developing regions. Although a number of infectious and parasitic diseases, such as tuberculosis and malaria, are likely to remain major health challenges, many developing regions are already faced with the problems of responding to a large burden of noncommunicable conditions and injuries. These combined demographic and epidemiological trends will increasingly shift the focus of policy debate and research to the adult health agenda. Yet research on policies targeting the health of adults in developing countries is extremely

limited (10). Some studies have examined the cost-effectiveness of various intervention options, but much more information on the cost-effectiveness of available preventive, rehabilitative, and curative interventions is required (11). Studies of interventions aimed at risk factor modification, treatment, and prevention of mental health conditions, as well as prevention, treatment, and rehabilitation of injuries are major priorities.

Three specific conclusions are worth emphasizing. When the burden of nonfatal health outcomes is included, our perception of priorities changes. The importance of disabling conditions is perhaps best illustrated by unipolar major depression, which ranks as the fourth most important cause of burden in 1990 and is likely to rise to second in 2020. The rise in unipolar major depression and other neuropsychiatric conditions as causes of burden is entirely due to demographic changes, as the age-specific rates of these conditions are projected to remain constant. Injuries, both intentional and unintentional, are also expected to become increasingly important causes of burden because of the dramatic growth expected to occur in the young adult population who have the greatest risk of injuries, even though age-specific death and disability rates from injuries may be declining. Finally, the extraordinary epidemic of tobacco-related mortality and disability (over 8 million deaths in 2020 due to tobacco) emerges as the most alarming trend over the next three decades.

Evidence-based health policy formulation would require regular updates of global and regional information (perhaps every 3 to 5 years) and equivalent information at the national and subnational levels. Efforts to address the latter are under way; more than 30 countries, including the United States, are applying the approach outlined in the GBD to national health problem assessment. Planning for future global and

Table 3. The global burden of disease and injury attributable to selected risk factors in 1990 (12). Burden attributable to occupation has been estimated largely on the basis of occupational injury and disease registries maintained in some countries. For the other risk factors, the attributable burden has been estimated by analysis of relative risks from cohort studies in developed countries and by various types of measures of the prevalence of exposure in each age-sex group in each region.

Risk factor	Deaths ($\times 10^3$)	Percent of total deaths	DALYs ($\times 10^6$)	Percent of total DALYs
Malnutrition	5881	11.7	219.6	15.9
Poor water supply, sanitation, and hygiene	2668	5.3	93.4	6.8
Unsafe sex	1095	2.2	48.7	3.5
Tobacco use	3038	6.0	36.2	2.6
Alcohol use	774	1.5	47.7	3.5
Occupation	1129	2.2	37.9	2.7
Hypertension	2918	5.8	19.1	1.4
Physical inactivity	1991	3.9	13.7	1.0
Illicit drug use	100	0.2	8.5	0.6
Air pollution	568	1.1	7.3	0.5

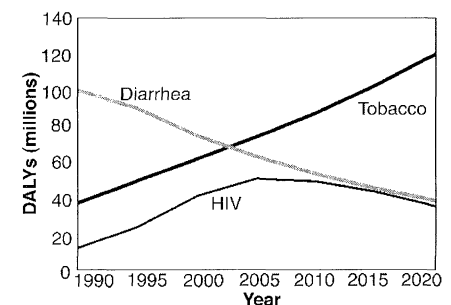


Fig. 1. DALYs attributable to diarrhea, HIV, and tobacco from 1990 to 2020, according to the baseline projection scenario. See the text for optimistic and pessimistic scenario projections for HIV and diarrhea.

regional assessments has not begun. A number of factors would be important ingredients for successful future iterations: an environment where the objective analysis of health problems can be fostered; widespread participation of epidemiologists and public health experts from many institutions and countries; sufficient time and resources to embark on the detailed analyses that are often required to develop internally consistent epidemiological profiles of health problems; and close links to the research community so that methodological developments and refinements continue and are incorporated in a timely fashion. The unique collaboration of the World Bank and WHO was critical to the success of the GBD. Similar collaboration and leadership will surely be needed if the health policy debates of the future are to be routinely and effectively informed by the available evidence on health problems and possibilities for intervention.

REFERENCES AND NOTES

1. Interest in tuberculosis had waned to an historic low in the mid-1980s, but a series of analyses stimulated by the World Bank as part of their Health Sector Priorities Review [for example, see C. J. L. Murray, K. Styblo, A. Rouillon, *Bull. IUATLD* **65**, 2 (1990); C. J. L. Murray *et al.*, *Lancet* **338**, 1305 (1991)], the rising case numbers of tuberculosis in developed nations, and the interaction between HIV and tuberculosis led to tuberculosis being declared a global emergency by WHO.
2. Preliminary results from the GBD were published in brief in the *World Development Report 1993: Investing in Health* (Oxford Univ. Press, New York, 1993) and more extensively in 1994 [C. J. L. Murray, *Bull. WHO* **72**, 429 (1994); — and A. D. Lopez, *ibid.*, p. 447; *ibid.*, p. 481; C. J. L. Murray *et al.*, *ibid.*, p. 495]. The complete details on the methods and final results are being published in a 10-volume series. The first two volumes of this series, which provide an overview of the study, have been published: C. J. L. Murray and A. D. Lopez, Eds., *The Global Burden of Disease*, vol. I: *A Comprehensive Assessment of Mortality and Disability from Diseases, Injuries, and Risk Factors in 1990 and Projected to 2020* (Harvard Univ. Press, Cambridge, MA, 1996) and *The Global Burden of Disease*, vol. II: *Global Health Statistics: A Compendium of Incidence, Prevalence, and Mortality Estimates for Over 200 Conditions* (Harvard Univ. Press, Cambridge, MA, 1996).
3. For each disease or injury, experts (or groups of experts in some cases) collaborated on the study. These experts were drawn from WHO; the World Bank; the U.S. Centers for Disease Control and Prevention; and academic institutions in many countries, including the United States, the United Kingdom, France, Mexico, New Zealand, Japan, India, Sri Lanka, China, and South Africa. Volumes III through X of the *Global Burden of Disease and Injury Series*, [C. J. L. Murray and A. D. Lopez, Eds. (Harvard Univ. Press, Cambridge, MA, 1996)] provide a series of disease-, injury-, and risk factor-specific chapters authored by these collaborators. In addition, a number of other individuals have provided critical input to the study (see the acknowledgments in the series.)
4. C. J. L. Murray and A. D. Lopez, in *The Global Burden of Disease*, C. J. L. Murray and A. D. Lopez, Eds. (Harvard Univ. Press, Cambridge, MA, 1996), vol. 1, pp. 325–396.
5. A computer program, DisMod, was developed specifically for the GBD to facilitate the analysis of internal consistency. In this program, the user inputs a set of age-specific incidence, remission, and case-fatality rates, and the program calculates the expected duration and prevalence and death rates in a stable population. Further information on the currently available versions of this software can be obtained at <http://www.hsph.harvard.edu/organizations/bclu> or by contacting the authors.
6. DALYs can be considered a standardized form of quality-adjusted life years (QALYs). For useful discussions of the strengths, limitations, and uses of QALYs, see M. C. Weinstein, *Int. J. Tech. Assess. Health Care* **6**, 93 (1990); E. Nord, *Soc. Sci. Med.* **41**, 1429 (1992); J. Richardson, *ibid.* **39**, 7 (1994).
7. DALYs are the combination of years of life lost due to premature mortality (YLLs) and years of life lived with disability adjusted for the severity of disability (YLDs). The duration of life lost due to a death at each age in YLLs is calculated by means of a standard life table based on the Coale and Demery model life table West with an expectation of life at birth for females of 82.5 years and for males of 80 years. Time lived at different ages has been valued with an exponential function of the form $Cxe^{-\beta x}$ (where C is a constant, x is age, and β is 0.04) to reflect the greater social role played by adults in caring and providing for the young and the old. Time lost due to premature mortality has been discounted at 3%, so that a year of life lost in the future is less valuable than a year of life lost today. Years Lived with Disability (YLDs) are time lived in health states worse than perfect health, weighted by a severity weight for each health state. The severity weights range from 0 (which is perfect health) to 1 (which is the weight for a health state equivalent to death). The preferences of groups of individuals for different health states have been measured by the person trade-off (PTO) method. In the most simple form of a PTO, a person is offered two alternatives. Alternative 1 is to extend life for x individuals in normal health, and alternative 2 is to extend life for y individuals in health state i. The term y is varied until the respondent is indifferent to the choice between the two alternatives, at which point the preference for state i is

$$\left(\frac{x}{1-y} \right)$$
 Other forms of PTOs can be structured in which people are asked to trade off restoring health to x individuals in health state i versus extending life for y healthy individuals for a fixed period of time. Severity weights for 22 indicator conditions have been developed with the PTO method applied to a group that was representative of each region of the world, convened at WHO. Very similar results have been found in eight other preference measurement exercises in other countries with the same PTO protocol. On the basis of the disability severity weights for the 22 indicator conditions, seven classes of disability have been defined, so that each class of disability contains two to three indicator conditions. For each of the remaining several hundred disabling sequelae included in the study, the group convened at WHO selected the distribution of severity across the seven classes for both treated and untreated forms of the condition. Time lived with disability is also age-weighted and discounted in the same manner as YLLs. For a complete discussion of various methods to measure preferences for living with various health conditions and the methods used to apply the PTO method in the GBD, see C. J. L. Murray, in *The Global Burden of Disease*, C. J. L. Murray and A. D. Lopez, Eds. (Harvard Univ. Press, Cambridge, MA, 1996), vol. 1, pp. 22–43; *ibid.*, pp. 90–98.
8. The term “demographic transition” is often used to describe the decline in fertility and mortality rates that most developed and a number of developing countries have undergone during this century. Omran [*Millbank Mem. Fund Q.* **49**, 509 (1971)] coined the term “epidemiological transition” to refer to the characteristic shift in the composition of causes of death from infectious and parasitic to noncommunicable diseases. More recently, J. Frenk *et al.* [*Health Policy Planning* **4**, 29 (1989)] have used the “health transition” to refer to the changes in fertility, mortality, cause of death composition, disability, and the health care system’s response to these trends. We use “demographic transition” to refer to the characteristic changes in fertility and mortality rates that accompany development, and “epidemiological transition” to refer to changes in the age-specific mortality and disability rates that may accompany development.
9. The impressive rise in the burden associated with neuropsychiatric conditions is exclusively due to the projected increase in the number of young and middle-aged adults who are at the highest risk of these conditions. As a result of past changes in fertility, the number of children under age 5 in the developing world will increase from 1990 to 2020 by 25% and the number of adults between ages 45 and 59 will increase by 140%. We were unable to find convincing evidence concerning the trends or determinants of trends in the age-specific rates of most neuropsychiatric conditions. We have therefore assumed for many of these conditions that age-specific incidence rates will remain constant. Some may argue persuasively that these estimates are conservative, as a number of socioeconomic developments may contribute to higher rates of mental illness; for example, the higher rates of war experienced in recent years may contribute to higher rates of post-traumatic stress disorder in the coming decades.
10. R. G. A. Feachem *et al.*, *The Health of Adults in the Developing World* (Oxford Univ. Press, New York, 1992) is one of the few examples of such research.
11. D. T. Jamison *et al.*, *Disease Control Priorities in Developing Countries* (Oxford Univ. Press, New York, 1993).
12. For a review of these 10 studies, see C. J. L. Murray and A. D. Lopez, in *The Global Burden of Disease*, C. J. L. Murray and A. D. Lopez, Eds. (Harvard Univ. Press, Cambridge, MA, 1996), pp. 295–324. More complete discussions of methods and results are provided in chapters on each specific risk factor.

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