

Box 1: History of the Global Burden of Disease and innovations in GBD 2010

The first GBD study was published as part of the World Development Report 1993. This original study generated estimates for 107 diseases, 483 sequelae (non-fatal health consequences), eight regions, and five age groups.

The authors' inspiration for the study came from the realization that policymakers lacked comprehensive and standardized data on diseases, injuries, and potentially preventable risk factors for decision-making. A second source of inspiration was the fact that disease-specific advocates' estimates of the number of deaths caused by their diseases of interest far exceeded the total number of global deaths in any given year. GBD authors chose to pursue a holistic approach to analyzing disease burden to produce scientifically sound estimates that were protected from the influence of advocates.

The GBD 1990 study had a profound impact on health policy as it exposed the hidden burden of mental illness around the world. It also shed light on neglected health areas such as the premature death and disability caused by road traffic injuries. Work from this study has been cited over 4,000 times since 1993.

The study also sparked substantial controversy. Many disease-specific advocates argued that the original GBD underestimated burden from the causes they cared about most. The use of age weighting and discounting also caused extensive debates. Age weighting assumed that a year of life increased in value until age 22, and then decreased steadily. Discounting counted years of healthy life saved in the present as more valuable than years of life saved in the future. Also controversial was the use of expert judgment to estimate disability weights (estimations of the severity of non-fatal conditions). As a result of this feedback and consultation with a network of philosophers, ethicists, and economists, GBD no longer uses age weighting and discounting. Also, GBD 2010 updated its methods for determining disability weights and used data gathered from thousands of respondents from different countries around the world.

GBD 2010 shares many of the founding principles of the original GBD 1990 study, such as using all available data on diseases, injuries, and risk factors; using comparable metrics to estimate the impact of death and disability on society; and ensuring that the science of disease burden estimation is not influenced by advocacy.

Despite these similarities, GBD 2010 is broader in scope and involved a larger number of collaborators than any previous GBD study. While the original study had the participation of 100 collaborators worldwide, GBD 2010 had 488 co-authors. Thanks to that network, the study includes vast amounts of data on health outcomes and risk factors. Researchers also made substantial improvements to the GBD methodology, described in detail in the "Methods" section and in the published studies. Among these improvements, highlights include using data collected via population surveys to estimate disability weights for the first time, greatly expanding the list of causes and risk factors analyzed in the study, detailed analysis of the effect of different components of diet on health outcomes, and reporting of uncertainty intervals for all metrics. GBD 2010 researchers reported uncertainty intervals to provide full transparency about the weaknesses and strengths of the analysis. Narrow uncertainty intervals indicate that evidence is strong, while wide uncertainty intervals show that evidence is weaker.

THE GBD APPROACH TO TRACKING HEALTH PROGRESS AND CHALLENGES

For decision-makers striving to create evidence-based policy, the GBD approach provides numerous advantages over other epidemiological studies. These key features are further explored in this report.

A CRITICAL RESOURCE FOR INFORMED POLICYMAKING

To ensure a health system is adequately aligned to a population's true health challenges, policymakers must be able to compare the effects of different diseases that kill people prematurely and cause ill health. The original GBD study's creators developed a single measurement, disability-adjusted life years (DALYs), to quantify the number of years of life lost as a result of both premature death and disability. One DALY equals one lost year of healthy life. DALYs will be referred to by their acronym, as years of healthy life lost, and years lost due to premature death and disability throughout this publication. Decision-makers can use DALYs to quickly assess the impact caused by conditions such as cancer versus depression using a comparable metric. Considering the number of DALYs instead of causes of death alone provides a more accurate picture of the main drivers of poor health. Thanks to the use of this public health monitoring tool, GBD 2010 researchers found that in most countries as mortality declines, disability becomes increasingly important. Information about changing disease patterns is a crucial input for decision-making, as it illustrates the challenges that individuals and health care providers are facing in different countries.

One DALY equals one lost year of healthy life.

In addition to comparable information about the impact of fatal and non-fatal conditions, decision-makers need comprehensive data on the causes of ill health that are most relevant to their country. The hierarchical GBD cause list, seen in the Annex, has been designed to include the diseases, injuries, and sequelae that are most relevant for public health policymaking. To create this list, researchers reviewed epidemiological and cause-of-death data to identify which diseases and injuries resulted in the most ill health. Inpatient and outpatient records were also reviewed to understand the conditions for which patients sought medical care. For example, researchers added chronic kidney disease to the GBD cause list after learning that this condition accounted for a large number of hospital visits and deaths.

GBD provides high-quality estimates of diseases and injuries that are more credible than those published by disease-specific advocates. GBD was created in part due to researchers' observation that deaths estimated by different disease-specific studies added up to more than 100% of total deaths when summed. The GBD approach ensures that deaths are counted only once. First, GBD counts the total number of deaths in a year. Next, researchers work to assign a single cause to each death using a variety of innovative methods (see the "Methods" section). Estimates of cause-specific mortality are then compared to estimates of deaths from all causes to

ensure that the cause-specific numbers do not exceed the total number of deaths in a given year. Other components of the GBD estimation process are interconnected with similar built-in safeguards, such as for the estimation of impairments that are caused by more than one disease.

Beyond providing a comparable and comprehensive picture of causes of premature death and disability, GBD also estimates the disease burden attributable to different risk factors. The GBD approach goes beyond risk-factor prevalence, such as the number of smokers or heavy drinkers in a population. With comparative risk assessment, GBD incorporates both the prevalence of a given risk factor as well as the relative harm caused by that risk factor. It counts premature death and disability attributable to high blood pressure, tobacco and alcohol use, lack of exercise, air pollution, poor diet, and other risk factors that lead to ill health.

The flexible design of the GBD machinery allows for regular updates as new data are made available and epidemiological studies are published. Similar to the way in

which a policymaker uses gross domestic product data to monitor a country's economic activity, GBD can be used at both the global and national levels to understand health trends over time.

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Policymakers in Brazil, Norway, Saudi Arabia, and the United Kingdom are exploring collaborations with IHME to adopt different aspects of the GBD approach. Box 3 contains decision-makers' and policy-influencers' reflections about the value of using GBD tools and results to inform policy discussions.

GBD data visualization tools on the IHME website allow users to interact with the results in a manner not seen in past versions of the study. Users of the visualization tools report that they provide a unique, hands-on opportunity to learn about the health problems that different countries and regions face, allowing them to explore seemingly endless combinations of data. The following list illustrates the range of estimates that can be explored using the GBD data visualization tools:

- Changes between 1990 and 2010 in leading causes of death, premature death, disability, and DALYs as well as changes in the amount of health loss attributable to different risk factors across age groups, sexes, and locations.
- Rankings for 1990 and 2010 of the leading causes of death, premature death, disability, DALYs, and health loss attributable to risk factors across different countries and regions, age groups, and sexes.
- Changes in trends for 21 cause groups in 1990 and 2010 in different regions, sexes, and metrics of health loss.
- The percentage of deaths, premature deaths, disability, or DALYs in a country or region caused by myriad diseases and injuries for particular age groups, sexes, and time periods.
- The percentage of health loss by country or region attributable to specific risk factors by age group, sex, and time period.

In addition to promoting understanding about the major findings of GBD, these visualization tools can help government officials build support for health policy changes, allow researchers to visualize data prior to analysis, and empower teachers to illustrate key lessons of global health in their classrooms.

THE EGALITARIAN VALUES INHERENT IN GBD

When exploring the possibility of incorporating GBD measurement tools into their health information systems, policymakers should consider the egalitarian values on which this approach is founded.

The core principle at the heart of the GBD approach is that everyone should live a long life in full health. As a result, GBD researchers seek to measure the gap between this ideal and reality. Calculation of this gap requires estimation of two different components: years of life lost due to premature death (YLLs) and years lived with disability (YLDs).

To measure years lost to premature death, GBD researchers had to answer the question: "How long is a 'long' life?" For every death, researchers determined that the most egalitarian answer to this question was to use the highest life expectancy observed in the age group of the person who died. The "Methods" section contains more information about the estimation of YLLs.

In order to estimate years lived with disability, or YLDs, researchers were confronted with yet another difficult question: "How do you rank the severity of different types of disability?" To determine the answer, researchers created disability weights based on individuals' perceptions of the impact on people's lives from a particular disability, everything from tooth decay to schizophrenia.

Box 2: Key terms

Years of life lost (YLLs): *Years of life lost due to premature mortality.*

Years lived with disability (YLDs): *Years of life lived with any short-term or long-term health loss.*

Disability-adjusted life years (DALYs): *The sum of years lost due to premature death (YLLs) and years lived with disability (YLDs). DALYs are also defined as years of healthy life lost.*

Healthy life expectancy, or health-adjusted life expectancy (HALE): *The number of years that a person at a given age can expect to live in good health, taking into account mortality and disability.*

Sequelae: *Consequences of diseases and injuries.*

Health states: *Groupings of sequelae that reflect key differences in symptoms and functioning.*

Disability weights: *Number on a scale from 0 to 1 that represents the severity of health loss associated with a health state.*

Uncertainty intervals: *A range of values that is likely to include the correct estimate of health loss for a given cause. Limited data create substantial uncertainty.*

Box 3: Views on the value of GBD for policymaking

"While the GBD 2010 offers significant epidemiologic findings that will shape policy debates worldwide, it also limns the gaps in existing disease epidemiology knowledge and offers new ways to improve public health data collection and assessment." **Paul Farmer**, Chair, Department of Global Health and Social Medicine, Harvard Medical School

"If we look at sub-Saharan Africa, you've got the double burden of communicable diseases and the rising instances of non-communicable diseases. The dilemma will be how to deal with the non-communicable diseases without compromising what you've already been doing for communicable diseases." **Christine Kaseba-Sata**, First Lady of Zambia

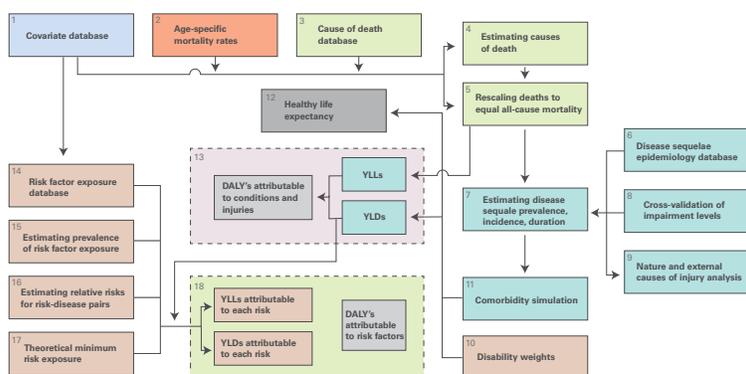
"At UNICEF we've always had a focus on metrics and outcomes as a driver of the work we do. We welcome the innovation, energy, and attention that this work is bringing to the importance of holding ourselves accountable to meaningful outcomes and results." **Mickey Chopra**, UNICEF Chief of Health/Associate Director of Programmes

METHODS

The analytical strategy of GBD

The GBD approach contains 18 distinct components, as outlined in Figure 1. The components of GBD are interconnected. For example, when new data is incorporated into the age-specific mortality rates analysis (component 2), other dependent components must also be updated, such as rescaling deaths for each cause (component 5), healthy life expectancy, or HALE (component 12), YLLs (component 13), and estimation of YLLs attributable to each risk factor (component 18). The inner workings of key components are briefly described in this publication, and more detailed descriptions of each component are included in the published articles.

Figure 1: The 18 components of GBD and their interrelations



Estimating age- and sex-specific mortality

Researchers identified sources of under-5 and adult mortality data from vital and sample registration systems as well as from surveys that ask mothers about live births and deaths of their children and ask people about siblings and their survival. Researchers processed that data to address biases and estimated the probability of death between ages 0 and 5 and ages 15 and 60 using statistical models. Finally, researchers used these probability estimates as well as a model life table system to estimate age-specific mortality rates by sex between 1970 and 2010.

Estimating years lost due to premature death

Researchers compiled all available data on causes of death from 187 countries. Information about causes of death was derived from vital registration systems, mortality surveillance systems, censuses, surveys, hospital records, police records, mortuaries, and verbal autopsies. Verbal autopsies are surveys that collect information from individuals familiar with the deceased about the signs and symptoms the person had prior to death. GBD 2010 researchers closely examined the completeness of the data. For those countries where cause of death data were incomplete, researchers used statistical techniques to compensate for the inherent biases. They also standardized causes of death across different data sources by mapping different versions of the International Classification of Diseases (ICD) coding system to the GBD cause list.

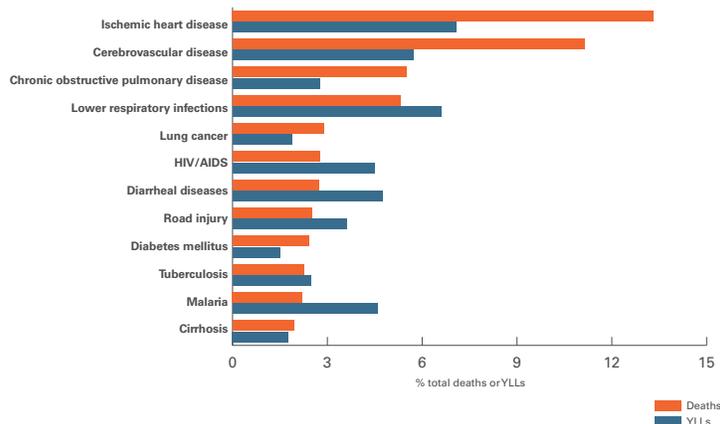
Next, researchers examined the accuracy of the data, scouring rows and rows of data for "garbage codes." Garbage codes are misclassifications of death in the data, and researchers identified thousands of them. Some garbage codes are instances where we know the cause listed cannot possibly lead to death. Examples found in records include "abdominal rigidity," "senility," and "yellow nail syndrome." To correct these, researchers drew on evidence from medical literature, expert judgment, and statistical techniques to reassign each of these to more probable causes of death.

After addressing data-quality issues, researchers used a variety of statistical models to determine the number of deaths from each cause. This approach, named CODEm (Cause of Death Ensemble modeling), was designed based on statistical techniques called "ensemble modeling." Ensemble modeling was made famous by the recipients of the Netflix Prize, BellKor's Pragmatic Chaos, in 2009, who engineered the best algorithm to predict how much a person would like a film, taking into account their movie preferences.

To ensure that the number of deaths from each cause does not exceed the total number of deaths estimated in a separate GBD demographic analysis, researchers apply a correction technique named CoDCorrect. This technique makes certain that estimates of the number of deaths from each cause do not add up to more than 100% of deaths in a given year.

After producing estimates of the number of deaths from each of the 235 fatal outcomes included in the GBD cause list, researchers then calculated years of life lost to premature death, or YLLs. For every death from a particular cause, researchers estimated the number of years lost based on the highest life expectancy in the deceased's age group. For example, if a 20-year-old male died in a car accident in South Africa in 2010, he has 66 years of life lost, that is, the highest remaining life expectancy in 20-year-olds, as experienced by 20-year-old females in Japan.

Figure 2: Leading causes of global death and premature death, 2010



When comparing rankings of the leading causes of death versus YLLs, YLLs place more weight on the causes of death that occur in younger age groups, as shown in Figure 2. For example, malaria represents a greater percentage of total YLLs than total deaths since it is a leading killer of children under age 5. Ischemic heart disease, by contrast, accounts for a smaller percentage of total YLLs than total deaths as it primarily kills older people.

Estimating years lived with disability

Researchers estimated the prevalence of each sequela using different sources of data, including government reports of cases of infectious diseases, data from population-based disease registries for conditions such as cancers and chronic kidney diseases, antenatal clinic data, hospital discharge data, data from outpatient facilities, interview questions, and direct measurements of hearing, vision, and lung-function testing from surveys and other sources.

Confronted with the challenge of data gaps in many regions and for numerous types of sequelae, they developed a statistical modeling tool named DisMod-MR (Disease Modeling–Metaregression) to estimate prevalence using available data on incidence, prevalence, remission, duration, and extra risk of mortality due to the disease.

Researchers estimated disability weights using data collected from almost 14,000 respondents via household surveys in Bangladesh, Indonesia, Peru, Tanzania, and the United States. Disability weights measure the severity of different sequelae that result from disease and injury. Data were also used from an Internet survey of more than 16,000 people. GBD researchers presented different lay definitions of sequelae grouped into 220 unique health states to survey respondents, and respondents were then asked to rate the severity of the different health states. The results were similar across all surveys despite cultural and socioeconomic differences. Respondents consistently placed health states such as mild hearing loss and long-term treated fractures at the low end of the severity scale, while they ranked acute schizophrenia and severe multiple sclerosis as very severe.

Finally, years lived with disability, or YLDs, are calculated as prevalence of a sequela multiplied by the disability weight for that sequela. The number of years lived with disability for a specific disease or injury are calculated as the sum of the YLDs from each sequela arising from that cause.

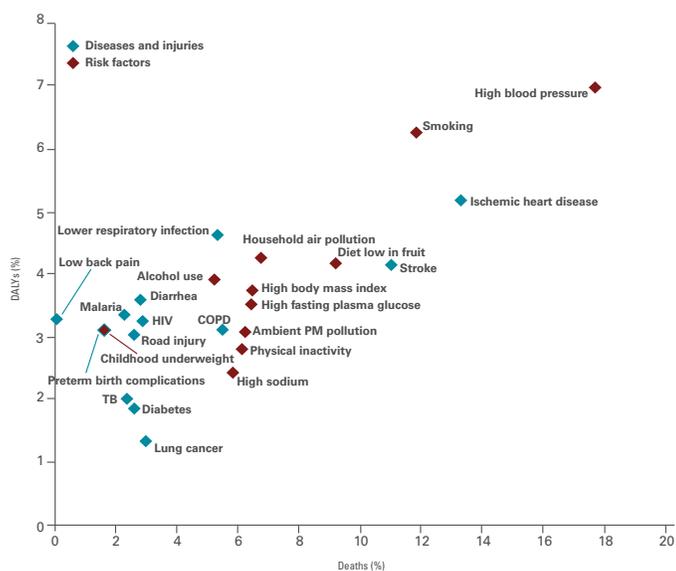
Estimating disability-adjusted life years

DALYs are calculated by adding together YLLs and YLDs. Figure 3 compares the 10 leading diseases and injuries calculated as percentages of both global deaths and global DALYs. This figure also shows the top 10 risk factors attributable to deaths and DALYs worldwide. It illustrates how a decision-maker looking only at the top 10 causes of death would fail to see the importance of low back pain, for example, which was a leading cause of DALYs in 2010. DALYs are a powerful tool for priority setting as they measure disease burden from non-fatal as well as fatal conditions. Yet another reason why top causes of DALYs differ from leading causes of death is that DALYs give more weight to death in younger ages. As another example, road injuries and diarrhea cause a greater percentage of total DALYs than total deaths because DALYs capture both premature death and disability from these causes. In contrast, stroke causes a much larger percentage of total deaths than DALYs as it primarily impacts older people.

Estimating DALYs attributable to risk factors

To estimate the number of healthy years lost, or DALYs, attributable to potentially avoidable risk factors, researchers collected detailed data on exposure to different risk factors. The study used data from sources such as satellite data on air pollution, breastfeeding data from population surveys, and blood and bone lead levels from medical examination surveys and epidemiological surveys. Researchers then collected data on the effects of risk factors on disease outcomes through systematic reviews of epidemiological studies.

Figure 3: The 10 leading diseases and injuries and 10 leading risk factors based on percentage of global deaths and DALYs, 2010



All risk factors analyzed met common criteria in four areas:

1. The likely importance of a risk factor for policymaking or disease burden.
2. Availability of sufficient data to estimate exposure to a particular risk factor.
3. Rigorous scientific evidence that specific risk factors cause certain diseases and injuries.
4. Scientific findings about the effects of different risk factors that are relevant for the general population.

To calculate the number of DALYs attributable to different risk factors, researchers compared the disease burden in a group exposed to a risk factor to the disease burden in a group that had zero exposure to that risk factor. When subjects with zero exposure were impossible to find, as in the case of high blood pressure, for example, researchers established a level of minimum exposure that leads to the best health outcomes.

RAPID HEALTH TRANSITIONS: GBD 2010 RESULTS

GBD 2010 found that the leading causes of premature death and disability, or DALYs, have evolved dramatically over the past 20 years. Figure 4 shows the changes in the leading causes of DALYs in 1990 and 2010. Communicable, newborn, maternal, and nutritional causes are shown in red, non-communicable diseases appear in blue, and injuries are shown in green. Dotted lines indicate causes that have fallen in rank during this period, while solid lines signal causes that have risen in rank.

Causes associated with ill health and death in adults, such as ischemic heart disease, stroke, and low back pain, increased in rank between 1990 and 2010, while causes that primarily affect children, such as lower respiratory infections, diarrhea, preterm birth complications, and protein-energy malnutrition, decreased in rank. Unlike most of the leading communicable causes, HIV/AIDS and malaria increased by 351% and 21%, respectively. Since 2005, however, premature mortality and disability from these two causes have begun to decline. Four main trends have driven changes in the leading causes of DALYs globally: aging populations, increases in non-communicable diseases, shifts toward disabling causes and away from fatal causes, and changes in risk factors.

Box 4: GBD data visualization tools

For the first time in the history of GBD research, IHME has developed many free data visualization tools that allow individuals to explore health trends for different countries and regions. The visualization tools allow people to view GBD estimates through hundreds of different dimensions. Only a few examples are explored in the figures throughout this document. We encourage you to visit the IHME website to use the GBD data visualization tools and share them with others.

To use the GBD data visualization tools, visit www.ihmeuw.org/GBDcountryviz