The Global Burden of Disease: Generating Evidence, Guiding Policy

INSTITUTE FOR HEALTH METRICS AND EVALUATION UNIVERSITY OF WASHINGTON
Over the last two decades, the global health landscape has undergone rapid transformation. People around the world are living longer than ever before, and the population is getting older. The number of people in the world is growing. Many countries have made remarkable progress in preventing child deaths. As a result, disease burden is increasingly defined by disability instead of premature mortality. The leading causes of death and disability have changed from communicable diseases in children to non-communicable diseases in adults. Eating too much has overtaken undernutrition as a leading risk factor for illness. These global trends differ across regions, and nowhere is this contrast more striking than in sub-Saharan Africa. Communicable, maternal, nutritional, and newborn diseases continue to dominate throughout sub-Saharan Africa.

The Global Burden of Disease (GBD) approach is a systematic, scientific effort to quantify the comparative magnitude of health loss due to diseases, injuries, and risk factors by age, sex, and geography for specific points in time. The latest iteration of that effort, the Global Burden of Diseases, Injuries, and Risk Factors Study 2010 (GBD 2010), was published in *The Lancet* in December 2012. The intent is to create a global public good that will be useful for informing the design of health systems and the creation of public health policy. It estimates premature death and disability due to 291 diseases and injuries, 1,160 sequelae (direct consequences of disease and injury), and 67 risk factors for 20 age groups and both sexes in 1990, 2005, and 2010. GBD 2010 produced estimates for 187 countries and 21 regions. In total, the study generated nearly 1 billion estimates of health outcomes.

GBD 2010 was a collaborative effort among 488 researchers from 50 countries and 303 institutions. The Institute for Health Metrics and Evaluation (IHME) acted as the coordinating center for the study. The collaborative strengthened both the data-gathering effort and the quantitative analysis by bringing together some of the foremost minds from a wide range of disciplines. Our intention is to build on this collaborative by enlarging the network in the years to come. Similarly, IHME and its collaborators hope to expand the list of diseases, injuries, and risk factors included in GBD and routinely update the GBD estimates. Continual updates will ensure that the international community can have access to high-quality estimates in the timeliest fashion. Through sound measurement, we can provide the foundational evidence that will lead to improved population health.

**INTRODUCTION**

**ABOUT IHME**

The Institute for Health Metrics and Evaluation (IHME) is an independent global health research center at the University of Washington that provides rigorous and comparable measurement of the world’s most important health problems and evaluates the strategies used to address them. IHME makes this information freely available so that policymakers have the evidence they need to make informed decisions about how to allocate resources to best improve population health.

To express interest in collaborating, participating in GBD training workshops, or receiving updates of GBD or copies of this publication, please contact IHME at:

Institute for Health Metrics and Evaluation
2301 Fifth Ave., Suite 600
Seattle, WA 98121
USA

Telephone: +1-206-897-2800
Fax: +1-206-897-2899
E-mail: comms@healthmetricsandevaluation.org

[www.healthmetricsandevaluation.org](http://www.healthmetricsandevaluation.org)

**ACKNOWLEDGMENTS**

The Global Burden of Disease Study 2010 (GBD 2010) was implemented as a collaboration between seven institutions: the Institute for Health Metrics and Evaluation (IHME) as the coordinating center, the University of Queensland School of Population Health, Harvard School of Public Health, the Johns Hopkins Bloomberg School of Public Health, the University of Tokyo, Imperial College London, and the World Health Organization. This summary draws on seven GBD 2010 papers published in *The Lancet* (2012 Dec 13; 380). GBD 2010 had 488 co-authors from 303 institutions in 50 countries.

The IHME community oversaw the production of this publication. In particular, we thank IHME’s Board for their continued leadership. We are grateful to the report’s writer Katherine Leach-Kemon; Christopher Murray, Michael Maclntyre, Theo Vos, Rafael Lozano, and William Heisel for content guidance; Summer Ohno for program coordination; Patricia Kiyono for editing and managing production; and Brian Childress for editorial support. This report would not have been possible without the ongoing contributions of Global Burden of Disease collaborators around the world.

Finally, we would like to extend our gratitude to the Bill & Melinda Gates Foundation for generously funding IHME and for its consistent support of the Global Burden of Disease research.
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 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.

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.

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 EGAITALIAN 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.
**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

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 sequel multiplied by the disability weight for that sequel. 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.
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.

**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.

**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
and North Africa lived 30 years longer on average in 2010 than they did in 1970. Tropical Latin America, which includes Brazil and Paraguay, People in the Middle East increased to 66 years in 2010. The average age of death increased from 31 to 63 in 1970, the People’s Republic of Korea, and Taiwan, people lived 36 years on average in 1970, occurred in Asia and Latin America. In East Asia, which includes China, the Democratic DYING AT LOWER RATES

Note: UI = uncertainty interval.

MOST OF THE WORLD’S POPULATION IS LIVING LONGER AND DYING AT LOWER RATES

In much of the world, GBD 2010 found that people are living to older ages than ever before, and the entire population is getting older. Since 1970, the average age of death has increased 35 years. Figure 5 illustrates the dramatic changes that have occurred in Asia and Latin America. In East Asia, which includes China, the Democratic People’s Republic of Korea, and Taiwan, people lived 36 years on average in 1970, increasing to 66 years in 2010. The average age of death increased from 31 to 63 in tropical Latin America, which includes Brazil and Paraguay. People in the Middle East and North Africa lived 30 years longer on average in 2010 than they did in 1970. Sub-Saharan Africa has not made nearly as much progress as other developing regions, and people in this part of the world tend to die at much younger ages than in any other region. Eastern sub-Saharan Africa made the most progress out of the four sub-Saharan African regions, with people living on average 12 years longer in 2010 than they did in 1970. In western, southern, and central sub-Saharan Africa, the average age at death has risen by less than 10 years. Compared to the rest of the developing world, progress in sub-Saharan Africa has in particular been held back by the HIV/AIDS epidemic, maternal deaths, and child mortality caused by infectious diseases and malnutrition. Some of those trends are changing, though. Over the past decade, sub-Saharan African regions have made encouraging strides in reducing child mortality and in lowering mortality from HIV/AIDS and malaria. These successes are explored elsewhere in this report.

Another way to understand changes in global demographic trends is to explore reductions in mortality rates by sex and age group. Figure 6 shows how death rates have declined in all age groups between 1970 and 2010. These changes have been most dramatic among males and females aged 0 to 9 years, whose death rates have dropped over 60% since 1970. Among age groups 15 and older, the decrease in female death rates since 1970 has been greater than the drop in male death rates. The gap in progress between men and women was largest between the ages of 15 to 54, most likely due to the persistence of higher mortality from injuries among men.
LEADING CAUSES OF DEATH ARE SHIFTING TO NON-COMMUNICABLE DISEASES

In part because many people are living longer lives and the population is growing older, the leading causes of death have changed. Worldwide, the number of people dying from non-communicable diseases, such as ischemic heart disease and diabetes, has grown 30% since 1990. Population aging and, to a lesser extent, overall population growth also contributed to this increase in deaths from non-communicable diseases. At the same time, the death rate from non-communicable diseases decreased over this period from 645.9 deaths per 100,000 people to 520.4, which is an indication that the world is making progress in this area.

The rise in the total number of deaths from non-communicable diseases has increased the number of healthy years lost, or DALYs, from these conditions. Figure 7 shows changes in the 25 leading causes of DALYs between 1990 and 2010 ordered from highest to lowest ranking cause from left to right. Non-communicable causes are shown in blue; communicable, nutritional, maternal, and newborn causes in red; and injuries in green.

Figure 7 shows that among non-communicable diseases, diabetes and different types of musculoskeletal disorders such as low back and neck pain increased the most between 1990 and 2010.

In many countries, non-communicable diseases account for the majority of DALYs. Figure 8 shows the percent of healthy years lost from this disease group by country in 2010. In most countries outside of sub-Saharan Africa, non-communicable diseases caused 50% or more of all healthy years lost, or DALYs. In Australia, Japan, and richer countries in Western Europe and North America, the percentage was greater than 80%.
An in-depth look at the country-level data reveals the specific diseases that are driving overall shifts from communicable to non-communicable diseases. As an example, Figure 9 displays the changes in the top 25 causes of DALYs in Mexican women between 1990 and 2010. The top causes are organized by ranking from left to right. Most non-communicable diseases rose over time, while communicable, newborn, nutritional, and maternal conditions have fallen during this period. Among the top five causes in 2010, chronic kidney disease increased the most (211%), followed by other musculoskeletal conditions and diabetes, which grew 88% and 75% each. Among communicable, nutritional, newborn, and maternal conditions, lower respiratory infections and diarrheal diseases experienced the most dramatic declines, falling by 65% and 83%, respectively.
Figure 10 shows declines in DALYs among Mexican men from communicable, nutritional, and newborn conditions coupled with increases in non-communicable diseases between 1990 and 2010. Out of all the non-communicable diseases shown in this figure, chronic kidney disease increased the most over the period (348%). Other leading causes of DALYs such as diabetes increased by 104%, ischemic heart disease grew by 98%, and cirrhosis by 58%. In addition to displaying the rising prominence of non-communicable diseases, this visualization shows that injuries are among the most dominant causes of healthy life lost in men in Mexico. DALYs caused by interpersonal violence ranked the highest in 2010, while road traffic injuries ranked third.

Figure 11a: Causes of DALYs, both sexes, all ages, India, 1990

Another visualization tool, GBD Compare, displays proportional changes in disease patterns over time using a treemap diagram, which is essentially a square pie chart. Causes of premature death and disability are shown in boxes. The size of each box represents the percentage of total DALYs, or numbers of healthy years lost, due to a specific cause. Figures 11a and 11b show how DALYs have changed in India between 1990 and 2010. In 1990, non-communicable diseases accounted for 31% of DALYs in both sexes, while communicable, nutritional, maternal, and newborn causes accounted for 43%. By 2010, they represented 45% and 43% of total disease burden, respectively. Premature death and disability from most communicable, nutritional, maternal, and newborn causes decreased during this period, with the exception of HIV/AIDS. DALYs from many non-communicable causes rose. Dramatic increases occurred in causes such as ischemic heart disease (66% increase), depression (53% increase), diabetes (93% increase), migraine (57% increase), and low back and neck pain (57% increase). In 2010, ischemic heart disease caused nearly 26 million DALYs, the largest number of any non-communicable cause. In addition to non-communicable disease burden, health loss from injuries such as self-harm and road traffic injuries increased 136% and 63%, respectively.
DISABILITY INCREASES IN MIDDLE- AND HIGH-INCOME COUNTRIES

Most countries in the world have succeeded in reducing deaths early in life, increasingly longer lives are redefining “old age” in many countries, and people in all age groups are dying at lower rates than in the past. Simply living longer does not mean that people are healthier. Little progress has been made in reducing the prevalence of disability, so people are living to an older age but experiencing more ill health. Many people suffer from different forms of disability throughout their lives, such as mental and behavioral health problems starting in their teens, and musculoskeletal disorders beginning in middle age. These findings have far-reaching implications for health systems.

While life expectancy can be used to measure a country’s health, it does not reflect the quality of life throughout a person’s lifespan. For this reason, GBD calculates healthy life expectancy, which reflects the number of years that a person can expect to live in good health free from disability. The difference between life expectancy and healthy life expectancy is the number of years lost to disability.

Figure 12 shows healthy years lost to disability versus life expectancy for males in 1990 and 2010. Researchers found that countries with higher life expectancies tend to have more years lived with disability. Three countries, Australia, Norway, and the US, are highlighted in the figure. Australia experienced the largest increase in life expectancy (5.4 years) during this period, and healthy years lost to disability increased by 1.1 years. While Norway’s life expectancy did not increase by as many years as Australia’s, rising just 4.9 years, its healthy years lost to disability increased by a greater amount, 1.5 years. In the US, life expectancy rose by 4.1 years from 1990 to 2010, and its healthy years lost to disability increased by 0.88 years. These countries illustrate how years lived with disability tend to increase as life expectancy rises. Valuable public health lessons could potentially be learned by understanding how Australia managed to increase its life expectancy while more effectively mitigating the corresponding increase in healthy years lost to disability compared to Norway.
To further elucidate the global shift towards disability, Figure 13 illustrates regional changes in the composition of healthy years lost, or DALYs. DALYs are broken out into years lived with disability (YLDs) and years of life lost (YLLs), also known as years lost to premature death. Outside southern sub-Saharan Africa, Eastern Europe, and the Caribbean, a greater percentage of healthy years were lost from disability in 2010 compared to 1990. As shown in Figure 13, this disability transition has been most dramatic in the Middle East and North Africa, parts of Latin America, and East, South, and Southeast Asia. For example, in the Middle East and North Africa region, 42% of healthy years lost were caused by disability in 2010, compared to 27% in 1990. In Andean Latin America, disability accounted for 41% of healthy years lost in 2010 and 25% in 1990.

Figure 14 tells a more detailed story about the different conditions that cause disability globally. It is important to keep in mind that these estimates reflect both how many individuals suffer from a particular condition as well as the severity of that condition. Mental and behavioral disorders, such as depression, anxiety, and drug use, are the primary drivers of disability worldwide and caused over 40 million years of disability in 20- to 29-year-olds. Musculoskeletal conditions, which include low back pain and neck pain, accounted for the next largest number of years lived with disability. People aged 45 to 54 were most impacted by these conditions, as musculoskeletal disorders caused over 30 million years of disability in each of these age groups. These findings have far-reaching implications for health systems.
Another way to view the world’s health challenges is by comparing how different conditions rank. Figure 15 ranks the leading causes of disability by region, using color coding to indicate how high a condition ranks in a region. Low back pain causes the most disability in many regions of the world. This condition can inhibit people’s ability to perform different types of work both inside and outside the home and impair their mobility. In addition to low back pain, neck pain and other musculoskeletal disorders rank in the top 10 causes of disability in most regions. Another musculoskeletal disorder, osteoarthritis, appears in the top 20 causes of disability in every region except central sub-Saharan Africa.

Depression is a major cause of disability across regions and is one of the top three causes of disability in every region except high-income Asia Pacific, where it ranked fourth. This disorder can cause fatigue, decreased ability to work or attend school, and suicide. Anxiety, a different type of mental disorder, is one of the top 10 causes of disability in most regions. Additionally, two other mental disorders, schizophrenia and bipolar disorder, appear among the top 20 causes of disability in many regions.
While mental and musculoskeletal disorders rank high among causes of disability across regions, Figure 15 also reveals substantial regional variation among other causes. Iron-deficiency anemia is a more important cause of disability in developing regions than in developed ones, and is the primary cause of disability in eastern, central, and western sub-Saharan Africa. Iron-deficiency anemia can lead to fatigue and lowered ability to fight infection, and may decrease cognitive ability.

Chronic obstructive pulmonary disease (COPD), a term used to describe emphysema and other chronic respiratory diseases, causes shortness of breath and difficulty breathing and ranks among the top five causes of disability in South and Southeast Asia and most of sub-Saharan Africa.

In many other regions, COPD appears in the list of the top 10 causes. COPD is caused by potentially modifiable risk factors like smoking, second-hand smoke, and air pollution. To further aid decision-makers as they shape health policy, GBD has developed analytic tools to estimate the number of premature deaths and disability, or DALYs, attributable to different risk factors. These tools are explored in the following section.

Using GBD tools to identify leading causes of disability, such as mental and behavioral disorders and musculoskeletal disorders, can help guide health system planning and medical education. Decision-makers can use GBD’s findings to ensure that health care systems are designed to address the primary drivers of disability in a cost effective way.

THE GLOBAL RISK FACTOR TRANSITION

Data on potentially avoidable causes of health loss, or risk factors, can help policymakers and donors prioritize prevention strategies to achieve maximum health gains. GBD tools estimate the number of deaths, premature deaths, years lived with disability, and DALYs attributable to 67 risk factors worldwide. This study benefited from the availability of new data, such as newly available epidemiologic evidence about the health impacts of different risk factors; population, nutrition, health, and medical examination surveys; and high-resolution satellite data on air pollution.

Figure 16 shows changes in the 25 leading global risk factors for premature death and disability, or DALYs, between 1990 and 2010. Over this period, many risk factors that primarily cause communicable diseases in children declined. Examples of these risk factors are childhood underweight and suboptimal breastfeeding, which dropped by 61% and 57% from 1990 to 2010, respectively. Childhood underweight is commonly used to measure malnutrition, and was formerly the leading risk factor for DALYs in 1990, but ranked eighth in 2010. Household air pollution, which contributes to lower respiratory tract infections in children, dropped by 37% between 1990 and 2010. Unlike other risk factors that primarily cause DALYs from communicable diseases, progress in reducing premature death and disability from iron deficiency was much lower, declining by just 7% between 1990 and 2010. Slow progress in reducing iron deficiency helps explain why iron-deficiency anemia ranks as the third leading cause of disability globally.

As most risk factors for communicable diseases in children have declined, many risks associated with non-communicable diseases have grown. DALYs from high blood pressure increased by nearly 30% between 1990 and 2010. High blood pressure is a major risk factor for cardiovascular and circulatory diseases. DALYs attributable to another risk factor for non-communicable diseases, tobacco smoking, increased slightly by 3% between 1990 and 2010. Smoking increases the risk of chronic respiratory diseases, cardiovascular and circulatory diseases, and cancer. DALYs attributable to another substance, alcohol use, increased 32% during this period. Alcohol use contributes to cardiovascular and circulatory diseases, cirrhosis, and cancer. In addition to being a contributor to non-communicable diseases, alcohol increases the risk of injuries.

Figure 16: Rankings of global DALYs for top 25 risk factors, 1990-2010

Note: Attributable DALYs were not quantified for physical inactivity and intimate partner violence for 1990.
GBD 2010 measured the health effects of different aspects of diet and physical inactivity. Together, all 15 dietary and physical inactivity risk factors measured in the study accounted for 10% of DALYs globally. Diets low in fruits ranked as the fourth leading cause of DALYs in 2010. The other risk factors responsible for the largest number of DALYs were physical inactivity and diets high in sugar, low in nuts and seeds, low in whole grains, low in vegetables, and low in seafood omega-3 fatty acids. GBD found the main diseases linked to poor diets and physical inactivity are primarily cardiovascular diseases as well as cancer and diabetes. While the focus of many public health messages about diet has stressed the importance of eating less saturated fat, GBD 2010’s findings indicate that these messages should emphasize a broader range of dietary components.

GBD 2010 used the most recent data available on the effects of different dietary risk factors. It is important to note that these data are constantly evolving as new studies provide new information. Future updates of GBD will incorporate new data on diet as they emerge.

High body mass index (BMI) was another major contributor to DALYs in 2010 and was the sixth leading risk factor. High BMI is typically used as an indicator of overweight and obesity. It increased by a dramatic 82% over the period 1990 to 2010. High BMI is a leading risk factor for cardiovascular and circulatory diseases as well as diabetes. It is striking that high BMI was a more important cause of poor health worldwide than childhood underweight in 2010, whereas childhood underweight was a much more prominent risk factor than high BMI in 1990.

Global rankings of risk factors mask important differences across countries and regions. The leading risk factors in sub-Saharan African countries differ greatly from other regions of the world. For example, Figure 17 shows the leading risks in central and eastern sub-Saharan African countries. In contrast to the global risk factor ranking, childhood underweight was the leading cause of premature death and disability, or DALYs, in most of these countries. Causes of communicable diseases in children dominate in these regions, such as suboptimal breastfeeding, household air pollution, and iron deficiency. Risk factors for non-communicable diseases also feature prominently in certain countries, such as Uganda, where alcohol is the top cause of DALYs, and the Congo, where high blood pressure is the second-highest cause. The rankings of risk factors among wealthier countries in this region, such as Gabon, Mauritius, and the Seychelles, exhibit very different patterns from other nations.

In addition to allowing users to explore how different risk factors rank across countries, decision-makers can use GBD visualization tools to understand how many DALYs could potentially be averted by addressing different risk factors. Figure 18 shows the number of DALYs attributable to outdoor air pollution for each cause, also known as ambient particulate matter (PM) air pollution, in China. The percentage of DALYs that could be averted by reducing this risk factor is shown in dark shading.
Figure 18: DALYs attributable to ambient particulate matter air pollution, both sexes, all ages, China, 2010

Figure 19: DALYs attributable to tobacco smoking and second-hand smoke, both sexes, all ages, United Kingdom, 2010

Note: The proportion of each cause attributable to the risk factor is shaded dark.

The figure indicates how reducing exposure to air pollution could prevent substantial amounts of premature death and disability from ischemic heart disease and stroke, as indicated by the portion of these causes that are shaded in dark blue. Lower levels of air pollution could also reduce DALYs from lung cancer and COPD.

Figure 19 shows how, in the UK, many DALYs could be averted by eliminating tobacco smoking, including second-hand smoke.

Most COPD and lung cancer is caused by tobacco smoking and second-hand smoke, as indicated by the dark blue portion of the boxes representing these causes. Substantial numbers of healthy years lost from ischemic heart disease, stroke, and esophageal cancer could also be prevented by reducing exposure to these risk factors.

Figure 20 shows the number of DALYs attributable to suboptimal breastfeeding in children from one month to 1 year old in Zambia.
Figure 20: DALYs attributable to suboptimal breastfeeding, both sexes, ages 1-11 months, Zambia, 2010

This figure can be used to understand the number of years of healthy life that could potentially be gained by ensuring that all Zambian children in this age group are adequately breastfed. Adequate breastfeeding is defined as exclusive breastfeeding of children for the first six months of life, and continued breastfeeding after the child reaches six months of age until age 2. Half of the DALYs attributable to diarrhea could potentially be prevented in this age group, as indicated by the dark shading in the boxes representing this cause. Adequate breastfeeding would also greatly reduce illness from lower respiratory infections among these children.

Note: The proportion of each cause attributable to the risk factor is shaded dark.

TREMENDOUS PROGRESS IN SUB-SAHARAN AFRICA, BUT MAJOR CHALLENGES REMAIN FOR MDGs 4, 5, AND 6

The rapid transition away from communicable, maternal, newborn, and nutritional conditions toward non-communicable diseases at the global level has not been universal. Communicable diseases that primarily affect children and young adults remain top causes of premature death and disability, or DALYs, in sub-Saharan Africa, as shown in Figure 21.

Figure 21: Causes of DALYs, both sexes, all ages, sub-Saharan Africa, 2010

In 2010, in sub-Saharan Africa nearly 20% of DALYs were caused by diarrhea, lower respiratory infections, meningitis, and other common infectious diseases. Neglected tropical diseases and malaria accounted for nearly 15% of total DALYs. HIV/AIDS,
tuberculosis, newborn disorders, and nutritional deficiencies are also responsible for a large portion of the premature death and disability in this region.

As 2015 is fast approaching, the Millennium Development Goals (MDGs) remain highly relevant for sub-Saharan Africa. MDGs 4, 5, and 6 accounted for 60% to 70% of DALYs in this area of the world in 2010, as shown in Figure 22. MDG 4 is intended to reduce by two-thirds, between 1990 and 2015, the under-5 mortality rate, while MDG 5 aims to reduce by three-quarters the maternal mortality ratio. The purpose of MDG 6 is to halt and begin reversing the spread of HIV/AIDS in that same period. In other regions, MDGs 4, 5, and 6 accounted for less than 40% of DALYs and, in some, the percentage was less than 20%.

The considerable differences between sub-Saharan Africa and other regions of the world highlight how GBD 2010 findings could be used to guide the establishment of region- and country-specific goals in the post-2015 era.

Figure 22: Percent DALYs related to Millennium Development Goals 4, 5, and 6 as a proportion, by region, 1990 and 2010

Despite the fact that disease patterns in sub-Saharan Africa have changed less than in other parts of the world over the past 20 years, most African countries have made impressive progress in reducing mortality rates for children under the age of 5. Figure 23 shows the annualized rate of decline in under-5 mortality in sub-Saharan African countries between 1990 and 2000 compared to 2000 to 2010. All countries that appear on the right side of the diagonal line had accelerated declines in child mortality rates between 2000 and 2010. Countries such as Botswana, Rwanda, Senegal, Sierra Leone, and Uganda made the most rapid progress out of all the sub-Saharan African countries. Other countries including Angola, Eritrea, Kenya, Republic of the Congo, and Swaziland also made substantial strides in this area. In contrast to the majority of countries in sub-Saharan Africa, multiple countries in western sub-Saharan Africa had higher rates of decline in under-5 mortality between 1990 and 2000 compared to 2000 and 2010, such as Burkina Faso, Côte d’Ivoire, Liberia, and Togo. Unlike other countries in the “HIV corridor” that extends from Kenya to South Africa, rates of under-5 mortality in Lesotho and Zimbabwe increased in the later period compared to the earlier period.

Figure 23: Annualized rate of decline in under-5 mortality, 1990-2000 compared to 2000-2010

While HIV/AIDS has exacted a devastating toll on many countries in sub-Saharan Africa, increasing by 328% in terms of healthy years lost from 1990 to 2010, the epidemic appears to have peaked in 2004. The number of years lost to premature death and disability declined by 22% between 2005 and 2010. This success is largely attributable to the massive scale-up in antiretroviral therapy over the past decade. Another encouraging area of progress is the reduction in the number of deaths from malaria in sub-Saharan Africa. Figure 24 shows how malaria deaths in children under 5 in sub-Saharan Africa started to decline rapidly in 2005. That same year, the number of malaria deaths in the over-5 age group in this region also began a steep decline. Increased availability of insecticide-treated bed nets and artemisinin combination therapy contributed to these declines. These interventions have been financed primarily by the Global Fund to Fight AIDS, Tuberculosis and Malaria.
(GFATM) as well as the US President’s Malaria Initiative. GBD 2010 echoes findings of past IHME research studies in highlighting the life-saving role of development assistance in sub-Saharan Africa.

Reduction of maternal deaths in sub-Saharan African countries is yet another positive finding of GBD 2010. Between 2005 and 2010, maternal mortality declined by 11.4%. Delving deeper into trends at the country level, Rwanda stands out as a major success story. While other countries in sub-Saharan Africa have made progress in saving mother’s lives, Rwanda is the only country on track to achieve MDG 5. Between 1990 and 2010, Rwanda reduced maternal deaths by 61%, as seen in Figure 25.

**Figure 24: Trends in malaria deaths by age within Africa and outside Africa, 1980-2010**

Most countries in sub-Saharan Africa have made tremendous strides in reducing child mortality between 1990 and 2010. The success of the fight against malaria has contributed to this reduction in child deaths. Finally, while the devastating impact of HIV/AIDS appears to be declining, many challenges remain in combating this disease. GBD 2010 findings highlight the important role of continuing donor health funding in addressing MDGs 4, 5, and 6. Future updates of GBD will closely monitor developments in health in this and other regions.
The GBD approach affords countries a unique opportunity to explore their success in improving health outcomes over time. GBD can also be used to better understand how fast a country’s health is improving relative to similar countries. This type of progress assessment is called benchmarking. Benchmarking is a tool that can help countries put their health achievements in context and identify areas for improvement. IHME invites countries interested in collaborating on benchmarking exercises to contact us.

As an example of a benchmarking exercise, Figure 26 shows levels of premature mortality in the US ranked relative to countries with similar levels of health expenditure in 2010. The columns are arranged from left to right by the top 30 causes of premature death in the US. The countries are ordered according to levels of premature mortality, with the country having the highest levels of premature mortality at the bottom (the US) and the lowest levels at the top (Sweden). Levels of premature mortality are measured using age-standardized years of life lost. For each cause, rankings are coded to reflect each country’s level of premature mortality relative to the others. The best performers for each cause are in green while the worst performers for each cause appear in red. The US performed best in brain cancer (first) and colorectal cancer (third) in comparison to the 18 other countries, while it performed better than average for prostate cancer (fifth), stroke (fifth), falls (seventh), and breast cancer (eighth). Relative to the other countries shown in Figure 26, the US was the worst (nineteenth) performer for conditions including COPD, diabetes, interpersonal violence, preterm birth complications, chronic kidney disease, cardiomyopathy, hypertensive heart disease, poisonings, and kidney cancers.

To further illustrate how benchmarking can be implemented at the country level, IHME is currently working with public health experts in the UK to explore changes in population health over time and to compare its health performance to other countries with similar and higher levels of health spending. Through close collaboration with decision-makers at the National Health Service and Public Health England, the IHME-UK benchmarking project is examining the context in which health progress has occurred, such as the UK’s provision of universal health coverage and its implementation of numerous public health interventions.

For the UK, GBD estimates of life expectancy and healthy life expectancy (HALE), years lost due to premature death (YLLs), years lived with disability (YLDs), and healthy years lost (DALYs) will provide a detailed and comprehensive picture of changes in health outcomes over time. Comparing GBD estimates across countries will elucidate areas of health where the UK performs both better and worse than its peers. In addition, analysis of potentially modifiable risk factors can shed light on ways that public health policy could address major causes of ill health and premature death. The IHME-UK benchmarking study aims to identify key opportunities to speed up the pace of health improvements in the nation.
The Global Burden of Disease provides detailed data on diseases, injuries, and risk factors that are essential inputs for evidence-based policymaking. This collaborative project shows that the world’s health is undergoing rapid change.

GBD 2010 identified major trends in global health that can be summarized by the three Ds: demographics, disease, and disability. As most countries have made great strides in reducing child mortality, people are living longer and the population is growing older. These demographic changes are driving up premature deaths and disability, or DALYs, from non-communicable diseases. Health problems are increasingly defined not by what kills us, but what ails us. In 1990, childhood underweight was the leading risk factor for ill health, but high body mass surpassed it in 2010 as a more important cause of premature death and disability. This finding illustrates global shifts away from risk factors for communicable disease in children toward risk factors for non-communicable diseases.

GBD 2010 found that non-communicable diseases and disability caused a greater share of health loss in 2010 compared to 1990 in most regions of the world. At the same time, the study revealed that the leading causes of DALYs in sub-Saharan Africa have changed little over the past 20 years. Still, GBD 2010 provides evidence of encouraging progress in this region, such as reductions in mortality from malaria, HIV/AIDS, and maternal conditions.

While GBD 2010 provides key information about health trends at global and regional levels, its tools also allow users to view data specific to 187 countries. Similar to the ways in which governments use financial data to monitor economic trends and make necessary adjustments to ensure continued growth, decision-makers can use GBD data to inform health policy. Continual updates of GBD will incorporate the most recent data on disease patterns as well as the latest science about the effects of different risk factors on health.

Future updates of GBD will be enriched by widening the network of collaborators. Expanded collaboration between researchers, staff of ministries of health, and IHME on national and subnational burden-of-disease studies will ensure that GBD tools are used to understand causes of premature death and disability at the community level. Despite similarities of epidemiological trends in most regions, GBD illustrates the unique patterns of diseases, injuries, and risk factors that exist in different countries. Local epidemiological assessment is crucial for informing local priorities. The GBD approach to health measurement can help guide the design of public health interventions to ensure they are tailored to countries’ specific needs.

IHME is seeking partners interested in conducting in-depth studies of the burden of disease in countries. Through such partnerships, IHME is helping governments and donors gain insights into localized health trends to inform planning and policymaking. IHME is committed to building capacity for GBD analysis in countries around the world, and will be conducting a variety of training workshops. Information on these trainings can be found at http://www.healthmetricsandevaluation.org/gbd/training

GBD data visualization tools can display regional and national data from burden-of-disease studies. These user-friendly tools are helpful for planning, presentations, and educational purposes. Also, IHME has designed a variety of data visualization tools to compare trends between various raw data sources at the national level. By visualizing all available data, ministry of health officials and researchers can quickly identify unexpected trends in the data that they may wish to flag for further investigation.

Currently, IHME is working to expand GBD to track expenditure for particular diseases and injuries. Also, IHME is estimating utilization of outpatient and inpatient facilities and other health services for specific diseases and injuries. Side-to-side comparisons of these estimates to the number of DALYs from myriad causes will allow decision-makers to evaluate health system priorities. Data on disease-specific expenditure and disease burden are essential for policymakers facing difficult decisions about how to allocate limited resources.
## Lymphatic filariasis

Malaria

Neglected tropical diseases and malaria

Tetanus

Whooping cough

Encephalitis

H influenzae type B meningitis

Upper respiratory infections

Other lower respiratory infections

HIV disease resulting in mycobacterial infection

44,970 (38,833–51,176)

43,895 (38,426–48,914)

514 (0–4,351)

20,472 (17,193–24,136)

21,315 (18,581–24,305)

81,547 (75,003–88,367)

9,563 (8,108–10,858)

8,372 (6,473–10,401)

6,611 (5,661–7,851)

-80·2

-34·7

-43·6

-57·6

-54·5

32·2

1,958 (1,623–2,333)

1,155 (1,046–1,341)

1,497 (1,363–1,706)

828 (725–923)

313 (256–376)

175 (24–323)

32 (19–53)

11 (6–18)

1,672 (1,485–1,843)

4,107 (3,691–4,608)

1,200 (921–1,594)

391 (344–433)

279 (245–311)

717 (581–814)

48 (25–91)

27 (15–46)

32 (25–41)

70 (55–86)

-78·8

-15·3

-54·3

-65·1

-60·9

-65·0

-59·9

-9·9

-8·0

-12·9

-33·6

-17·9

-54·8

-6·7

-4·4

-60·9

-65·0

-59·9

-9·9

-8·0

-12·9

-33·6

-17·9

-54·8

-6·7

-4·4

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<th>% change</th>
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| | *Note:* The perinatal deaths for the 2000 data include all deaths of children under 1 month of age.