Measuring global health: motivation and evolution of the Global Burden of Disease Study

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Background

People everywhere, but particularly those charged with improving the health of populations, want to know whether human beings are living longer and getting healthier. There is an inherent fascination with quantification of levels and patterns of disease, the emergence of new threats to health, and the comparative importance of various risk factors for the health of populations. Before the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) was initiated, no comprehensive assessments of human health were done. The studies that were available[1] examined single causes and tended to err toward overestimation. As a result, the sum of such estimates of lives lost considerably exceeded even the upper limits of the number of deaths worldwide. The World Bank's *World Development Report 1993*, which was focused on health in the developing world, required a comparative, comprehensive, and detailed study of health loss worldwide to provide the basis for objective assessments about the probable benefits of applying packages of interventions. The GBD Study was initiated to fill some of these gaps at the time.

Work on GBD began in 1991, with the first preliminary results (for base year 1990) published in the *World Development Report 1993*. The ensuing vigorous scientific and philosophical debate[2,3] about the construction of disability-adjusted life-years (DALYs), methods, assumptions, and data sources led to the first complete revision of the GBD 1990 study, which was published in a series of four articles in *The Lancet* in 1997.[4–7] Further scientific detail was simultaneously or subsequently published in supporting books and articles.[8,9] Since that first effort, five cycles of GBD estimates have been published in different forms as a series of updates for the years 1999–2004,[10,11] 2010,[12] 2013,[13] 2015,[14] and 2016.[15] More than 16 000 peer-reviewed publications and reports have been generated from this work, and references to the GBD Study having been cited more than 700 000 times according to Google Scholar.

Governments and the development community have used the GBD data in diverse ways. For example, Public Health England explicitly states that their strategy is based on GBD findings,[16] GBD findings have been used at the highest levels of government in China, and GBD data have been used to inform prioritisation of specific policy interventions in Rwanda[17] and Botswana.[18] Based on searches of government documents available online, 156 country governments reference the GBD Study. Local use appears to be steadily growing, with more countries embarking on subnational assessments with each GBD cycle. Subnational assessments in GBD 2015 included the USA, China, UK, Brazil, Mexico, Japan, Kenya, South Africa, and Saudi Arabia, with additional subnational assessments for India and Indonesia added for GBD 2016. Global organisations such as WHO,[19] the World Bank,[20] and the Bill & Melinda Gates Foundation,[21] use GBD results extensively.

Over the years, in response to vigorous scientific critique,[22] philosophical debate,[23] and innovation from authors involved in the study, the GBD Study has continued to grow in scope, relevance, participation, and scale, to the point that it is now arguably the de facto source for global health accounting. In this Viewpoint, we trace the evolution of ten key dimensions of the GBD Study, which, in our view as the two founders of the GBD, have had an important role in increasing the utility, relevance, and integration of the GBD findings in national and global health policy debates, and highlight what we see as some of the principal challenges for the future.

What is the GBD Study?

The GBD Study is best described as a systematic scientific effort to quantify the comparative magnitude of health loss from diseases, injuries, and risks by age, sex, and population over time. The goal of the study is to provide decision makers at the local, regional, national, and global level with the best and most up-to-date evidence on trends in, and drivers of, population health so that decisions are ultimately more evidence-based. The GBD Study in its current form covers 195 countries and territories, with subnational assessments for 12 countries, calculated for each year since 1990. It is deliberately comprehensive: 333 diseases and injuries, 2982 sequelae of these diseases and injuries, and 84 risks or combinations of risks are included. Since 2015, the GBD Study has been updated annually, with results released each September.

GBD is predicated on the belief that decision makers need timely, local, and valid estimates of every quantity of interest, whether or not recent data are available for a disease, injury, or risk in a particular population. Too often, no estimate of a problem is interpreted as an estimate of no problem. There is a risk that policy debates could focus on well documented or popular health issues to the exclusion of poorly documented or ignored challenges that could turn out to be of greater relevance to improvement of a population's health. Our goal is to produce the best possible estimate of each quantity of interest and to make highly transparent the data and assumptions used to build that estimate. To increase the usefulness and uptake of the information in policy circles, we also communicate to the user the strength of the evidence by reporting 95% uncertainty intervals for each

quantity of interest. Although the GBD Study is extensive, it is focused on measuring health and its determinants and does not encompass measurements of other critical dimensions of welfare outside this scope.

Ten key evolutions

1: From a small group of analysts to a global collaboration

The first GBD analysis was done by a very small group of analysts, who worked under our direction and used what would now be thought of as rudimentary methods (eg, many of the calculations were done in spreadsheets). Since GBD 2010, a growing global collaboration has been working together to generate the estimates. 2518 collaborators from 133 countries and three territories, half of whom are from low-income or middle-income countries, are involved in GBD 2016. This growth is more than an increase in the number of people involved: it represents a major change in mindset. From essentially a small academic effort, the GBD Study has evolved to be a collaboration that is co-owned by a highly diverse group of contributors from around the world who represent different clinical areas, statistical traditions, and policy interests. This shift has necessitated the development of governance mechanisms—most notably the GBD Scientific Council, which was established in 2013 to resolve scientific disputes from within the collaboration and decide on the adoption of new methods, diseases, or risks.

2: Ever-increasing granularity

With each cycle of the GBD Study, the granularity of the analysis has increased (table). GBD 1990 covered 9360 condition-age-sex-location-years, not including individual sequelae estimates. GBD 2016 includes 400·8 million condition-age-sex-location-years—nearly 43 000 times the detail of GBD 1990. In total, the GBD 2016 included more than 3·5 billion estimated quantities. We see this as an essential response to the demand for timely, local, detailed, and valid assessments for decision makers at diverse levels.

3: From plausible estimates to a full statistical theory of measurement

For GBD 1990, we produced point estimates for each quantity of interest that were internally consistent in our respect of inherent relationships between incidence, prevalence, and deaths. Critical debate on the formulation and estimation for GBD 2000 spurred a shift to more rigorous statistical estimation.[24] From GBD 2010 onwards, the entire GBD approach to estimation shifted to the use of statistical models tailored to the available types of data. This change is more than a statistical advance. Disease burden estimates are widely used to guide health policy debates, and it is important that policy decisions that might eventuate from this application are appropriately informed by an understanding of how certain those estimates are. The shift to statistical estimation substantially reduces, but does not eliminate, subjective choices in the process of estimation. Dedicated analytic models have been developed for the GBD Study, most notably the Cause of Death Ensemble model[25] to estimate causes of death. DisMod-MR[26] is a Bayesian statistical meta-regression environment used to synthesise data on disease incidence, remission, prevalence, excess mortality, and cause-specific mortality. ST-GPR is a version of Gaussian Process Regression that borrows strength over space and time in the estimation. These tools have become essential building blocks for the GBD Study's annual estimation cycle.

	1990	2000–04	2010	2013	2015	2016
Diseases and injuries	107	136	291	306	315	333
Risk factors	10	25	67	79	79	84
Sequelae	483	500+	1160	2337	2619	2982
Age groups	5	8	20	20	20	23
Sexes	2	2	2	2	2	2
Geographies	8	211	215	295	590	774
Years of estimation	1	1	21	24	26	27

Counts of diseases and injuries include aggregates at different levels of the cause hierarchy. For some GBD outcomes such as all-cause mortality, the analysis spans a longer time period than shown. GBD=Global Burden of Diseases, Injuries, and Risk Factors Study.

Table: **The granularity of the GBD analysis in the six cycles to date of the GBD estimation.**

4: Philosophical and empirical underpinnings of DALYs

GBD 1990 introduced the DALY as a summary metric of premature mortality and functional health loss in a population due to death and disability. The original variant of DALYs included age-weighting and discounting. The incorporation of these social values into the DALY generated intense debate in the philosophy and economics literature.[2,3,27] The original disability weights were based on health expert panels. On the basis of the recommendations of a group of philosophers and ethicists, discounting and age-weighting were dropped from the DALY construct in GBD 2010.[12] This simplification has facilitated communication about DALYs and broadened the appeal of DALYs to a wider group of users. We have moved from estimation of DALYs based on disease and injury incidence to estimation based on prevalence—a shift that has allowed for incorporation of the effects of comorbidity into the calculations. As a result of debates about the values that should be used to estimate disability weights,[28] from GBD 2010, the weights have been based on measurement of the general public's view of health state weights.[29–31]

5: Increased transparency

The GBD 1990 analysis was published in two volumes,[8,9] but neither the primary data nor the spreadsheets used were made available. Public debate about strengthening

global health metrics led to the creation of the Guidelines for Accurate and Transparent Health Estimates Reporting (GATHER).[32,33] As of GBD 2015, all of our studies are GATHER compliant: we release documentation for each source, provide an online searchable catalogue of all sources used, and post the code for each step in the analysis. This general shift towards transparency is inexorable and an important step in the promotion of better, contestable science.

For the **code** see https://github.com/ihmeuw/ihme-ui

6: Improved communication of findings

For GBD 1990 and the GBD cycles from 1999 to 2004, very traditional figures and tables were used to communicate results. For GBD 2010, we introduced a series of online dynamic data visualisations to enhance exploration of the comprehensive detail in GBD results. GBD Compare supports ten views of the data, includes 24 billion results for GBD 2015, and facilitates a range of user-driven comparisons and benchmarking exercises. In addition to an emphasis on dynamic data visualisations, the GBD release each year has invested heavily in media outreach for the capstone papers and disease-specific and risk factor-specific papers.

For **GBD Compare** see https://vizhub.healthdata.org/gbd-compare/

7: Expanded scope of systematic analyses to support estimates

In the absence of reliable data in some locations, our estimates depend heavily on robust covariates for the various statistical models. For GBD 2016, we made use of 581 covariate time series from 1980 to 2016, which were based on GBD analyses of surveys, censuses, and other data sources. Key covariates include income per capita, educational attainment, vaccine coverage, and dietary indicators. In future iterations of the GBD Study, we plan to produce population estimates that are consistent with the mortality and fertility rates estimated in the study by using available census counts.

8: Increased contribution to global health and development priorities

We have been progressively trying to build benchmarking tools to facilitate interpretation and uptake of GBD results in national and global policy dialogue. We introduced for GBD 2015 the notion of the expected burden of disease, which is based on a population's level of development as measured by the Socio-demographic Index. By quantifying the expected value for each GBD outcome in every population, we can report the ratio of observed to expected outcomes for various quantities of interest. In GBD 2015, we also started reporting on the health-related Sustainable Development Goal indicators.[34] Most recently, we have used the death rates from 32 causes that are highly sensitive to health care to track personal health-care access and quality.[35] We plan to progressively expand the scope of these policy-driven analyses in future iterations of GBD to provide detailed global comparative assessments of health-system performance.

9: Increasingly formalised review processes

A 35-member GBD Scientific Council, including members from all regions, convenes condition-specific annual scientific reviews to critique proposed changes to the estimation procedures and to comment on preliminary results for leading diseases and risks. Additionally, an Independent Advisory Committee for GBD has been established. The committee is chaired by Professor Peter Piot and meets every 6 months to provide an overall review of the work of the GBD Study and strategic guidance on areas that can be strengthened. Formal peer-review of the principal methods and outputs by scientific journals such as *The Lancet* provides a final degree of scientific scrutiny of the methods and results.

10: From episodic to annual production

One of the biggest changes to the GBD Study over the past 25 years has been the shift from an episodic academic analysis on an essentially opportunistic timeline to an annual assessment of the state of the world's health. Annual estimation necessitates increased standardisation and more careful documentation of what drives changes in estimation, and encourages innovation in methods and data collection practices. The shift to annual assessments has also greatly increased the relevance of GBD as a tool for surveillance and monitoring of global or national health goals, rather than it being simply an academic undertaking. By having annual assessments, attention can be directed to the pace of change rather than differences in levels; for example, which countries are making the fastest progress reducing child mortality. In our view, annual assessments are also essential for creation of a culture of accountability in health.

Challenges ahead

The scientific debates that have accompanied each cycle of publication of the GBD Study have identified many outstanding scientific challenges. Datasets such as insurance claims or hospital admission statistics are being increasingly used in the GBD Study as methodological advances to correct for known biases in these sources are deployed. Nonetheless, huge data gaps remain. To identify the most important of these gaps, with each cycle of the GBD Study, we have put more emphasis on quantification of the availability and quality of data for each outcome, beginning with a quality assessment of cause of death data in GBD 2016. Careful quantification of data gaps will lead to the identification of important opportunities for new data collection by governments, donor organisations, foundations, and research funders.

One of the biggest remaining analytic challenges for the GBD Study is distinguishing between true spatial variation in an outcome and non-sampling error. Widely known methods are available to assess sampling error. However, even after taking sampling error into account, whether the remaining variation reflects real differences

in rates or non-sampling error—such as variation due to survey implementation, assay processing, or selection bias—is difficult to ascertain. When repeated measurements are taken, such as for child mortality, statistical methods can be used to clarify this issue, but for other quantities of interest, for which the data are more sparse, statistical solutions are less promising. This issue is likely to remain a serious scientific challenge for the GBD Study in the coming years.

For many outcomes, the available evidence can be interpreted by experts in different ways. The minimum risk level for sodium intake, for example, has sparked intense scientific debate. Other areas, including the health effects of risk factors such as diet, remain contentious.[36] We expect vigorous debate to continue about key aspects of the GBD Study. This contention is not unusual in scientific discourse and should be encouraged, because it can lead to a more intensive scientific effort to increase knowledge. Our goal in this endeavour is not to align with one group or another within the scientific community, but rather to reflect, in a reasoned and scientifically responsible way, the diversity of views supported by the evidence.

Often choices are made in the processing of data or in data analysis that are consequential but are not scrutinised. For example, by assuming that a disease is not present in a given location, or that *Haemophilus influenzae* type b only occurs in children younger than 2 years, we substantially affect results. Decisions about which risk–outcome pairs meet evidence criteria for inclusion also affect findings. These categorical choices create fulcrum points such that subsequent changes to such choices can alter estimates substantially. Uncertainty intervals using standard statistical methods do not usually reflect the uncertainty stemming from these upstream categorical choices. Future iterations of global health estimates should explore how such uncertainties can be propagated into the final results.

Data processing often requires considerable effort to understand what has been done to produce estimates. Opening all steps of data processing to vigorous debate should eventually yield benefits. In some areas, such as the estimation of child mortality, the GBD Study and the UN Inter-agency Group for Child Mortality Estimation have produced parallel estimates of under-5 mortality for several years, and the data universe and the models have converged. Yet the approaches used by both estimation groups to process summary birth history data, for example, remain fundamentally different. Data processing issues are often less interesting to professional statisticians, which could partly explain why this important topic has been little debated.

Conclusion

During the past 25 years, the scope, magnitude, and uses of the GBD Study have increased substantially. The study has continued to evolve in an attempt to provide a robust scientific framework for measurement of health worldwide. Despite evolution, the scope to improve the GBD Study, primarily through increased scientific collaboration and data sharing, is considerable. Progress will come from many directions: sharing data that have been collected but not analysed, strategic efforts to collect new data to fill critical gaps, improved methods for correction for bias in data processing, innovations in statistical modelling, and enhanced clarity on the meaning of different results in different locations. Importantly, the GBD Study has become an essential public good—a dynamic, collaborative scientific effort that routinely provides the essential information required to support decision makers everywhere to improve the health of populations.

Contributors

CJLM and ADL drafted and reviewed the manuscript and both accept full responsibility for its contents.

Declaration of interests

We declare no competing interests.

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