IHME

Measuring population health: 25 years of the Global Burden of Disease study

UNIVERSITY of WASHINGTON

Institute for Health Metrics and Evaluation

Outline

1) **What is the GBD?**
2) From GBD 1990 to GBD 2017
3) Key observations from the GBD
4) Future

What is the Global Burden of Disease Study?

- A ***systematic, scientific*** effort to quantify the ***comparative*** magnitude of ***health loss*** from all major diseases, injuries, and risk factors by age, sex, and population, and over time.
- *Fundamental premise*: Policy should be informed by **valid**, **reliable** and **timely** data; poor quality data → poor decisions → lost opportunities to improve population health

- *Key principles*:

  - comprehensiveness;

  - informed estimates better than no estimates;

  - comparability (across locations, time, diseases, injuries, risk factors, age and sex)

GBD: standardized solution to global health measurement challenges

Challenges:

1. Inconsistent coding and case definitions
2. No data
3. Conflicting data
4. Sampling and non-sampling measurement error
5. Excluded groups

GBD solutions:

1. Quality review of all sources and corrections for garbage coding
2. Cross-walking different case definitions, diagnostic technologies, recall periods, etc., using statistical methods
3. Statistical methods to deal with missing data, inconsistent data, excluded groups and measurement error

Multiple metrics for health to facilitate different types of uses

1) **Traditional metrics:** Disease and injury prevalence and incidence, death numbers and rates.
2) **Years of life lost** due to premature mortality (YLLs) – count the number of years lost at each age compared to a reference life expectancy of 86 at birth.
3) **Years lived with disability** (YLDs) for a cause in an age-sex group equals the prevalence of the condition times the disability weight for that condition.
4) **Disability-adjusted life years (DALYs)** are the sum of YLLs and YLDs and are an overall metric of the burden of disease.
5) **Healthy life expectancy (HALE)** is a positive summary measure counting the expected years of life in full health.

Scope of Global Burden of Disease today

- Today covers 195 countries and territories from 1990 to present. Sub-national assessments for some countries including Brazil, China, Ethiopia, India, Indonesia, Iran, Japan, Kenya, Mexico, New Zealand, Norway, Russia, South Africa, Sweden, UK, and US
- 359 diseases and injuries, 3,228 clinical sequelae, 84 risk factors or clusters of risk factors.
- Time series from 1990 to most recent year updated annually
- Findings published in major medical journals, policy reports, and online data visualizations.


THE LANCET
Volume 388 · Number 10053 · Pages 1447-1850 · October 8-14, 2016
www.thelancet.com
The Global Burden of Disease Study 2015
£5.00 Registered as a newspaper · ISSN 0140-6736
Founded 1823 · Published weekly


THE LANCET
Volume 390 · Number 10100 · Pages 1083-1464 · September 16-22, 2017
www.thelancet.com
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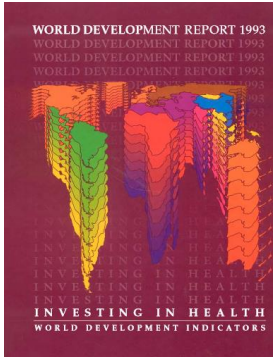
1) **What is the GBD?**
2) **From GBD 1990 to GBD 2017**
3) State of global health: results from GBD 2017
4) GBD extensions

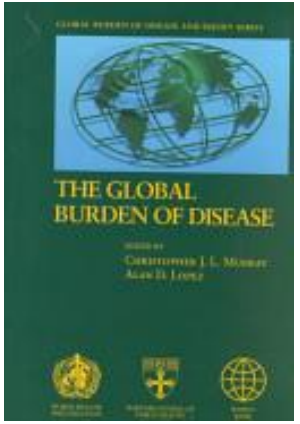
Origins in late 1980s; what did we know about world health and major causes of health loss?

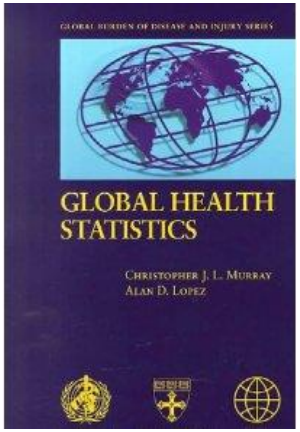
- At the time, no coherent, comparable set of figures were available on the relative contribution of diseases, injuries and risk factors to population health (anywhere).
- Summation of claims by different international disease control programs about the number of deaths due to different causes exceeded the total number of deaths by *several fold.*
- Comparable information on non-fatal health outcomes across populations was not available.

First GBD study

- Originated by the World Bank and WHO in 1991 to address these critical information gaps and provide analytical basis for cost-effective intervention strategies.
- Preliminary results published in WDR 1993.
- Final results published in 2 GBD volumes in 1996 and a quartet of papers in *The Lancet* in 1997
- 8 regions; 107 diseases; 10 risk factors
- Estimates for 1990 and projections to 2020







Defining the GBD: then and now

- 1990: ambitious, under-resourced, ad hoc effort to quantify health loss worldwide to better inform health policy debates
- 2017: massive growth in scope, relevance, participation and scale; arguably the *de facto* source for global health accounting.
- How has this come about? 8 key evolutions of the GBD Study, 1990-2017

1. Producing results for units where decisions are made

With each cycle of the GBD Study, the degree of analytical detail has expanded, sometimes considerably:

- **GBD 1990;** 9,360 condition–age–sex–location–years, not including individual sequelae estimates
- **GBD 2016;** 400·8 million condition–age–sex–location–years; 43,000 times the detail of GBD 1990!

	1990	2000–2004	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.

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

2. Shifting from a Statist model to a collaborative scientific model of measurement (I)

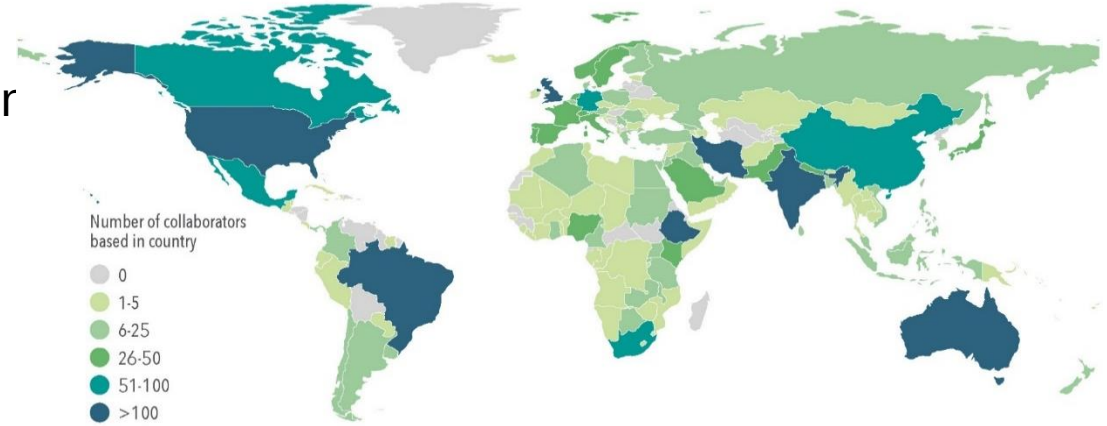
- Statistics emerged from States. The Statist model of measurement where only legal authorities generated measurements dominated global measurement from the 19th century to 1950.
- The IMF and the World Bank began developing country estimates to support national policy dialogue. These inter-governmental organization estimates were an alternative to figures reported by States.
- The UN Population Division in the 1960s received a mandate to generate population estimates on their own without consultation with Member States that often differ from national assessments, this has continued until today.
- The WHO in the 1990s began generating for selected topics their own country-specific estimates that differed from Member States statistics: maternal mortality, TB, HIV, leprosy were the first.

2. Shifting from a Statist model to a collaborative scientific model of measurement (II)

- Academic studies in the last 25 years have started producing country specific measurements not grounded in the legal authority of states but on the principles of good science subject to peer-review.
- The GBD has been a leader in this shift to the scientific model of measurement.
- The development of the GBD collaboration with widespread global participation has taken the scientific model of measurement a further step to the collaborative scientific model.
- Authority and legitimacy is grounded both in the rigor of the science and the broad participation of scientists from nearly all countries.

State of the collaboration

- *GBD2017*: worldwide collaboratior with rich diversity of academic skills, statistical traditions and policy interests
- Elaborate governance and oversight mechanisms developed (GBD Scientific Council, Independent Advisory Committee on the GBD)



3,641 collaborators
143 countries
2 territories

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

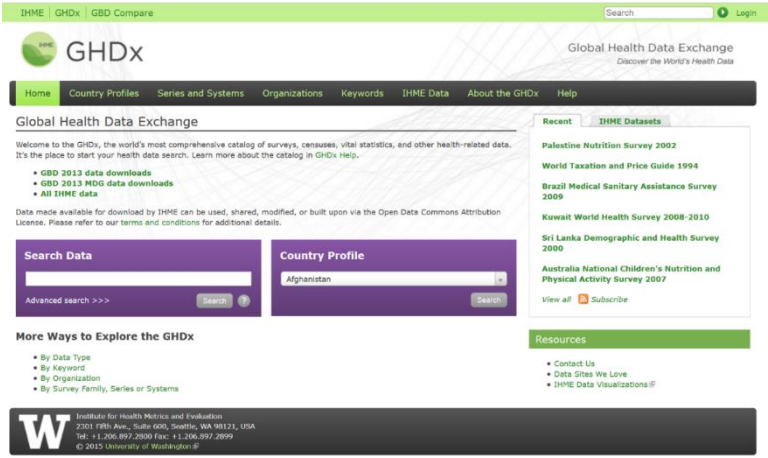
- *GBD 1990*; point estimates for each quantity of interest that preserved epidemiological consistency between incidence, prevalence, and mortality; based on DisMod I and anchored on the parameter value we trusted most. Strongly judgemental (M&L).
- *GBD 2010 onwards*; switched to Bayesian statistical models, tailored to the available types of data
  - Dedicated analytic models developed for the GBD Study:
    - Cause of Death Ensemble model (CODEm)
    - DisMod-MR2.1 – meta-regression tool estimating incidence, prevalence, remission, excess mortality, cause-specific mortality by age simultaneously
    - Spatio-temporal Gaussian Process Regression
    - ***Uncertainty intervals*** calculated around every quantity of interest in the GBD Study

4. Increased transparency

- GBD 1990 analysis published in two volumes (1000p +); neither the primary data nor the spreadsheets used were made available (for various reasons);limited methodological detail published

- Subsequently, public debate about strengthening global health metrics led to the creation of the *Guidelines for Accurate and Transparent Health Estimates Reporting* (GATHER)

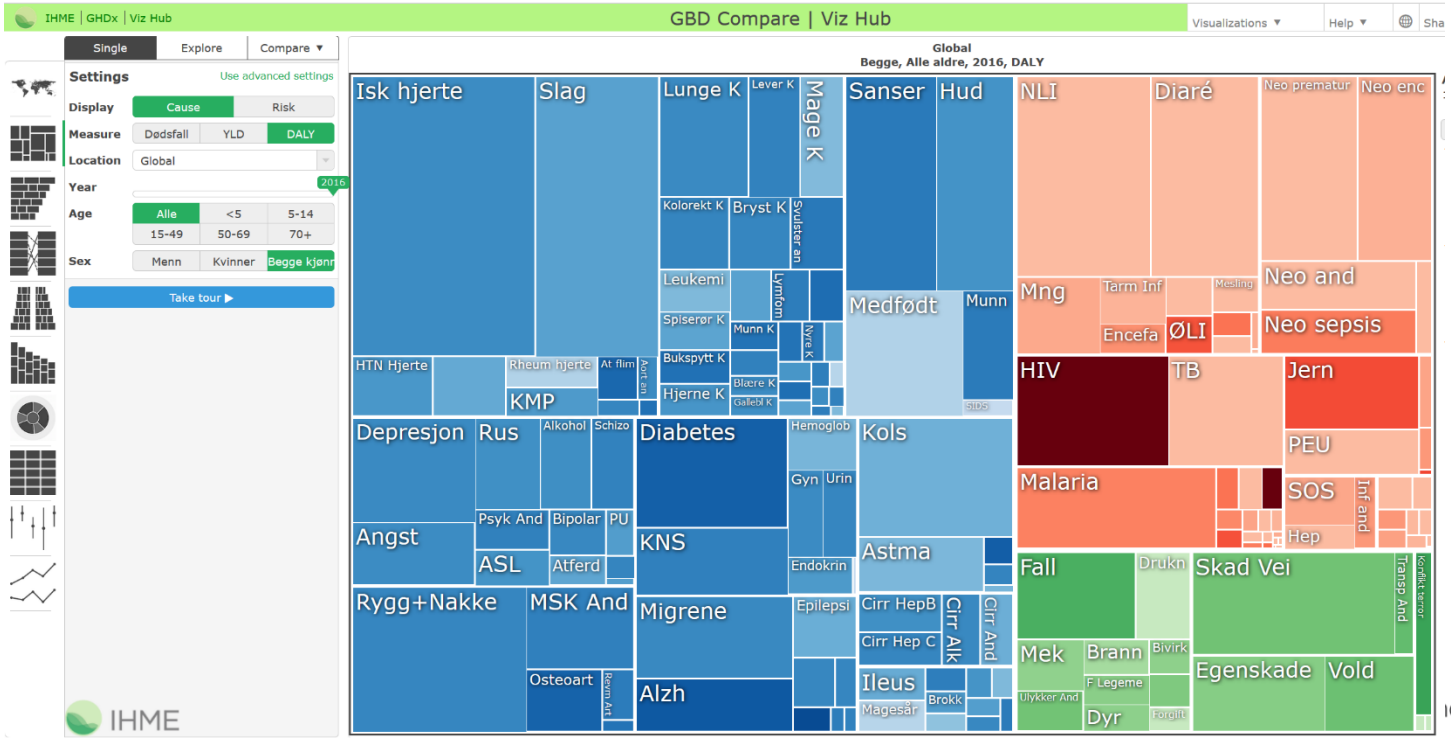
- As of GBD 2015, all GBD studies are GATHER compliant: we release documentation for each source, provide an online searchable catalogue of the more than 100,000 sources used, and post the code for each step in the analysis



5. New ways to share information: GBD Compare

www.healthdata.org

Chinese, English, French, Italian, Japanese, Norwegian, Portuguese, Russian, Spanish, Swedish



6. Expanded scope

- **Benchmarking** by development status: Socio-demographic Index and analysis of the epidemiological transition
- **Monitoring** the health-related Sustainable Development Goals
- **Insights on health systems**: Measuring Universal Health Coverage; Monitoring key interventions including vaccine coverage; Healthcare Access and Quality Index; Human resource for health monitoring
- **Health and development**: Measuring Human Capital Index.

Articles

Healthcare Access and Quality Index based on mortality from causes amenable to personal health care in 195 countries and territories, 1990–2015: a novel analysis from the Global Burden of Disease Study 2015

Articles

Measuring human capital: a systematic analysis of 195 countries and territories, 1990–2016

7. From episodic efforts to annual assessments

Beginning with GBD2015, key shift in purpose from an *episodic academic analysis* to an *annual assessment of the state of the world's health.*

- necessitates increased standardisation and more careful documentation of what drives changes in estimation
- encourages innovation in methods and data collection practices
- greatly increases the relevance of the GBD as a tool for surveillance and monitoring of global or national health goals, rather than its being simply a massive academic exercise in global descriptive epidemiology
- focuses policy attention on the ***pace of change*** rather than on differences in levels; e.g., which countries are making the fastest progress in reducing child mortality? (arguably of greater policy relevance than levels)h

8. Closer collaboration with WHO

May 22, 2018: WHO and IHME formally agree to collaborate in improving the accuracy, timeliness, and policy-relevance of health data. The MOU signed will result in increased awareness and understanding of health problems globally, as well as the evaluation of strategies to address them.

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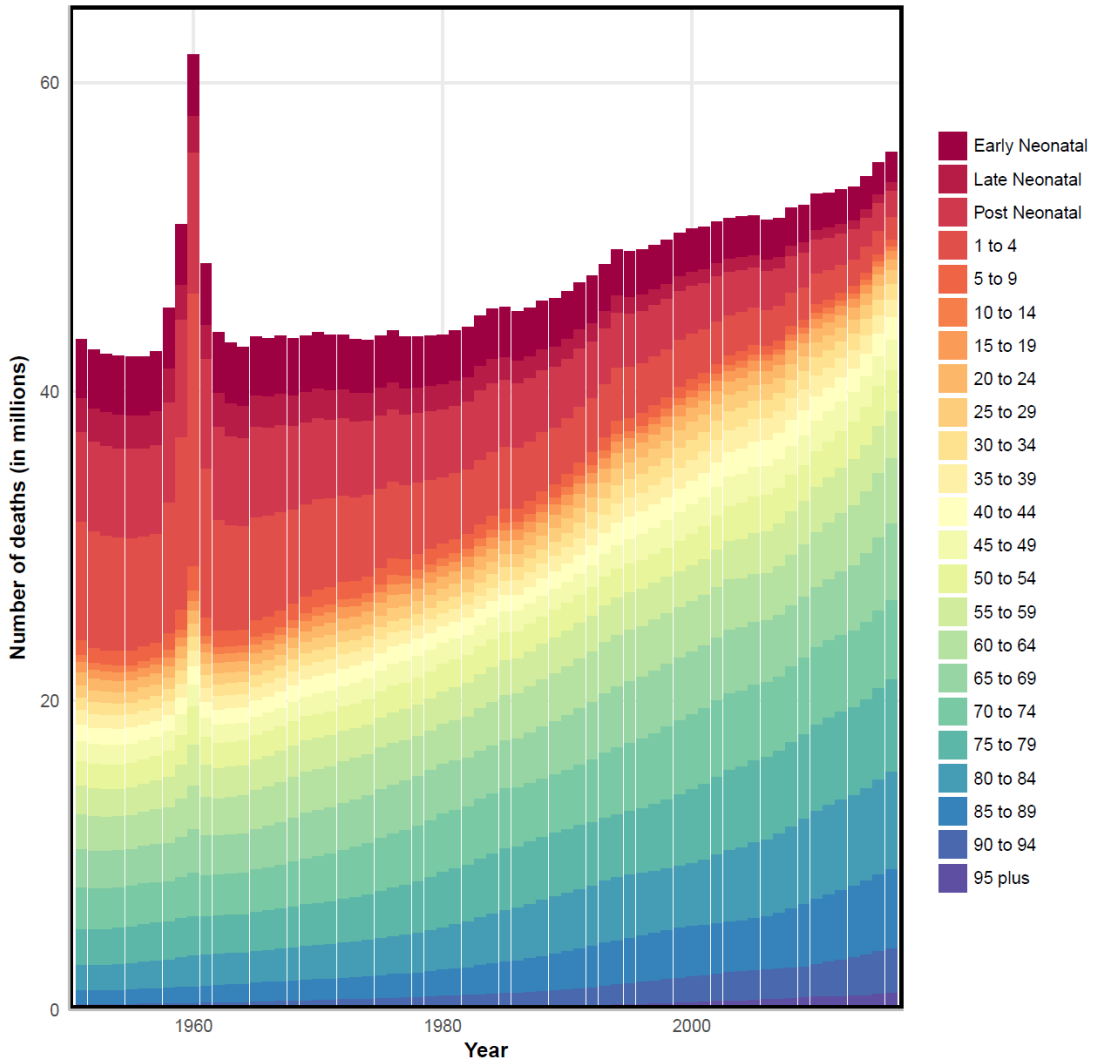
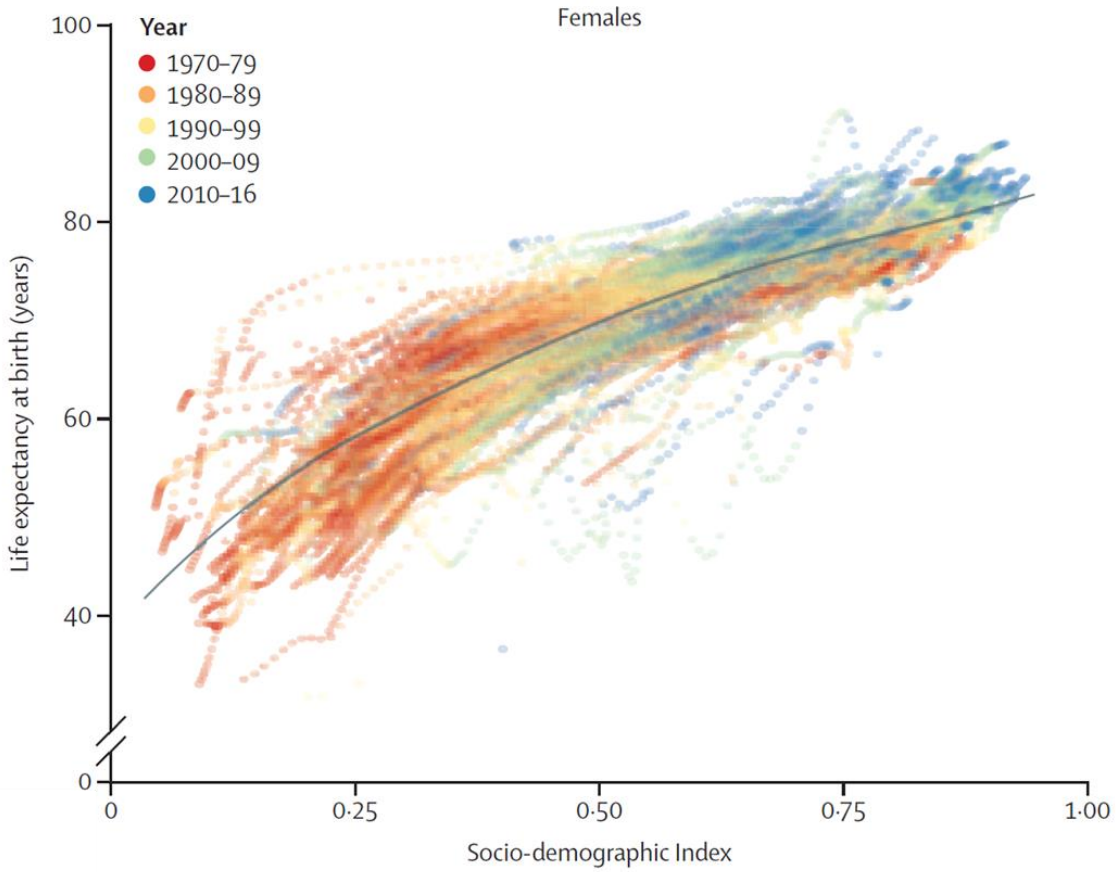
1. Transition from mortality dominantly in the first 5 years of life to mortality over 65



2. Level of development explains a large share of variation across place and time in life expectancy and other health outcomes. But there is also 10 years of variation across locations in life expectancy at each level of development.

SDI is a measure of development status based on GDP per capita, average years of schooling and the TFR

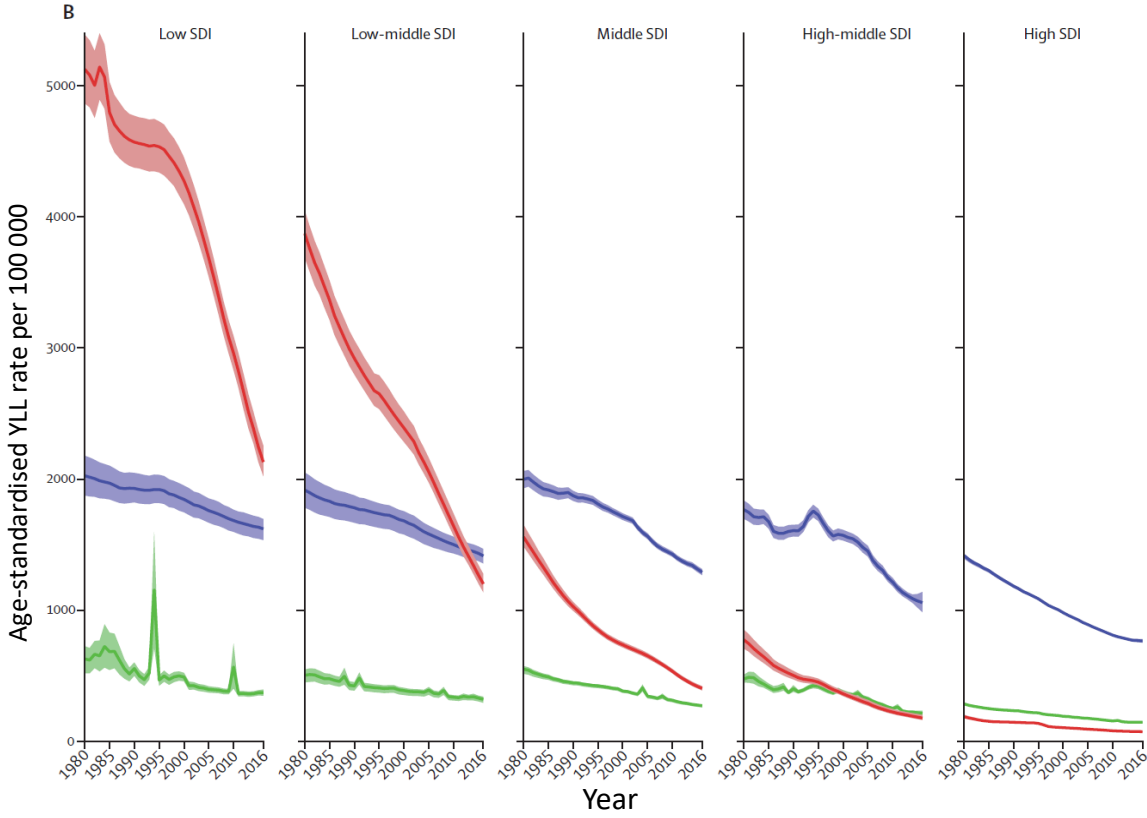
Life expectancy at birth, by sex, and fit of expected value



3. Epidemiological transition leading to reductions in age-standardized death rates from most causes

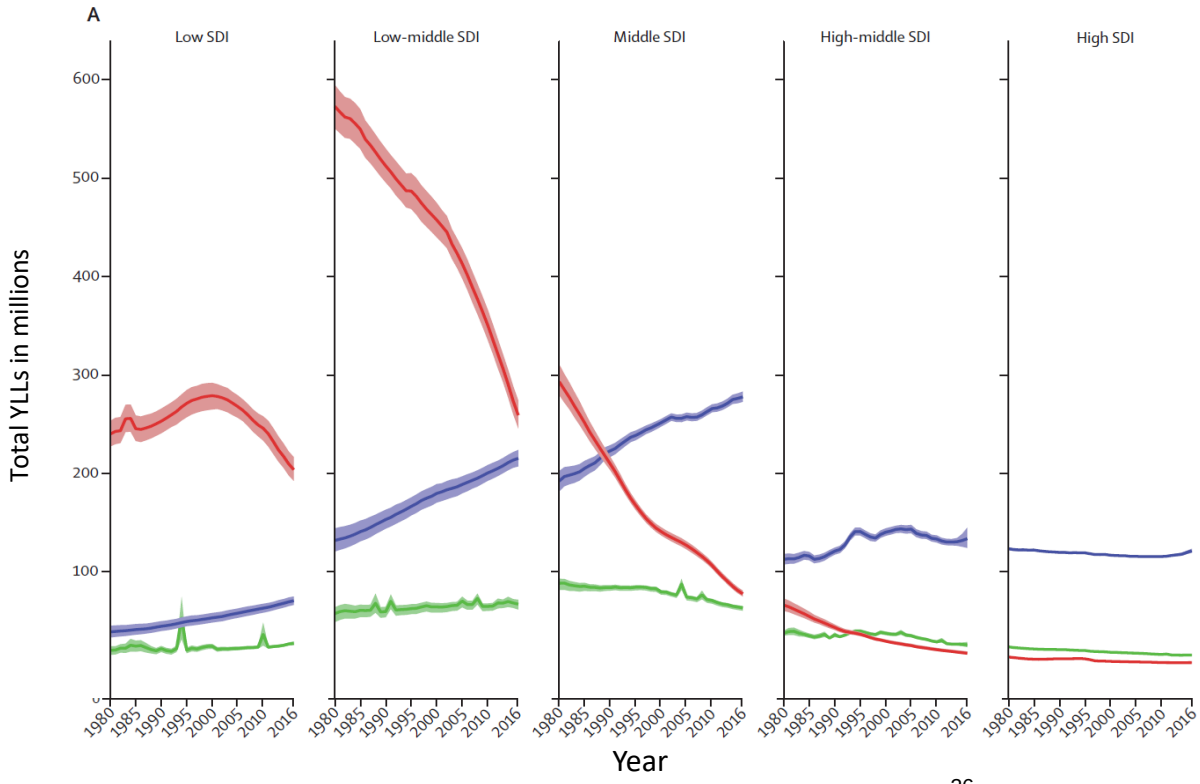
Rates of decline for communicable, maternal, neonatal and nutritional causes are faster than NCDs and injuries

Trends of age-standardised YLL rates from 1980 to 2016, by GBD Level 1 cause, by SDI quintile



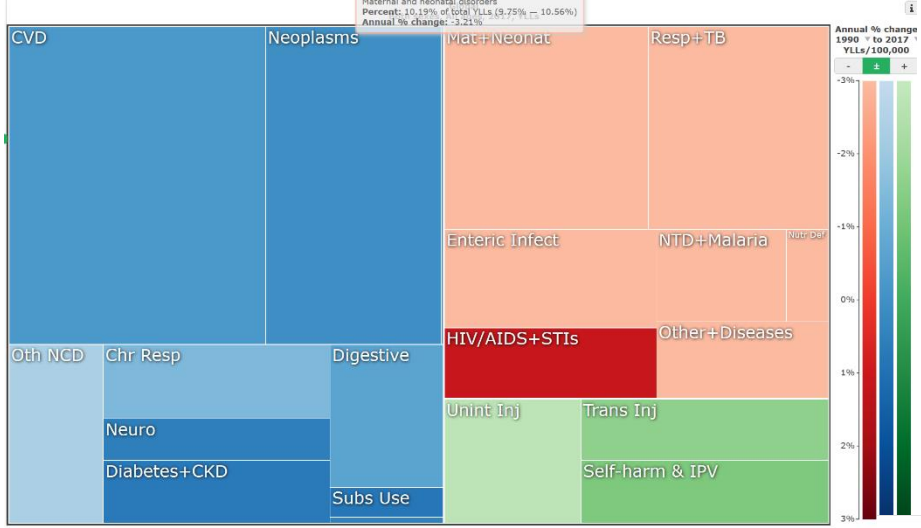
4. Population growth and rising mean age of populations creates the large increase in NCD burden

Trends of total YLLs from 1980 to 2016, by GBD Level 1 cause, by SDI quintile



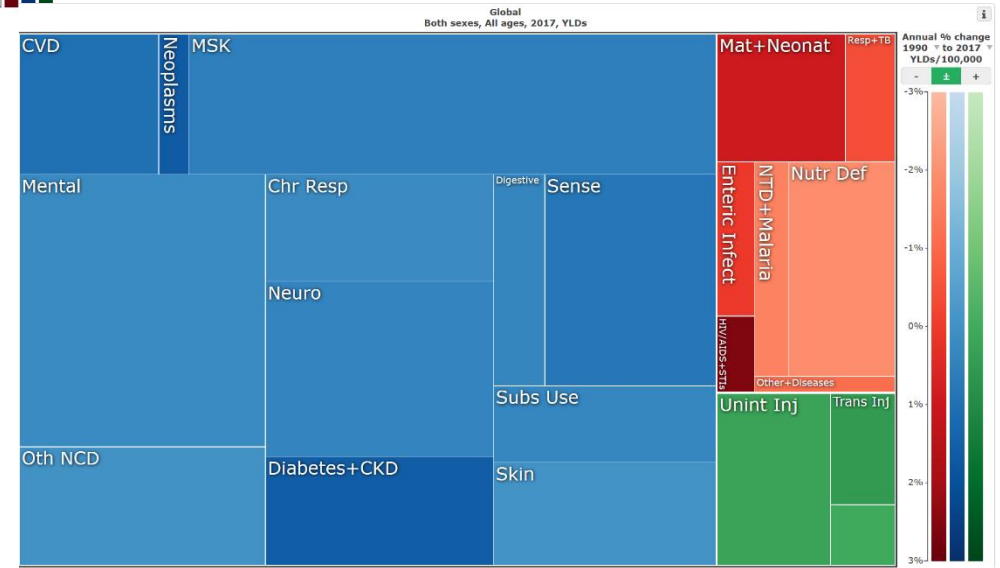
5. What ails you is not what kills you.

Major causes of years lived with disability including mental health, musculoskeletal disorders, vision/hearing loss, neurological substance abuse



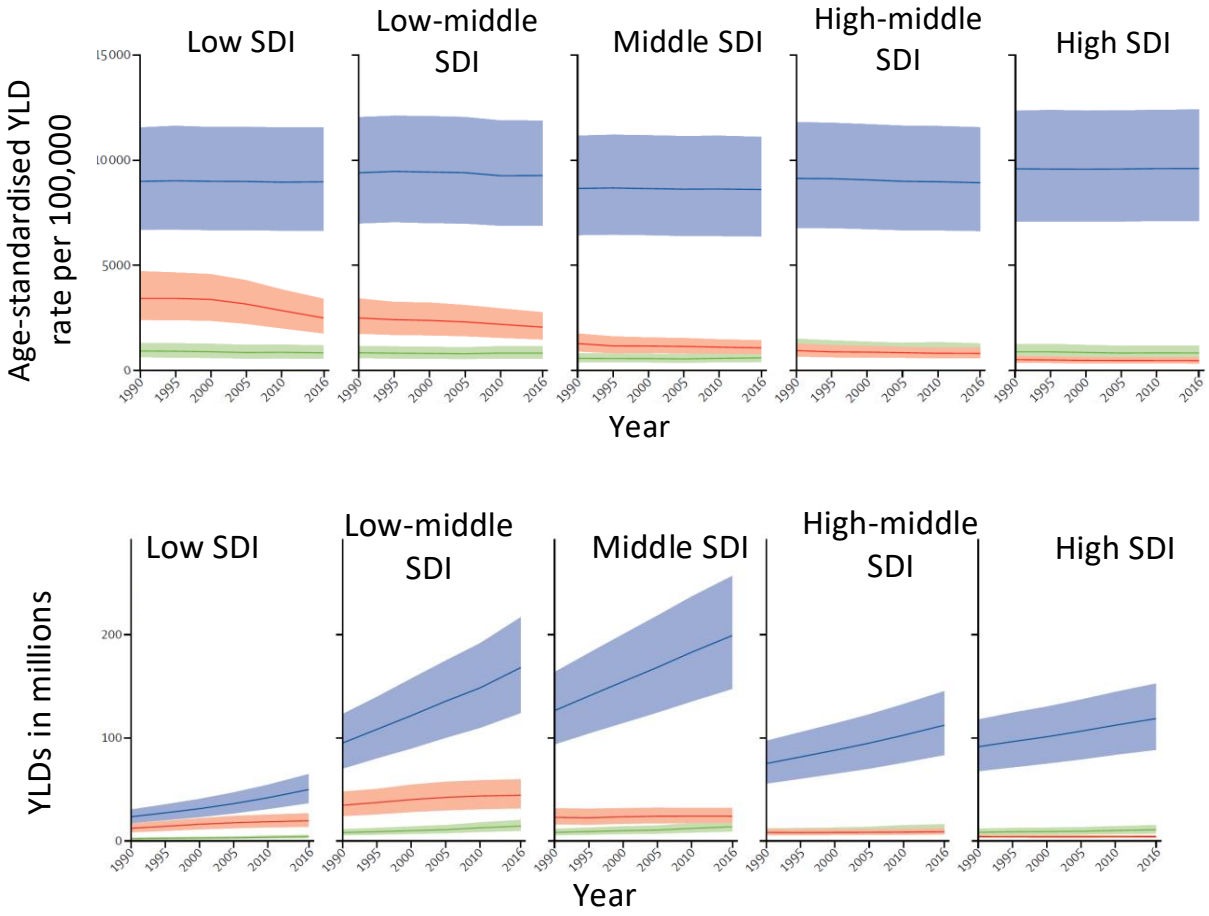
YLLs

YLDs



6. Shift from burden of disease profile dominated by YLLs to YLDs

YLL rates for nearly all causes declining but YLD age-standardized rates for major causes of burden are not.



6. Risk transition with development.

Overweight and obesity stands out as a major risk factor that is increasing with development

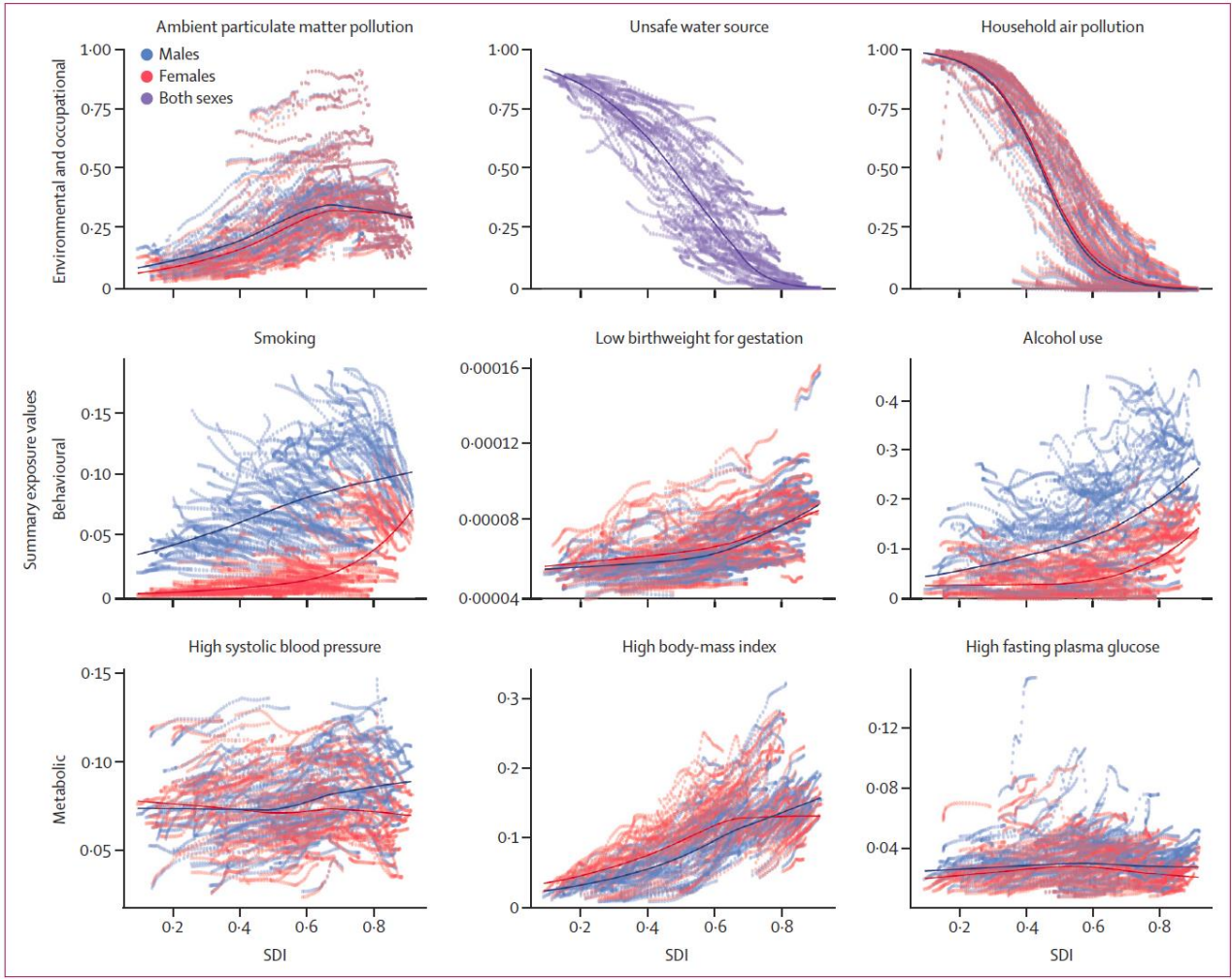
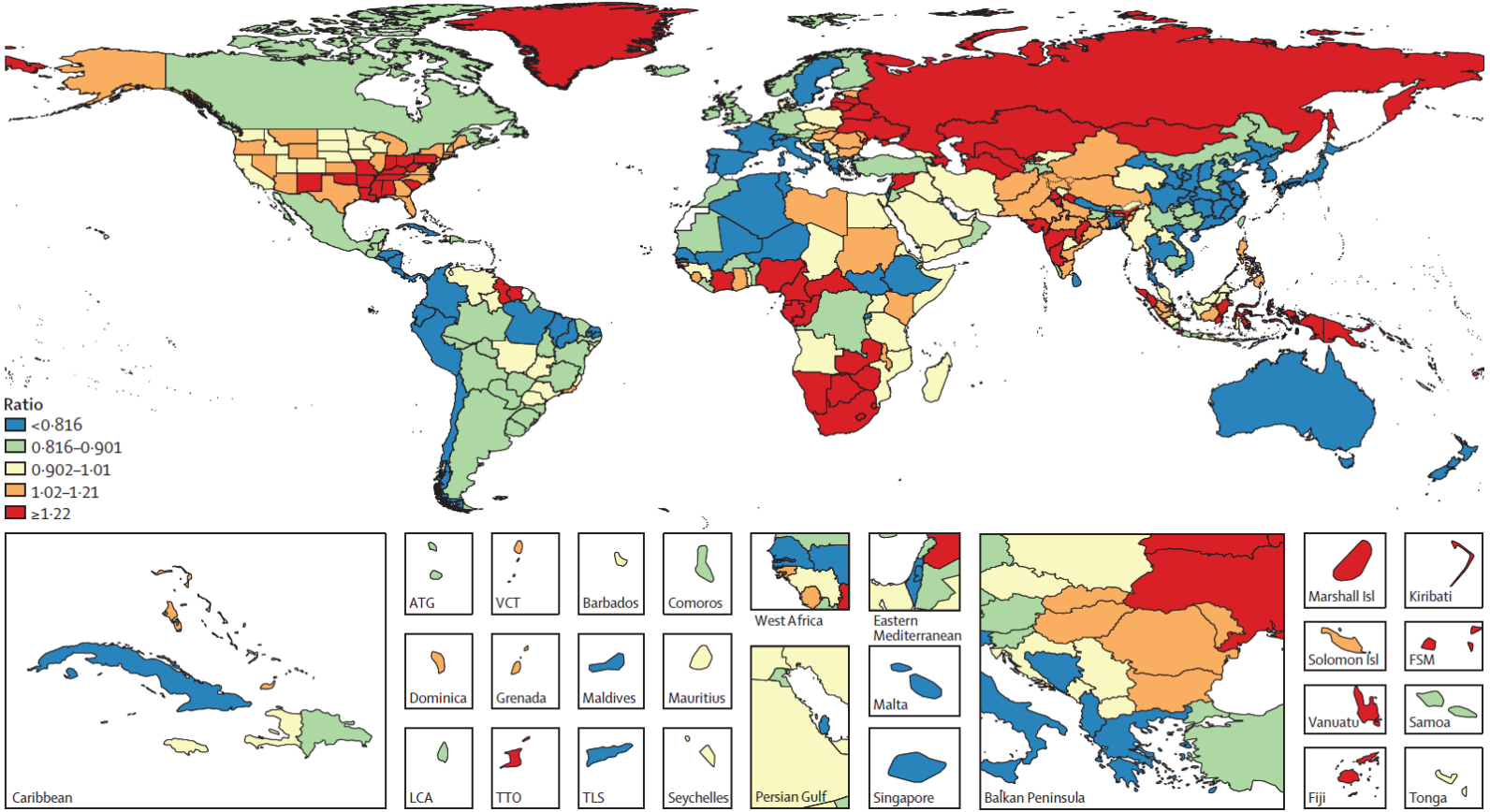
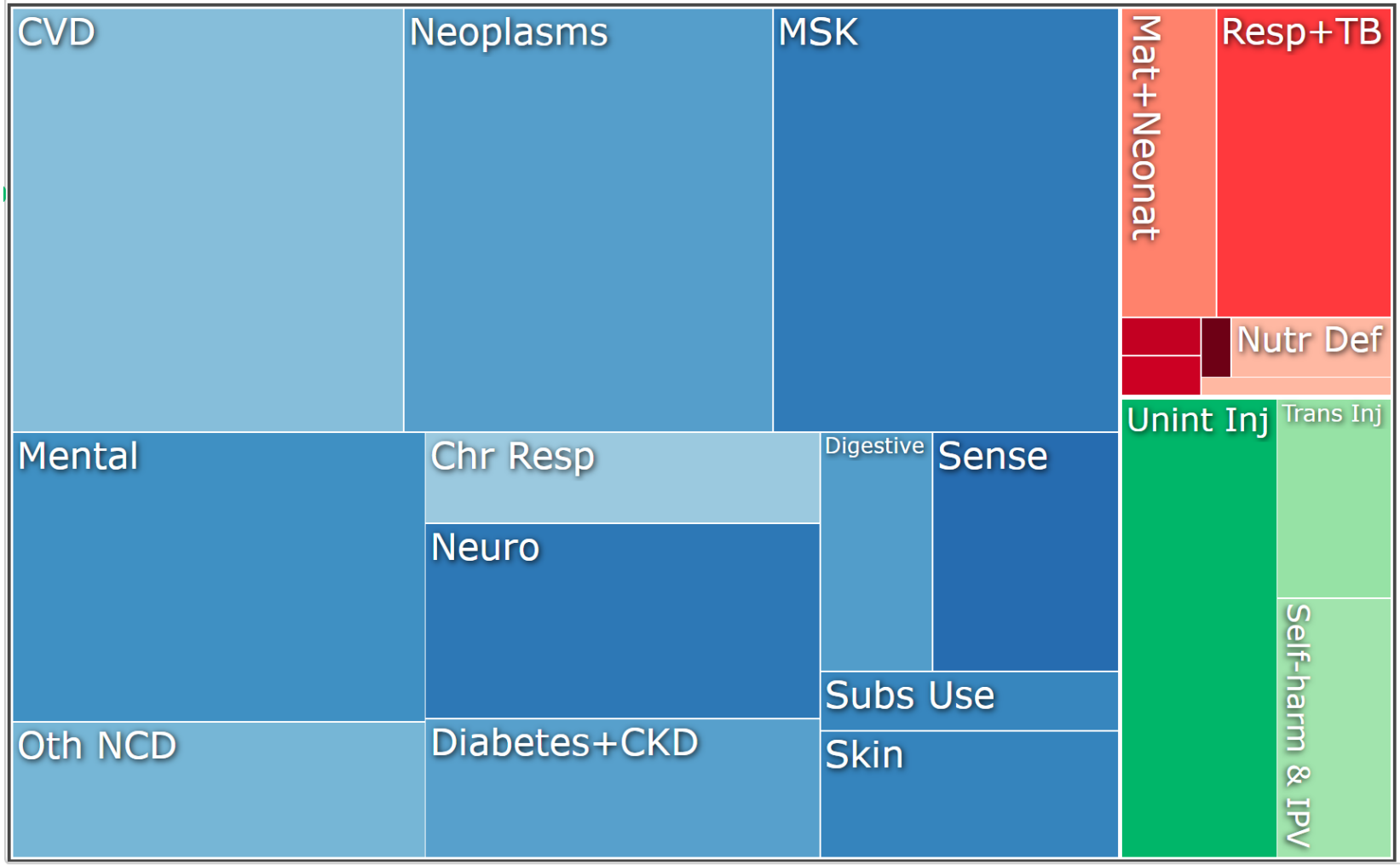


Figure 1: Relationship between age-standardised summary exposure values and SDI for three of the top environmental and occupational, behavioural, and metabolic risk factors by number of attributable DALYs globally

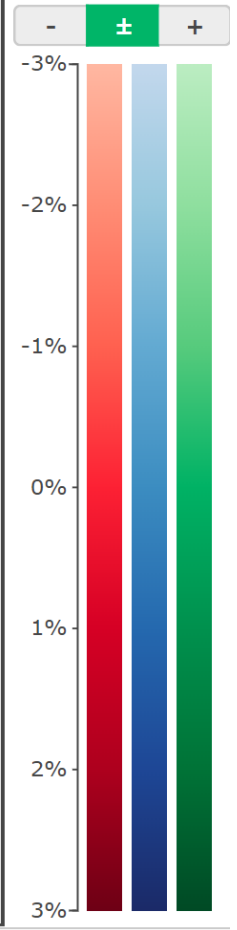
8. Benchmarking burden relative to development status: ratio of observed DALYs to DALYs expected on the basis of SDI



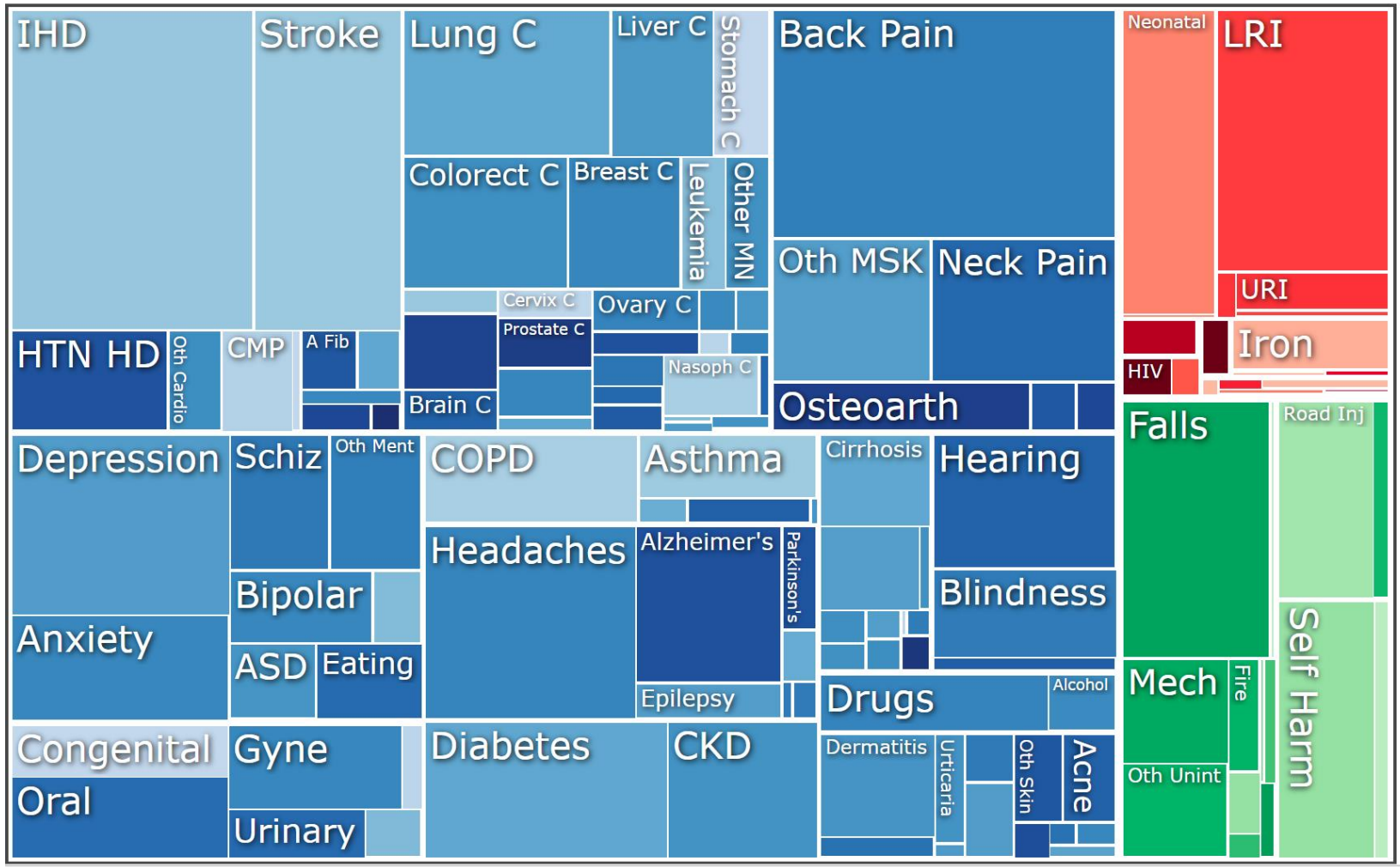
Singapore
Both sexes, All ages, 2017, DALYs



Annual % change
1990 to 2017
DALYs/100,000



Singapore
Both sexes, All ages, 2017, DALYs



Annual % change
1990 to 2017
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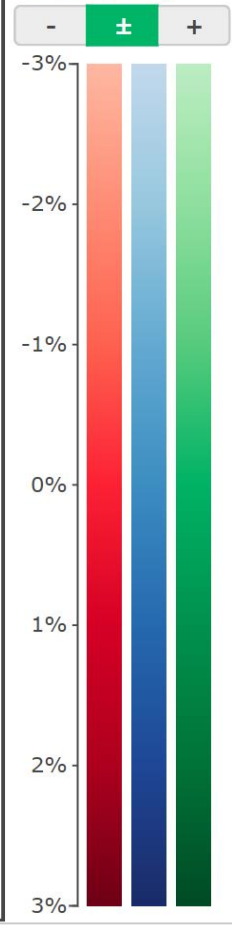

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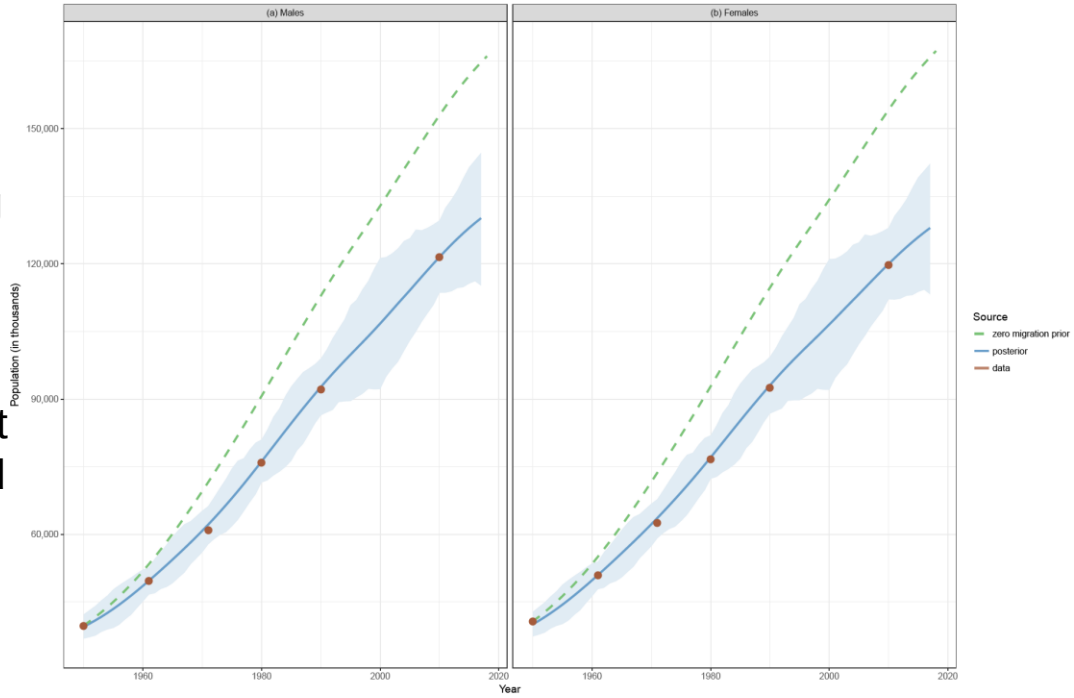
Some of the new directions for GBD

GBD is a dynamic study with constant search for new data, improved methods and analytical extensions grounded on the GBD approach to measurement

- Grading strength of evidence
- Population and fertility
- Forecasting and future health scenarios
- Burden of AMR
- Decomposition of changes in the GBD cycle to cycle

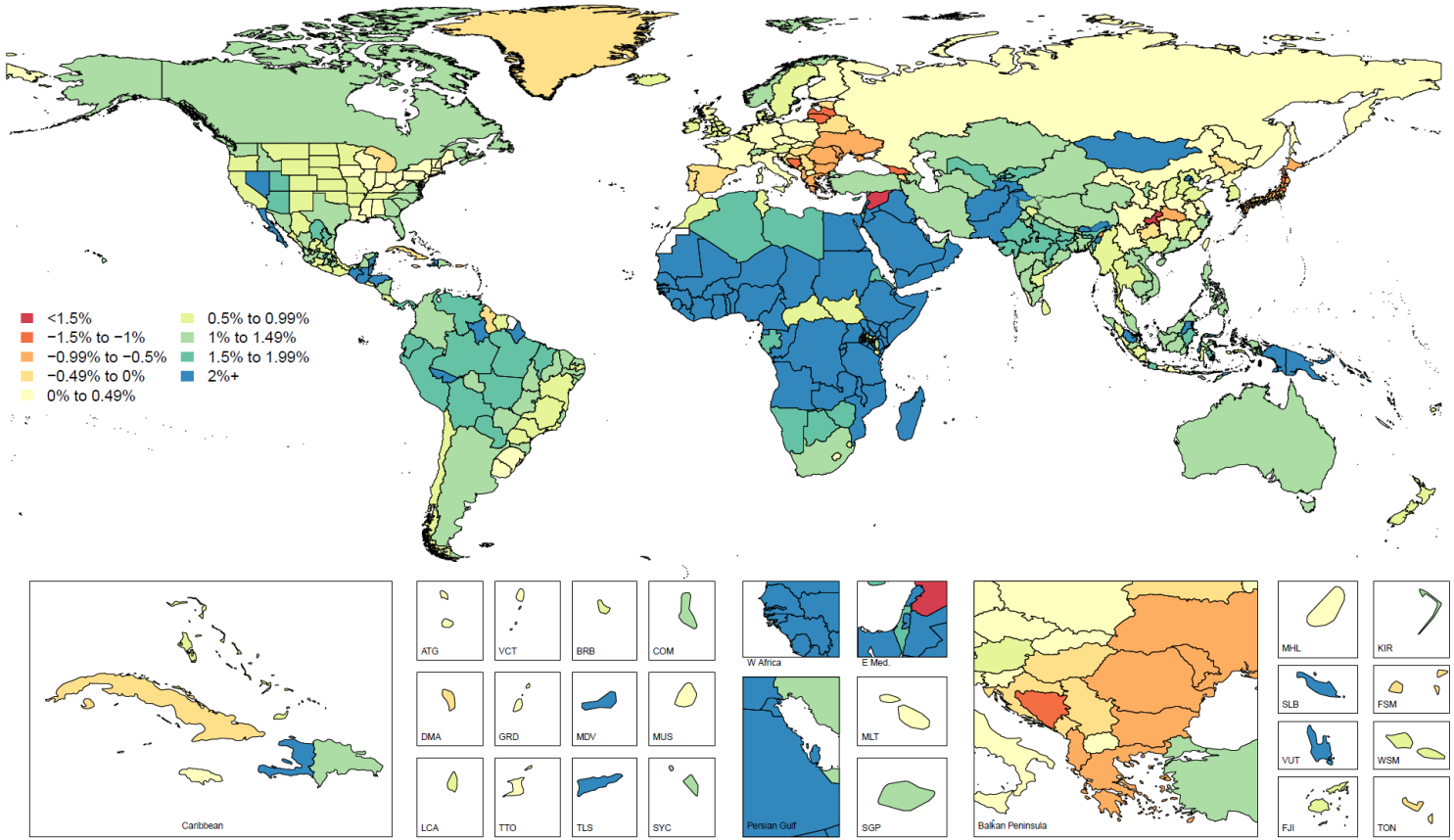
GBD 2017: estimation of population by location, age, sex, 1950-2017

- Analyzed 1257 census counts, 761 population registry-years from 26 registries covering the period 1950 to 2017.
- Census counts adjusted for age-heaping and under enumeration based on systematic analysis of Post-enumeration Surveys.
- Bayesian model using cohort component model to estimate population by age and sex using population counts as observations and GBD estimated fertility and mortality. Migration estimated as a residual except in locations with good annual migration data such as EU.



Population growth rate, 2010–2017

Half of the countries in the world now below replacement fertilty



GBD future health scenarios

1) GBD forecasts and alternative scenarios for 195 countries to 2040 published Lancet October 17, 2018.
2) Model is a causal model (79 independent drivers) with good out-of-time predictive validity.
3) Three components:
   a) Outcomes explained by risk factors/interventions based on exposure and relative risk for each risk factor/intervention as assessed in the GBD
   b) Risk/intervention deleted outcomes modeled on GDP per capita, educational attainment, total fertility rate, year (global secular trend)
   c) Hierarchical auto-regressive model for variation in outcomes not explained by components 1 and 2

Forecasting life expectancy, years of life lost, and all-cause and cause-specific mortality for 250 causes of death: reference and alternative scenarios for 2016–40 for 195 countries and territories

Kyle J Foreman, Neal Marquez, Andrew Dolgert, Kai Fukutaki, Nancy Fullman, Madeline McGaughey, Martin A Pletcher, Amanda E Smith, Kendrick Tang, Chun-Wei Yuan, Jonathan C Brown, Joseph Friedman, Jiawei He, Kyle R Heuton, Mollie Holmberg, Disha J Patel, Patrick Reidy, Austin Carter, Kelly Cercy, Abigail Chapin, Dirk Douwes-Schultz, Tahvi Frank, Falko Goettsch, Patrick Y Liu, Vishnu Nandakumar, Marissa B Reitsma, Vince Reuter, Nafis Sadat, Reed J D Sorensen, Vinay Srinivasan, Rachel L Updike, Hunter York, Alan D Lopez, Rafael Lozano, Stephen S Lim, Ali H Mokdad, Stein Emil Vollset, Christopher J L Murray

Summary

Background Understanding potential trajectories in health and drivers of health is crucial to guiding long-term investments and policy implementation. Past work on forecasting has provided an incomplete landscape of future health scenarios, highlighting a need for a more robust modelling platform from which policy options and potential health trajectories can be assessed. This study provides a novel approach to modelling life expectancy, all-cause mortality and cause of death forecasts—and alternative future scenarios—for 250 causes of death from 2016 to 2040 in 195 countries and territories.

Methods We modelled 250 causes and cause groups organised by the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) hierarchical cause structure, using GBD 2016 estimates from 1990–2016, to generate predictions for 2017–40. Our modelling framework used data from the GBD 2016 study to systematically account for the relationships between risk factors and health outcomes for 79 independent drivers of health. We developed a three-component model of cause-specific mortality: a component due to changes in risk factors and select interventions; the underlying mortality rate for each cause that is a function of income per capita, educational attainment, and total fertility rate under 25 years and time; and an autoregressive integrated moving average model for unexplained changes correlated with time. We assessed the performance by fitting models with data from 1990–2006 and using these to forecast for 2007–16. Our final model used for generating forecasts and alternative scenarios was fitted to data from 1990–2016. We used this model for 195 countries and territories to generate a reference scenario or forecast through 2040 for each measure by location. Additionally, we generated better health and worse health scenarios based on the 85th and 15th percentiles, respectively, of annualised rates of change across location-years for all the GBD risk factors, income per person, educational attainment, select intervention coverage, and total fertility rate under 25 years in the past. We used the model to generate all-cause age-sex specific mortality, life expectancy, and years of life lost (YLLs) for 250 causes. Scenarios for fertility were also generated and used in a cohort component model to generate population scenarios. For each reference forecast, better health, and worse health scenarios, we generated estimates of mortality and YLLs attributable to each risk factor in the future.

Findings Globally, most independent drivers of health were forecast to improve by 2040, but 36 were forecast to worsen. As shown by the better health scenarios, greater progress might be possible, yet for some drivers such as high body-mass index (BMI), their toll will rise in the absence of intervention. We forecasted global life expectancy to increase by 4·4 years (95% UI 2·2 to 6·4) for men and 4·4 years (2·1 to 6·4) for women by 2040, but based on better and worse health scenarios, trajectories could range from a gain of 7·8 years (5·9 to 9·8) to a non-significant loss of 0·4 years (−2·8 to 2·2) for men, and an increase of 7·2 years (5·3 to 9·1) to essentially no change (0·1 years [−2·7 to 2·5]) for women. In 2040, Japan, Singapore, Spain, and Switzerland had a forecasted life expectancy exceeding 85 years for both sexes, and 59 countries including China were projected to surpass a life expectancy of 80 years by 2040. At the same time, Central African Republic, Lesotho, Somalia, and Zimbabwe had projected life expectancies below 65 years in 2040, indicating global disparities in survival are likely to persist if current trends hold. Forecasted YLLs showed a rising toll from several non-communicable diseases (NCDs), partly driven by population growth and ageing. Differences between the reference forecast and alternative scenarios were most striking for HIV/AIDS, for which a potential increase of 120·2% (95% UI 67·2–190·3) in YLLs (nearly 118 million) was projected globally from 2016–40 under the worse health scenario. Compared with 2016, NCDs were forecast to account for a greater proportion of YLLs in all GBD regions by 2040 (67·3% of YLLs [95% UI 61·9–72·3] globally); nonetheless, in many lower-income countries, communicable, maternal, neonatal, and nutritional (CMNN) diseases still accounted for a large share of YLLs in 2040 (eg, 53·5% of YLLs [95% UI 48·3–58·5] in Sub-Saharan Africa). There were large gaps for many health risks between the reference

www.thelancet.com Published online October 16, 2018 http://dx.doi.org/10.1016/S0140-6736(18)31694-5

Published Online October 16, 2018 http://dx.doi.org/10.1016/S0140-6736(18)31694-5
See Online/Comment http://dx.doi.org/10.1016/S0140-6736(18)31861-0

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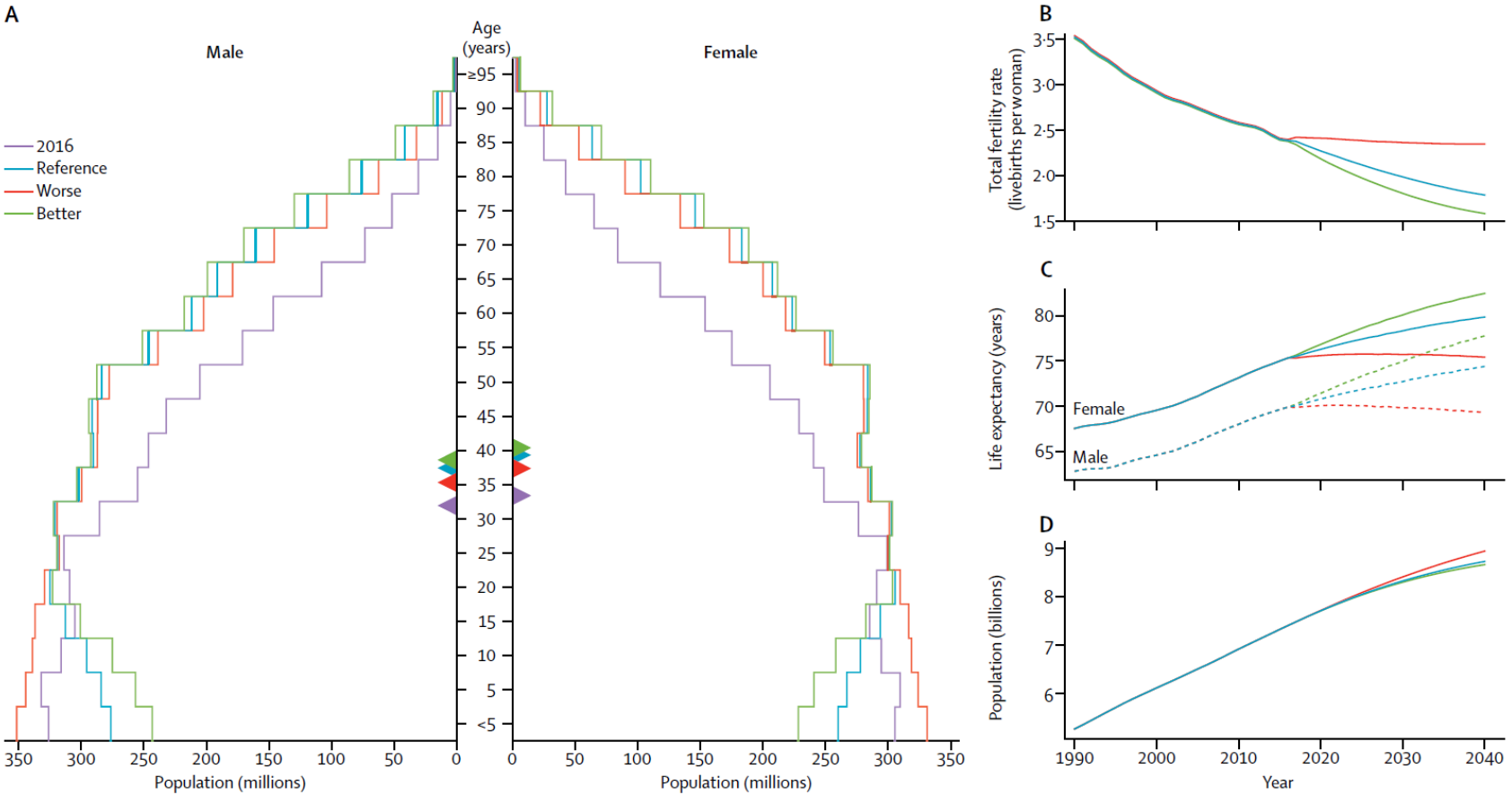
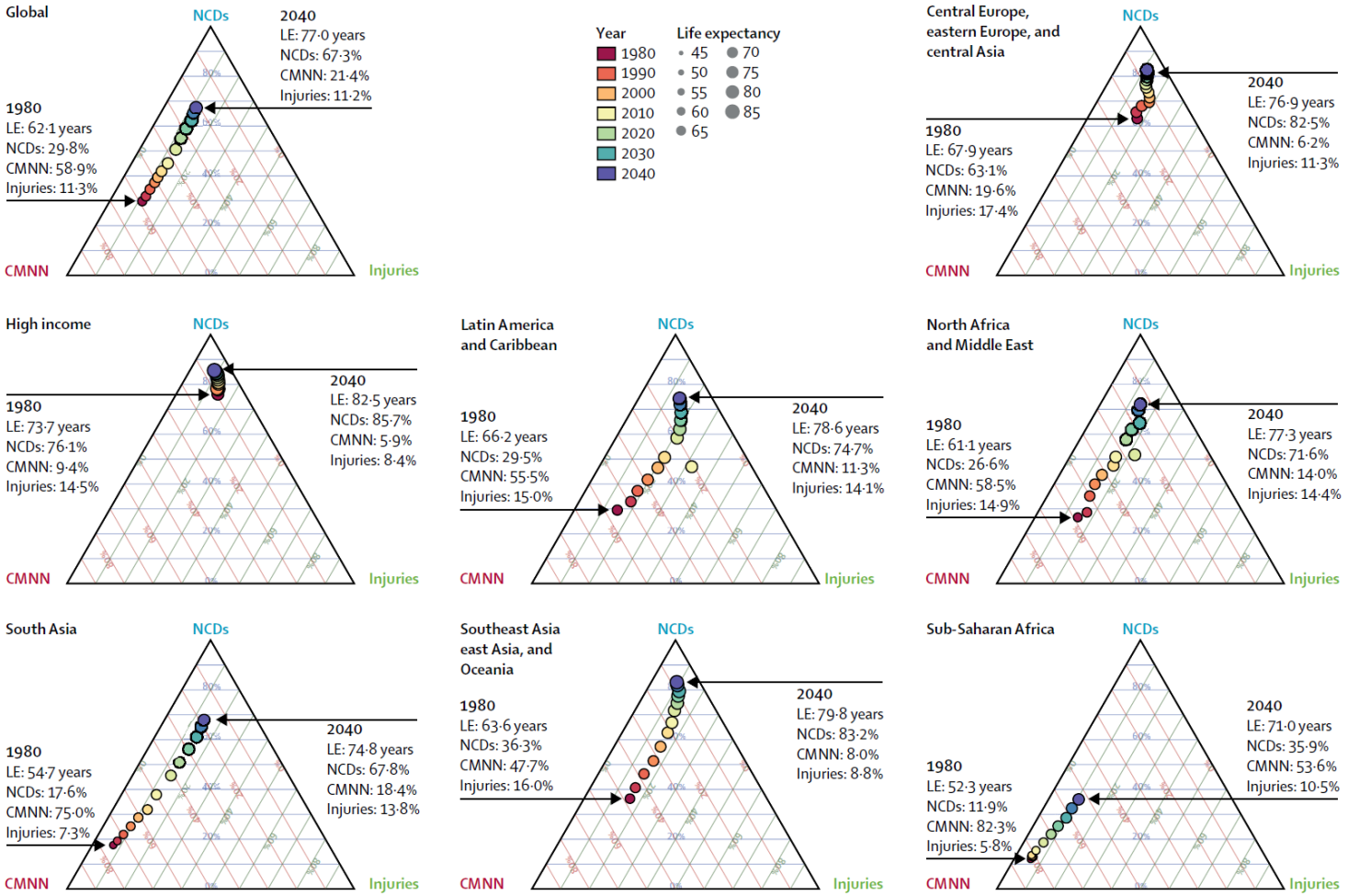
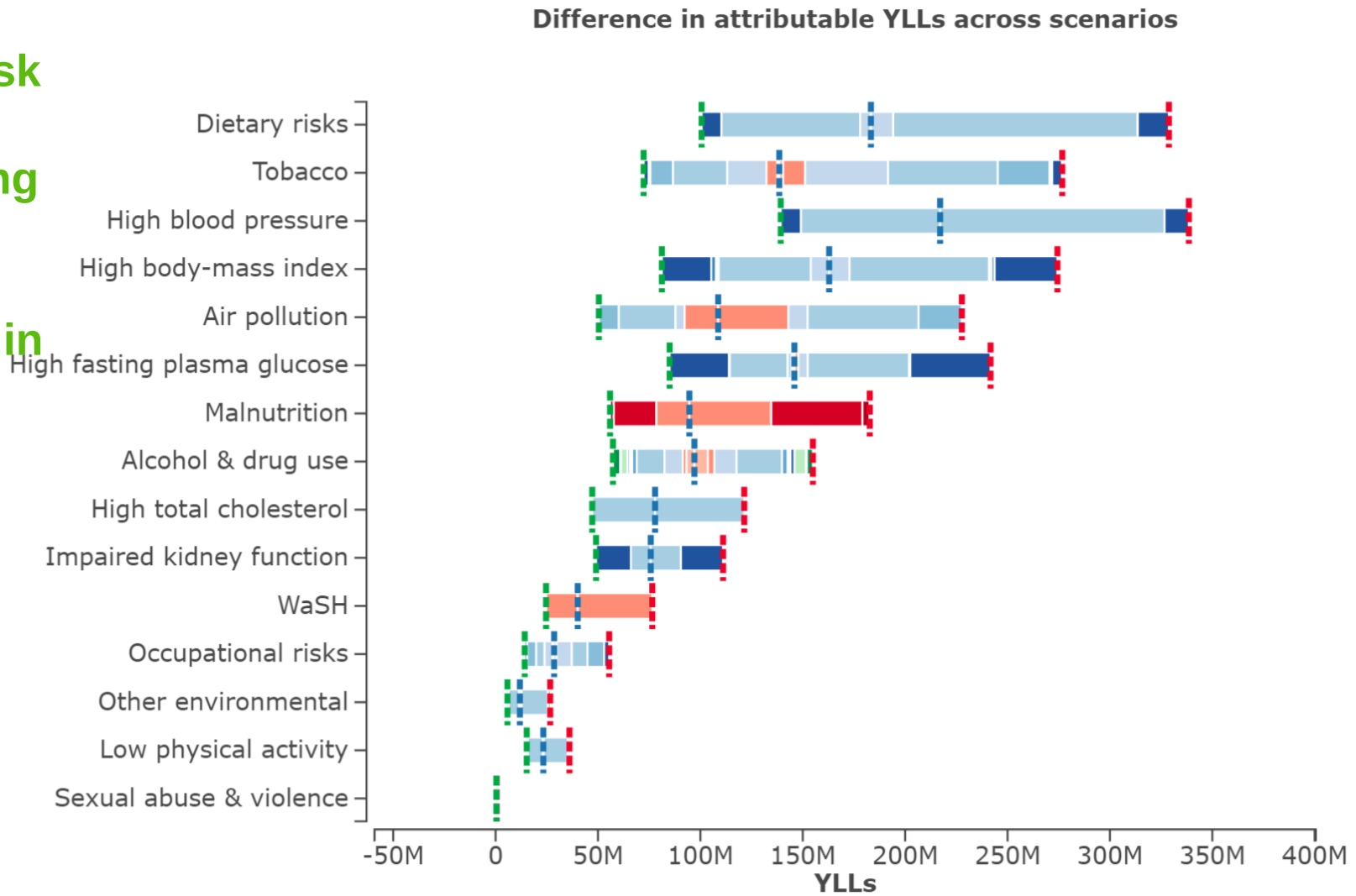
Global distribution of population in 2016 and 2040 reference forecasts, 2040 better health scenario, and 2040 worse health scenarios

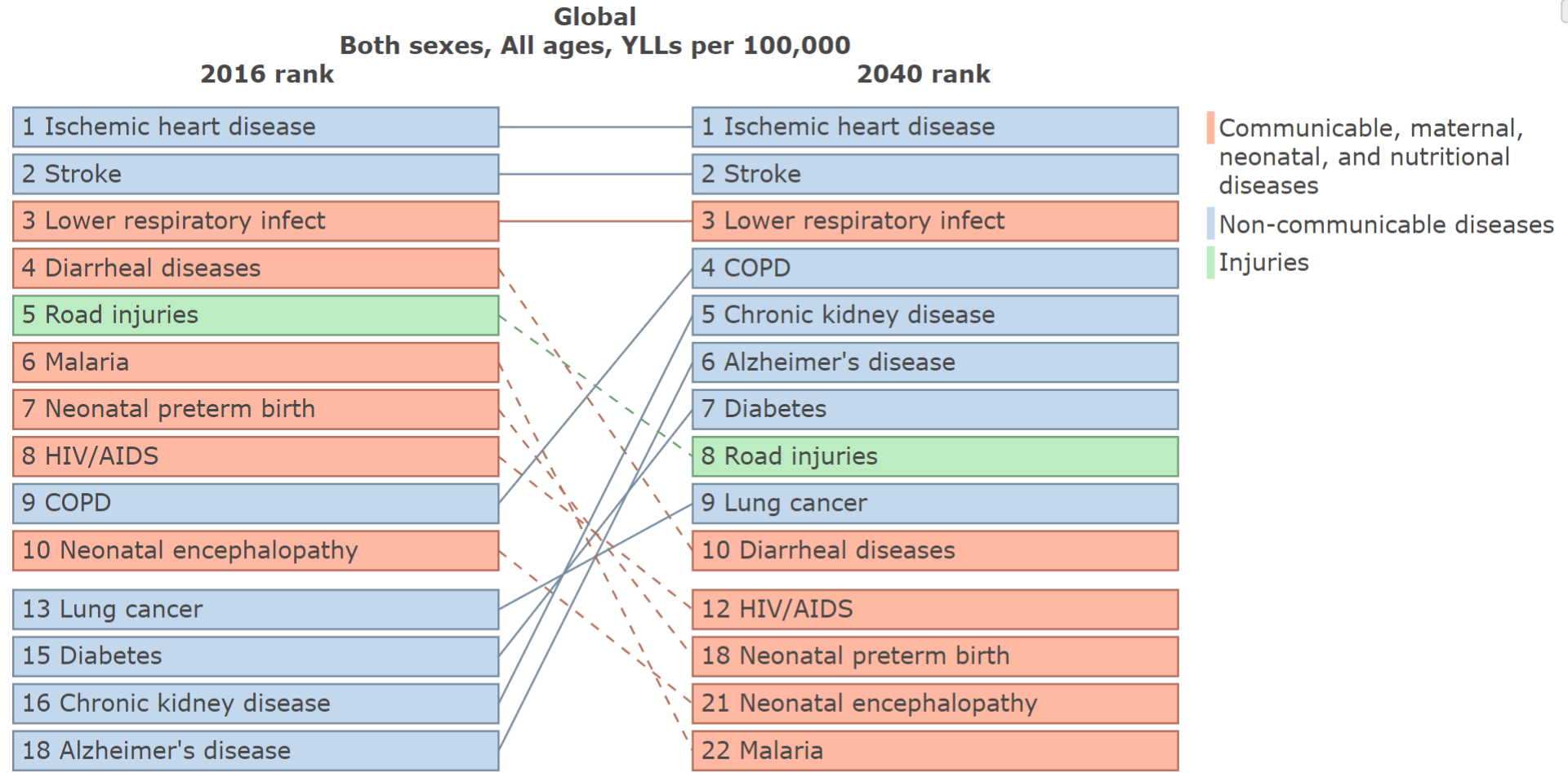


Global and super-region relative contribution of Level 1 GBD cause groups to total YLLs, 1980–2040, for the reference scenario

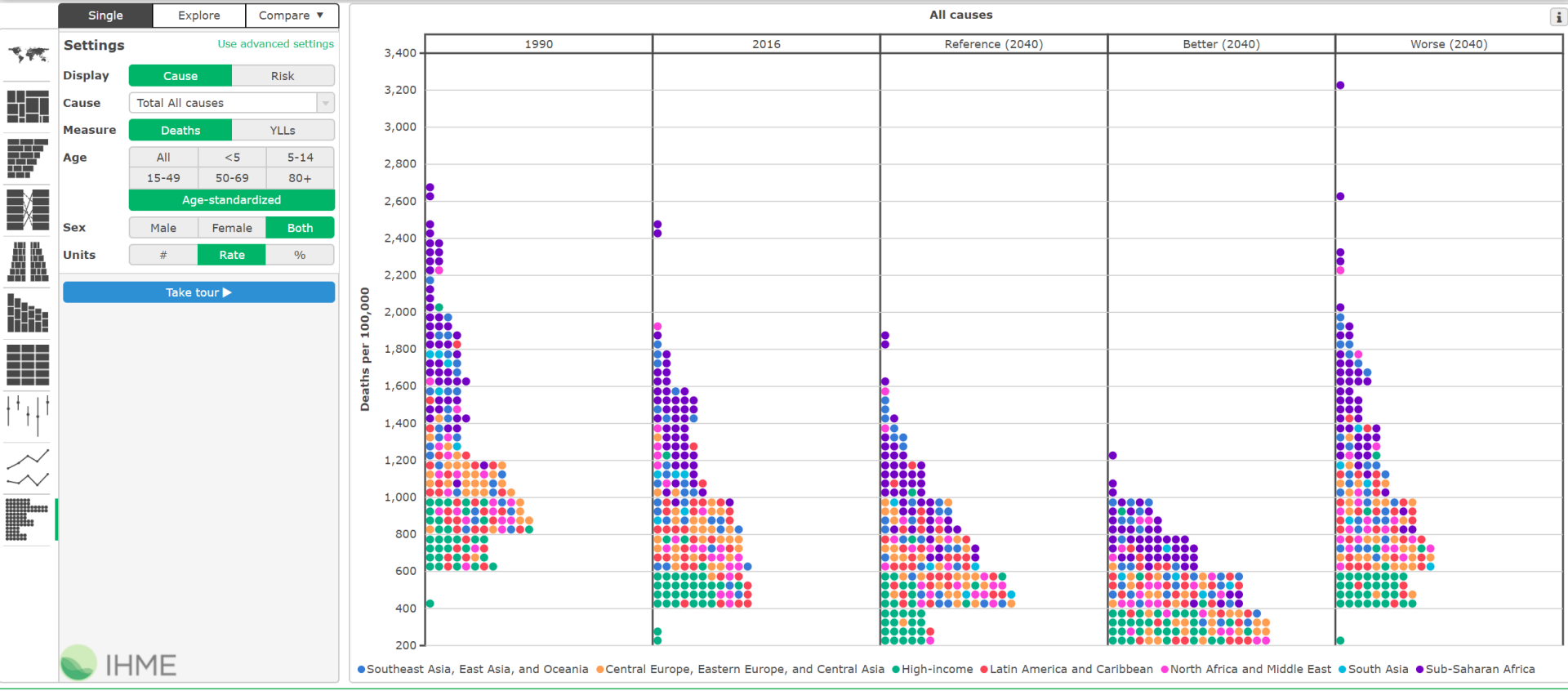


Leading risk factors contributing to global 2040 difference in YLLs between reference, better and worse health scenario



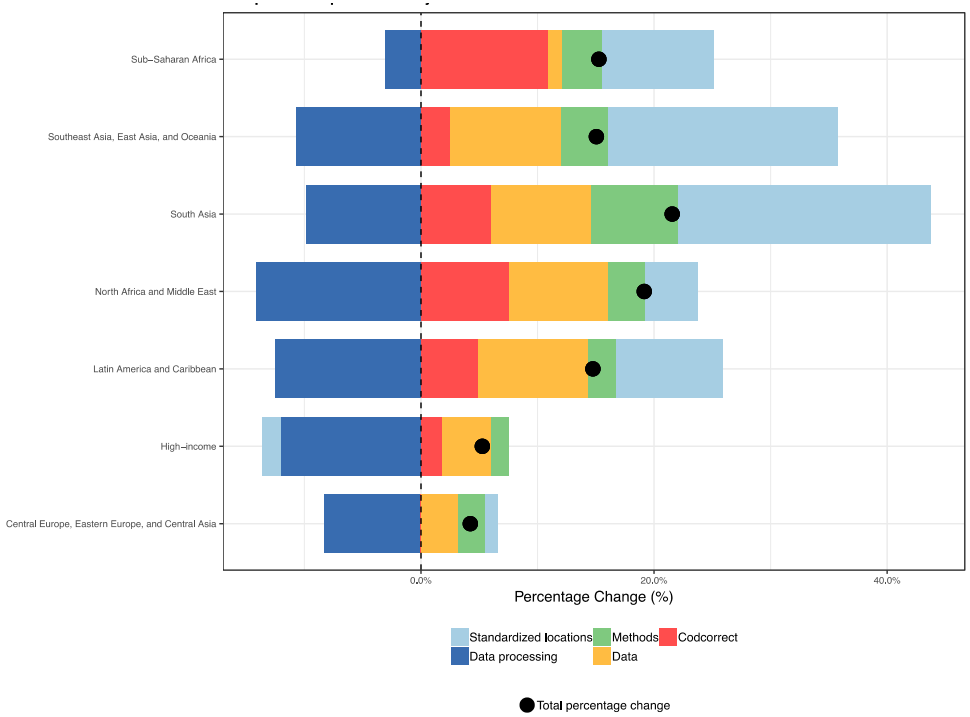

Global
Both sexes, All ages, YLLs per 100,000
2016 rank
2040 rank
1 Ischemic heart disease
2 Stroke
3 Lower respiratory infect
4 Diarrheal diseases
5 Road injuries
6 Malaria
7 Neonatal preterm birth
8 HIV/AIDS
9 COPD
10 Neonatal encephalopathy
13 Lung cancer
15 Diabetes
16 Chronic kidney disease
18 Alzheimer's disease
1 Ischemic heart disease
2 Stroke
3 Lower respiratory infect
4 COPD
5 Chronic kidney disease
6 Alzheimer's disease
7 Diabetes
8 Road injuries
9 Lung cancer
10 Diarrheal diseases
12 HIV/AIDS
18 Neonatal preterm birth
21 Neonatal encephalopathy
22 Malaria
Communicable, maternal, neonatal, and nutritional diseases
Non-communicable diseases
Injuries

GBD Foresight



Decomposition for GBD 2019

- For GBD 2019, we will formally decompose all changes in estimate into the a) the effects of adding new subnational units to the analysis; b) changes in data processing includir garbage code redistribution and cross-walking between different measurement methods; c) changes in methods and d) new data.
- For every outcome, we will provide the percentage change due to each of these factors for each location, age, sex, cause, outcome.



Global Burden of Disease

- Dynamic study involving thousands of scientists focused on using the best available data and methods to understand health and its determinants; power of large global scientific collaborations
- Committed to best science and local ownership and understanding through the collaborative scientific model
- De facto standard for global health accounting with multiple applications for monitoring progress with key global health priority challenges , including obesity and UHC
- Firmly based on the principle that informed health planning requires detailed, timely , granular and scientifically defensible estimates of the leading causes of health loss, and how they are changingd