

***Updated projections of global mortality  
and burden of disease, 2002-2030:  
data sources, methods and results.***

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# 1. Introduction

As part of the original Global Burden of Disease study for the year 1990, Murray and Lopez prepared projections of mortality and burden of disease by cause forward to 2000, 2010 and 2020 under three alternate scenarios (Murray and Lopez A.D. 1996; Murray and Lopez 1997). These projections have been widely used and continue to be quoted by WHO programs seeking to provide information on likely future trends in global health, see for example (Mackay and Mensah 2004). However, these projections were based on the GBD 1990 estimates and on projections of HIV/AIDS, smoking, income and human capital from 1990 to 2020. The HIV/AIDS projections in particular have proven to substantially underestimate to spread of the HIV epidemic and the level of HIV/AIDS mortality around 2000.

To address the need for updated projections of mortality and burden of disease by region and cause, we have prepared projections of future trends for mortality and burden of disease between 2002 and 2030 using methods similar to those used in the original Global Burden of Disease (GBD) study, but based on the latest available GBD estimates for 2002, and using the latest available projections for HIV/AIDS, income, human capital and other inputs. Funding support was provided for this work by two WHO programs requiring up-to-date mortality and burden of disease projections: the WHO Department of Chronic Diseases and Health Promotion (NMH/CHP), and the WHO Commission on Intellectual Property Rights, Innovation and Public Health (CIPRH).

An earlier version of these projections, documented in the first (October 2005) version of this Working Paper were extensively used in the recently released WHO global report *Preventing chronic diseases: a vital investment* (World Health Organization 2005). These were updated to include latest detailed WHO projections for tuberculosis mortality and to revise certain method used for projecting DALYs based on the mortality projections. The changes to the projections methods and results are summarized in Section 2 below.

Full details of the data sources and methods, together with a discussion of principal results and comparisons with other global and regional mortality projections, have been published in a recent paper by Mathers and Loncar (2006). This working paper provides a brief overview of methods and results.

## 2. Methods and data sources

Rather than attempt to model the effects of the many separate direct determinants or risk factors for disease from the limited data that are available, the GBD methodology considered a limited number of socio-economic variables: (1) average income per capita, measured as gross domestic product (GDP) per capita; (2) the average number of years of schooling in adults, referred to as “human capital”; and (3) time, a proxy measure for the impact of technological change on health status. This latter variable captures the effects of accumulating knowledge and technological development, allowing the implementation of more cost-effective health interventions, both preventive and curative, at constant levels of income and human capital (Murray and Lopez A.D. 1996).

A set of relatively simple models were used to project future health trends under various scenarios, based largely on projections of economic and social development, and using the historically observed relationships of these with cause-specific mortality rates. The data inputs for the projections models have been updated to take account of the greater number of countries reporting

death registration data to WHO, particularly from developing regions, and to take into account other recently developed projection models on HIV/AIDS and other conditions where appropriate, and smoking epidemics.

These socio-economic variables show clear historical relationships with mortality rates, and may be regarded as indirect, or distal, determinants of health. In addition, a fourth variable, tobacco use, was included in the projections for cancers, cardiovascular diseases and chronic respiratory diseases, because of its overwhelming importance in determining trends for these causes. Tobacco use was measured in terms of “smoking intensity” - that component of observed lung cancer mortality that is attributable to tobacco smoking (Peto et al. 1992).

For the projections reported here, death rates for all major causes excluding HIV/AIDS and tuberculosis were related to these four variables using historical death registration data for 107 countries between 1950 and 2002. Death rates were then projected using World Bank projections of GDP per capita, WHO projections of human capital, and smoking intensity projections based on historical patterns of tobacco use and further adjusted for recent regional trends in tobacco consumption where appropriate. Baseline, pessimistic and optimistic projections of income per capita, human capital and smoking intensity were developed. These were used to prepare baseline, optimistic and pessimistic projections of cause-specific mortality and burden of disease.

Separate projections for HIV/AIDS mortality were prepared by UNAIDS and WHO, under a scenario in which coverage with anti-retroviral drugs reaches 80% by 2012, remaining constant beyond that year, and that there are no changes to current transmission rates due to increased prevention efforts. Projected tuberculosis mortality rates were based on recent projections prepared by the Stop TB Partnership (Stop TB Partnership 2006). Since a substantial proportion of diabetes mortality is attributable to overweight and obesity (James et al. 2004), a separate projection model for diabetes mortality was developed using WHO projection of trends in body mass index distributions from 2000 to 2010. Similarly, projections of mortality for chronic respiratory diseases were adjusted for projected changes in smoking intensity.

The WHO projections of mortality rates to 2015, together with UN medium variant assumptions for fertility rates and migration rates (United Nations Population Division 2003), were also used to prepare consistent population projections for all regions. The projected global population in 2015 was 7.1 billion compared to the UN medium variant projection of 7.2 billion, reflecting somewhat higher adult death rates in the WHO mortality projections.

Projections of Years of Life lived with Disability (YLDs) were developed based on the ratio of YLDs to Years of Life Lost due to premature mortality (YLLs) in the GBD results for 2002. For those conditions where there is little or no mortality, alternative assumptions were used. For ischaemic heart disease and stroke, future case fatality rates were assumed to decline with improvements in income per capita. Baseline, optimistic and pessimistic projections of the numbers of deaths and DALYs for each condition were made using the projected rates and population projections.

Full details of the methodology and data sources have been published by Mathers and Loncar (2006). We provide here a summary of changes in methods from those used by Murray and Lopez, and of revisions to the methodology for the earlier version of the projections used in the WHO report *Preventing chronic diseases: a vital investment*.

## **Changes in methodology for the new WHO projections**

While the new projections have followed the general approach developed by Murray and Lopez (Murray and Lopez A.D. 1996; Murray and Lopez 1997), there are a number of methodological improvements and changes. These are summarized below.

1. The new projections were carried out at country level for 192 WHO Member States, using the GBD mortality estimates for 2002 as a base. The resulting country projections are added back into regional groups for presentation of results. In general, results will not be displayed at country level.
2. Whereas the original GDP projections applied a single set of models based on all observed death registration data for projections in all regions, the new projections have used a second set of models for low income countries based on the observed relationships for a low income data set consisting of 3,468 country-years of observation where GDP per capita was less than \$10,000. These models were used for projections for countries with income per capita less than \$3,000 per capita in 2002. For other countries, the models were based on the full data set of 5,210 country-years of historical data.
3. Whereas the original GDP projections treated diabetes as part of a single “Other non-communicable disease” group for which age-specific death rates were projected to decline with development, the new projections treated diabetes as a separate cause. A separate projection model for diabetes mortality was developed using the Comparative Risk Assessment project's analysis of the relative risk of diabetes mortality with increasing overweight (as measured by BMI) and WHO analysis and projection of trends in BMI distributions for WHO Member States from 2000 to 2010. Projected trends in BMI were assumed to flatten between 2010 and 2015 and to be constant beyond 2015.
4. Separate projection models were developed for chronic respiratory diseases using the Comparative Risk Assessment analysis of the chronic respiratory disease mortality risks associated with tobacco smoking, together with projections of smoking intensity. The non-smoker rates for all these chronic respiratory diseases were assumed to be declining with socioeconomic growth at one half the rate for “Other non-communicable diseases”.
5. For countries with populations of 5 million or more, and with at least 5 years of recent complete death registration data, cause-age-sex specific trends in mortality rates were estimated for ischaemic heart disease, cerebrovascular disease, tuberculosis, suicide and homicide. The resulting estimates for recent annual trends by cause, age and sex were used to adjust the initial years of projection for these causes for the selected countries. This adjustment ensured that available country-specific information on recent trends in mortality was incorporated into the projections for selected important causes.
6. The predictions of the projections model were compared with historical trends in child mortality from 1990 to 2002, and as a result, certain regression coefficients were modified for low income countries, reducing the rates at which death rates are expected to decline for these countries.
7. Projections of DALYs were carried out using a similar approach to that of the original GBD projections. For ischaemic heart disease and stroke, future case fatality rates were assumed to decline with improvements in income per capita. For vision and hearing disorders, prevalence rates and disability weights were assumed to decline with improvements in income per capita. YLD for HIV/AIDS were calculated from projections of HIV incidence rates assuming increasing duration for the period with AIDS as ARV coverage increases.
8. Population projections also included UN projections for net migration rates.

## **Revisions to the methodology in 2006**

The projections published here on the WHO website, and also by Mathers and Loncar (2006), differ in some respects from those released in 2005 and used in the WHO report *Preventing chronic diseases: a vital investment*. The main differences are

1. Tuberculosis mortality projections were revised based on three projection scenarios prepared by the Stop TB Partnership based on different assumptions about the pace of scale-up and coverage of interventions to achieve the Millennium Development Goal for tuberculosis [29]. These revised projections give a substantially greater decline in tuberculosis mortality than the first version of the projections.
2. Methods used to project YLD for causes with significant case fatality rates were revised. For ischaemic heart disease and stroke, future incidence rates were assumed to decline at 50% of their mortality rate declines, in other words the mortality rate decline was assumed to result from declines in incidence rates and case fatality rates. For long-term sequelae associated with certain cancer sites, incidence rates were projected to increase with improvements in income per capita in line with the cross-regional variations seen in the 2002 estimates.
3. Methods used to project decreases in average disability weights for non-fatal causes such as vision and hearing loss were revised and simplified.
4. The adjustment factor for major cause regressions was revised from 0.25 to zero for the pessimistic scenario and 0.75 to 1.0 for the optimistic scenario (see Table 1)
5. For diabetes, COPD and asthma, non-overweight and non-smoker death rates were assumed to decline at 75% of the 'Other Group II' rate rather than 50% in the baseline scenario. Rates of decline were also modified for the other scenarios (see Table 1).

## **The GBD 2002 base estimates**

The data sources and methods used for the GBD 2002 are documented elsewhere (Mathers, Lopez, and Murray 2006) and summary results for 14 regions of the world are published in the World Health Report 2004 (World Health Organization 2004) and on the world wide web ([www.who.int/evidence/bod](http://www.who.int/evidence/bod)). These estimates were revised for some causes as follows:

- HIV/AIDS deaths were revised to reflect the latest estimates published in the 2004 Report on the global AIDS epidemic (UNAIDS 2004). Estimates of HIV/AIDS mortality for some countries were substantially revised to take into account new and different sources of data, such as national household surveys, as well as improved information on emerging epidemics in Eastern Europe, Asia and the Americas.
- Further updates were also carried out for malaria, schistosomiasis and intestinal helminths. Country-specific estimates of malaria mortality and incidence were updated to reflect recent work carried out in collaboration with other WHO programs and external expert groups to refine and revise these country-specific estimates of malaria mortality (Korenromp et al. 2003; Rowe et al. 2005).

## **Optimistic, baseline and pessimistic scenarios**

Table 1 summarizes the assumptions and inputs for the optimistic, baseline and pessimistic scenarios. These are described in more detail elsewhere (Mathers and Loncar 2006).

**Table 1. Summary of assumptions and inputs for baseline, optimistic and pessimistic projection scenarios**

|  | <b>Baseline scenario</b>   | <b>Pessimistic scenario</b>  | <b>Optimistic scenario</b>  |
|--|--|--|---|
| <b>Projected covariates</b>                                      |  |  |   |
| GDP per capita   | World Bank projections   | Assume GDP annual growth rates from 2005 at 50% of baseline projections, with some regional variations   | Assume GDP annual growth rates from 2005 approximately 40% higher than baseline projections, somewhat lower increase for high income countries, China and India |
| Human capital  | EIP projections based on projected GDP growth  | Approximately 1% lower annual growth with GDP compared to baseline scenario  | Approximately 1% higher annual growth with GDP compared to baseline scenario  |
| Smoking intensity  | Weighted average based on previous EIP regional projections, country trends in apparent consumption, and lung cancer trends where available. | Weighted average giving more weight to previous EIP regional projections.  | Weighted average giving more weight to country trends in apparent consumption.  |
| <b>Adjustment factor for major cause regression coefficients</b> |  |  |   |
| Time   | 0 for AFRO low income countries, 0.25 for other low income countries   | 0 for AFRO low income countries, 0 for other low income countries  | 0.25 for AFRO low income countries, 0.75 for other low income countries   |
| Human capital  | 0.5 for low income countries   | 0.25 for low income countries  | No adjustment   |
| <b>Disease-specific mortality projections</b>                    |  |  |   |
| HIV/AIDS   | Achievement of 80% ARV coverage by 2012  | Achievement of 60% ARV coverage by 2012 in all regions except Latin America (60% by 2013)  | Achievement of 80% ARV coverage by 2012 plus additional prevention activities   |
| Tuberculosis   | Sustained DOTS scenario: case detection and treatment success rates increase until 2005 and then remain constant to 2030                     | Annual trends halfway between sustained DOTS scenario and "No DOTS" scenario from 2006 onwards. "No DOTS" scenario assumes pre-DOTS case detection and cure rates. | Annual trends projected with full implementation of the GLObal Plan to Stop TB 2006-2015. Annual trends from 2015 to 2030 remain constant.                      |
| Diabetes   | Non-overweight death rates declining at 75% of rate for Other Group II deaths  | Non-overweight death rates declining at 50% of rate for Other Group II deaths  | Non-overweight death rates declining at 100% of rate for Other Group II deaths  |
| COPD and asthma  | Non-smoker death rates declining at 75% of rate for Other Group II deaths  | Non-smoker death rates declining at 50% of rate for Other Group II deaths  | Non-smoker death rates declining at 100% of rate for Other Group II deaths  |
| Violence   | Assume rates constant over time in high income countries   | Projected trends for intentional injuries assumed to apply   | Assume rates constant over time in high income countries  |
| War  | Assume rates constant over time in all regions   | Assume rates rise for EMRO and AMRO regions between 2002 and 2005 and then remain constant over time in all regions  | Assume rates decline at 1.5% per annum from 2006 onwards.   |

### 3. Results

Projection results for deaths and DALYs for 2005, 2015 and 2030 are available as downloadable Excel workbooks on the WHO website ([www.who.int/evidence/bod](http://www.who.int/evidence/bod)) by cause, age, and sex, for several different regional groupings of countries, and for each of the three scenarios. Each Excel workbook contains a sheet defining the regions used. Base GBD results for 2002 are also available on the WHO website at the same location.

In all three scenarios there is a dramatic shift in the distribution of deaths from younger to older ages and from communicable, maternal, perinatal and nutritional causes to non-communicable disease causes. The risk of death for children aged under 5 is projected to fall by nearly 50% in the baseline scenario, between 2002 and 2030. The proportion of deaths due to non-communicable disease is projected to rise from 59 per cent in 2002 to 69 per cent in 2030. Global HIV/AIDS deaths are projected to rise from 2.8 million in 2002 to 6.5 million in 2030 under the baseline scenario, which assumes coverage with anti-retroviral (ARV) drugs reaches 80% by 2012. Under the optimistic scenario, which also assumes increased prevention activity, HIV/AIDS deaths are projected to drop to 3.7 million in 2030.

Total tobacco-attributable deaths are projected to rise from 5.4 million in 2005 to 6.4 million in 2015 and 8.3 million in 2030, under our baseline scenario. Tobacco is projected to kill 50% more people in 2015 than HIV/AIDS, and to be responsible for 10% of all deaths globally.

The three leading causes of burden of disease in 2030 are projected to include HIV/AIDS, unipolar depressive disorders and ischaemic heart disease in the baseline and pessimistic scenarios. Road traffic accidents are the fourth leading cause in the baseline scenario, and the third leading cause ahead of ischaemic heart disease in the optimistic scenario. Under the baseline scenario, HIV/AIDS becomes the leading cause of burden of disease in middle income countries, as well as low income countries, by 2015.

A more detailed presentation of the projection results is given by Mathers and Loncar (2006).

### 4. Discussion and conclusions

The uncertainty in regional and global assessments of mortality and disease burden for 2002 must be kept in mind when using the projections of mortality and burden of disease to 2030. The projections of burden are also highly uncertain. The projections are not intended as forecasts of what will happen in the future but as projections of current and past trends, based on certain explicit assumptions. The results depend strongly on the assumption that future mortality and risk factor trends in poor countries will have the same relationship to economic and social development as has occurred in the higher income countries over the last 50 years. If this assumption is not correct, then the projections for low income countries will be over-optimistic in the rate of decline of communicable diseases and the speed of the epidemiological transition. Improved projections building on available information on trends in risk factors and other health determinants in developing countries will await the further development and application of more sophisticated projection methods to cause-specific mortality projection (Giroso and King 2003).

The methods used base the disease burden projections largely on broad mortality projections driven by World Bank projections of future growth in income and WHO projections of increases in human

capital in different regions of the world, together with a model relating these to cause-specific mortality trends based on the historical observations in countries with death registration data over the last 50 years. The predictions of the projections model were compared with historical trends in child mortality from 1990 to 2002, and as a result, certain regression coefficients were modified for low income countries. This reduced the projected rates of decline in Group I conditions for low income countries compared to the original GBD projections, and it is entirely possible, that this adjustment may be too conservative. On the other hand, the many problems facing low income countries in improving and sustaining access to effective health interventions, and in scaling up health systems to cost-effectively address these challenges, may mean that the low income countries do not experience the temporal pace of health improvement at constant levels of income and human capital that have been seen in the high income countries over the last fifty years.

The projections have also not taken explicit account of trends in major risk factors apart from tobacco smoking, and to a limited extent overweight and obesity. If broad trends in risk factors are for worsening of risk exposures with development, rather than the improvements observed in recent decades in many high income countries, then again the projections for low and middle income countries presented here will be too optimistic. There is a need to develop much more comprehensive projection models that take explicit account of available information on trends in a wide range of risk factors. The HIV/AIDS projections in particular assume that transmission probabilities will remain largely unchanged into the future and there will not be substantial reductions in risk factors for HIV.

A projections exercise such as this by its nature involves substantial assumptions about the similarity of future trends to past trends, and about the future trends in broad drivers of health improvement. There are thus wide uncertainty ranges around future projections. Nevertheless, there are some aspects of the projections which clearly involve more uncertainty than others. For example, the projections of HIV/AIDS mortality are strongly affected by the assumptions made about the level of additional prevention effort that occur over the next two decades. Additionally, there are substantial uncertainties about the future trends in chronic respiratory disease mortality for non-smokers, and diabetes mortality for persons not overweight. Also, the evidence on the associations of injury mortality with income and human capital was weaker than for Group I and Group II conditions, and stronger assumptions were thus required for injury projections for some external causes. In the absence of any realistic approach to forecasting future war deaths, rates for these were assumed to remain constant over time in the baseline scenario. This may be too conservative, given the substantial decrease in numbers of wars and civil conflicts over the last decade or two. Finally, the entire set of YLD projections apart from those for HIV/AIDS are based on simplistic assumptions which may prove to be incorrect. It may be the case that case fatality rates for many diseases decline over the next thirty years, so that YLD become an increasing proportion of the total DALYs for these causes. On the other hand, improvements in risk factors and/or health interventions may lead to decreases in burden for some non-fatal conditions.

Despite these uncertainties, projections provide a useful perspective on population health trends and health policies, provided that they are interpreted with a degree of caution. Projections enable us to appreciate better the implications for health and health policy of currently observed trends, and the likely impact of fairly certain future trends, such as the ageing of the population, and the continuation of the epidemiological transition in developing countries. In using these projections, users should keep in mind that they represent a set of three visions of the future for population health, under an explicit set of assumptions and for specific projections of income, human capital, and of future trends in tobacco smoking, HIV/AIDS transmission and survival, and overweight and obesity. If the future

is not like the past, for example through sustained and additional effort to address MDG goals, then the world may well achieve faster progress than projected here, even under the optimistic scenario.

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