Regional patterns of disability-free life expectancy and disability-adjusted life expectancy: Global Burden of Disease Study

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Summary

Background Information on non-fatal health outcomes of disease and injury has been largely neglected in health planning because of the conceptual and definitional complexity of measuring morbidity and disability in populations. One of our major objectives was to quantify disability for inclusion in health policy debates. We analysed these health outcomes in terms of disability-free life expectancy (DFLE) and disability-adjusted life expectancy (DALE).

Methods Published and unpublished data were systematically reviewed to estimate the incidence, prevalence, and duration of 483 disabling sequelae of 107 diseases and injuries. To ensure internal consistency of these estimates, a software programme (DisMod) was applied many times until consistent parameters were identified. The severity of disability, on a scale of 0 (perfect health) to 1 (death), was measured in a deliberate manner by the person-trade-off method. Spearman's and Pearson's correlation coefficients were used to measure disability weights among groups. Prevalence of seven classes of disability was back-calculated from the distribution of each disabling sequela across disabilities. Prevalence for each class of disability for different age-sex groups was used to calculate seven forms of DFLE and DALE based on Sullivan's method.

Findings Prevalence of most disability classes is highest in sub-Saharan Africa and lowest in established market economies. Low-severity disabilities (class I and class II) are the most common. The expectation at birth of class I disability ranges from 6-5 years in established market economies to 14-7 years in sub-Saharan Africa, and for class II disabilities, from 8-5-18-4 years. DFLE varies significantly among regions: DFLE for class I disabilities at birth ranges from 9-9 years in sub-Saharan Africa to 47-7 years in established market economies for females and DFLE for class V disabilities ranges from 43-4 years for men in sub-Saharan Africa to 74-8 years for women in established market economies. The proportion of expected life span at birth lived with disability adjusted for severity, varies from about 8% in established market economies to 15% in sub-Saharan Africa, with little difference between men and women. In high-income regions, nearly 90% of expected disability is due to non-communicable diseases and most of the remainder to injuries. In poorer regions, almost half of expected disability is due to communicable diseases and injuries.

Interpretation The higher proportion of lifespan spent disabled in high-mortality populations is consistent with the compression of morbidity hypothesis. The threshold definition of disability used substantially affects the results of DFLE. DALE, which incorporates severity weights for disabilities, is a useful summary measure of the burden of disability and mortality.

Lancet 1997; 349: 1347-52

Introduction

In this second instalment of a four-part series on the findings of the Global Burden of Disease Study (GBD), we report the regional rates and patterns of disability by age, sex, and region, with various health expectancy measures for 107 diseases (see Lancet 1997; 349: 1269-76 for part 1; parts 3 and 4 follow in the next two issues). Disability-free life expectancy (DFLE) and disability-adjusted life expectancy (DALE)—a health-adjusted expectancy based on the GBD's disability severity weights—are used to describe regional differences in health expectancy. We also discuss the relevance of the cross-sectional pattern of DALE by region to the debate on the compression of morbidity hypothesis.

Health expectancies refer to life expectancy in various health states, and can be divided into indicators such as DFLE, in which the expected length of life lived without a given impairment or disability is calculated, or into health-adjusted life expectancy, which can be estimated by calculation of life expectancy for different health states with adjustment for severity weights. Both types of health expectancies may be useful ways to summarise the health status of the population. International comparisons of DFLE and other health expectancies have, however, been severely hampered by differences in calculation and definition. Some investigators have examined trends in health expectancies in only one country to try to reduce such discrepancies. Even interpretation of trends in DFLE has been confounded by changes in definition and method. When measurements are based on self-reported disability, trends in health expectancies may be affected by changes in the perception of illness, the willingness to take on the sick role, and the cost to the individual of missing work or school. Trends in life lived with disability that have accompanied the rise in life expectancy during this century have been subject to extensive debate. There are three types of theories about the changes in disability that go with longer life expectancy. Fries and colleagues argue that with improvements in survival, the prevalence of disability will decrease and, therefore, the proportion of life lived with disability will also decrease. This theory is often called compression of morbidity. Conversely, other theories predict that the proportion of life lived with disability will increase as mortality declines. Gruenberg and Kramer suggest that as the length of survival of individuals with chronic disorders such as Down's syndrome increases, the
prevalence of these disorders will also rise. Others suggest that improved survival among frail individuals who have higher expected incidence rates of disability will lead to an increased prevalence of disability. A third, "mixed" theory predicts that the progression of chronic diseases to severe disability will be slowed by medical intervention, which will lead to a decline in the prevalence of severe disability, but a rise in the prevalence of mild disability; increasing life expectancy would also contribute to the latter. Available cross-sectional estimates of health expectancies and longitudinal analyses were not very useful in the investigation of these theories. For example, recent evidence from France suggests that a compression of morbidity is occurring, but similar studies in Australia have more ambiguous results. Several data sources suggest that the prevalence of disability in the USA is rising.

Methods

We emphasised in the GBD examination of internal consistency of epidemiological estimates, and, therefore, that incidence, prevalence, case-fatality, and death rates for each disease or sequel were all compatible with each other. As discussed in more detail elsewhere, the efforts to ensure internal consistency included reviews of all available published and unpublished surveys or studies for each sequela and repeated estimation of rates specific for age and sex that were based on available data and cross-checked for internal consistency. A software program (DisMod) was used to check for internal consistency of epidemiological parameters.

Measurement of disability severity weights

Opinions vary widely on which method is best suited to assess individuals' or society's preferences for health states and which of epidemiological parameters.

Table 1: Disability classes based on person-trade-off method

<table>
<thead>
<tr>
<th>Disability class</th>
<th>Severity weights</th>
<th>Indicator of conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0-0.020</td>
<td>Vitaligo on face, weight-for-height less than 2 SDs</td>
</tr>
<tr>
<td>II</td>
<td>0-0.021-0.120</td>
<td>Watery diarrhea (five episodes per day), severe sore throat, severe anaemia</td>
</tr>
<tr>
<td>III</td>
<td>0-0.121-0.240</td>
<td>Radius fracture in a stiff cast, infertility, erectile dysfunction, rheumatoid arthritis (morning stiffness and pain in interphalangeal, metacarpophalangeal, and wrist joints with metacarpophalangeal deformity), angina (reproducible 5/10 chest pain walking 50 m)</td>
</tr>
<tr>
<td>IV</td>
<td>0-0.241-0.360</td>
<td>Below-knee amputation, deafness</td>
</tr>
<tr>
<td>V</td>
<td>0-0.361-0.500</td>
<td>Rectoveginal fistula, mental retardation (IQ 55-70), Down's syndrome</td>
</tr>
<tr>
<td>VI</td>
<td>0-0.501-0.700</td>
<td>Unipolar major depression, blindness, paraplegia</td>
</tr>
<tr>
<td>VII</td>
<td>0-0.701-1.000</td>
<td>Active psychosis, dementia (memory impairment, aphasia, and apraxia), severe migraine (bed-ridden with severe pain), quadriplegia</td>
</tr>
</tbody>
</table>

The prevalence of the seven classes of disability was back-calculated from distribution of each disabling sequela across them. The prevalence of disability of a particular class is the sum of all disabilities of that class in the set of 483 sequelae studied (ie, the prevalence of each sequela multiplied by the proportion of that sequela in the class) plus an estimation of the prevalence of disabilities from residual categories of disease and injury that were not explicitly analysed. The correction was based on the number of deaths estimated for residual categories and the assumption that the ratio of disability to mortality for residual categories is likely to be similar to related causes that have been formally evaluated. Because the epidemiological estimates in this study were constructed for each disorder, individuals may have had more than one disabling sequela. Given that class I and II disabilities are common, the sum of the prevalences of all classes of disability exceeds 100% in several age-groups in various regions. Although, on average, individuals, in these groups, may have more than one disabling sequela, in all of these groups there are individuals with no disability.
disabling sequela is constant within each of the five age-groups for which prevalence estimates are available from the GBD.

Calculation of DALE

Barendregt and colleagues \(^27\) proposed calling the health-adjusted life expectancy calculated with the GBD disability weights DALE, or the expectation of the equivalent number of health years of life at birth. The Sullivan method \(^28\) was used to calculate DALE, which is the number of years of healthy life lived at age \(x\); \(L_x\) is the number of years of healthy life lived at age \(x\); and \(D_x\) is the disability severity weight for disabling sequela \(j\) at age \(x\). DALE is calculated in the same way as DFLE at birth, except that the \(L_x\) column is used instead of the \(L_x\) column from a life table so that:

\[
DALE = \int_0^x L_x + D_x \, dx
\]

Table 2 shows summarised prevalences of each of the seven classes of disability for age, sex, and region.

Results

Table 2 shows summarised prevalences of each of the seven classes of disability for age, sex, and region. For nearly every class of disability and every region, prevalence rises with age. The exception is female class III disability, for which prevalence reaches a peak in the 45–54 years age-group in the six developing regions. This pattern is largely due to a concentration of infertility caused by sexually transmitted diseases and maternal disorders. The rise in prevalence with age is much less for class I disability than for other classes of disability.

Perhaps surprisingly, prevalence in most disability classes is highest in sub-Saharan Africa and lowest in established market economies, although there is substantial variation in the rank order of the regions depending on the age-group and the class of disability. There is, however, a high prevalence of class V disability in Chinese men and women, which is largely due to high rates of chronic obstructive pulmonary disease. Prevalence of class VII disabilities is highest in China, established market, and formerly socialist economies of Europe, which is due to higher crude prevalences of dementia in these three regions than other regions. Crude prevalence of dementia is lower in the other five regions because the population older than 75 years is a smaller proportion of the population older than 60 years.
defined as the difference between life expectancy and disability (table 4). Life expectancy with disability is disability and the proportion of lifespan affected by Caribbean) in females.

11·4 (China) to 16·1 years (Latin America and the Caribbean) in males and 11·8 (established market and formerly socialist economies of Europe) to 15·8 years (Latin America and the Caribbean) in females.

The expectation at birth of disability is similar across regions, the cause structure of disability appears to be very different for the two sexes in different regions. The expectation at birth of disability is higher for females than for males in all regions, mostly because women live longer than men and not because the prevalence of disability is higher. The expectation of disability from group 1 and group 2 disorders is higher for females than for males in all regions, but the reverse is true for group 3 disorders. In higher-income regions, such as established market economies, nearly 90% of expected disability is due to group 2 causes, whereas in India and sub-Saharan Africa nearly half is due to group 1 and 3 causes.

Table 3: DFLE at birth by sex and region in seven classes of disability

<table>
<thead>
<tr>
<th>Region*</th>
<th>Males</th>
<th></th>
<th>Females</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>EME</td>
<td>45·2</td>
<td>51·8</td>
<td>60·7</td>
<td>65·7</td>
</tr>
<tr>
<td>FSE</td>
<td>34·6</td>
<td>41·9</td>
<td>52·3</td>
<td>57·8</td>
</tr>
<tr>
<td>CHN</td>
<td>29·5</td>
<td>41·5</td>
<td>53·7</td>
<td>57·8</td>
</tr>
<tr>
<td>LAC</td>
<td>26·1</td>
<td>34·9</td>
<td>48·6</td>
<td>56·1</td>
</tr>
<tr>
<td>OAI</td>
<td>21·0</td>
<td>32·4</td>
<td>47·5</td>
<td>52·7</td>
</tr>
<tr>
<td>MEC</td>
<td>22·5</td>
<td>33·4</td>
<td>48·0</td>
<td>52·4</td>
</tr>
<tr>
<td>IND</td>
<td>32·0</td>
<td>44·9</td>
<td>49·8</td>
<td>52·5</td>
</tr>
</tbody>
</table>

*Abbreviations for regions as in table 2.

Table 3 shows estimates of the seven types of DFLE according to sex in each region. Individuals who have more than one disability are assigned to the disability class of the highest order. The regional rankings of DFLE-I (ie, life expectancy free of class I, or worse, disability) at birth for females exactly parallel the rankings of life expectancy at birth. In males, the only difference in the regional rankings of DFLE-I at birth and life expectancy at birth is the reversal of the middle eastern crescent and other Asia and islands. The rank order for other types of DFLE, however, varies by region.

These estimates would suggest that there is great heterogeneity across regions in the distribution of disability by class for the two sexes. The expectation at birth of class I disability (range across region 6·5–14·7 years) and class II disability (8·5–18·4 years) is high compared with other classes. The sum of these two classes exceeds the sum of the other five classes in all regions. Communicable, maternal, perinatal, and nutritional disorders account for a large proportion of the common mild disabilities in classes I and II. However, even after exclusion of common mild (class I and class II) disabilities, DFLE varies greatly among regions. The difference between DFLE-VII and DFLE-III ranges from 11·4 to 16·1 years (Latin America and the Caribbean) in males and 11·8 to 15·8 years (Latin America and the Caribbean) in females.

We calculated life expectancy at birth with and without disability and the proportion of lifespan affected by disability (table 4). Life expectancy with disability is defined as the difference between life expectancy and DALY. The expectation of life at birth is 2–14% higher for girls than for boys (lowest in India, highest in formerly socialist economies of Europe). Even after adjustment for time lived with disability in terms of DALY at birth the gap in favour of females remains similar. Moreover, the male-female difference in life expectancy is not much larger than the male-female difference in DALY at birth, which suggests that the female advantage in life expectancy is largely due to lower rates of mortality, not disability. Figure 1 shows the expectation of disability by region separated into the three cause groups (group 1=communicable, maternal, perinatal, and nutritional disorders; group 2=non-communicable disorders; group 3=injuries). Although the number of years of expected disability is similar across regions, the cause structure of disability appears to be very different for the two sexes in different regions. The expectation at birth of disability is higher for females than for males in all regions, mostly because women live longer than men and not because the prevalence of disability is higher. The expectation of disability from group 1 and group 2 disorders is higher for females than for males in all regions, but the reverse is true for group 3 disorders. In higher-income regions, such as established market economies, nearly 90% of expected disability is due to group 2 causes, whereas in India and sub-Saharan Africa nearly half is due to group 1 and 3 causes.

Figure 2 shows the proportion of the expected lifespan lived with disability adjusted for the severity of disability. For males this ranged from 8·1% in established market economies to 15·3% in sub-Saharan Africa, and for females the range was 8·3% in established market economies to 14·9% in sub-Saharan Africa. The proportion of the expected lifespan affected is marginally higher for males than females in established market and...
Discussion

The estimates of DFLE and DALE may be affected by two potential sources of bias. First, the approximation method used to estimate the prevalence of disability from the residual categories of diseases may be inaccurate. If the set of diseases and injuries that have been estimated are representative of the relation between disability and mortality for all conditions, then the estimates may not be biased. One factor that may have compromised representativeness is that idiopathic disabilities (for which, by definition, there is no known cause) are not included. For example, disability from blindness is included in the estimated burden of disease via a series of disorders that cause blindness, including trachoma, onchocerciasis, glaucoma, cataract, congenital and perinatal disorders, diabetes, neurological damage from malaria, road-traffic accidents, and other trauma. But some idiopathic causes of blindness, such as macular degeneration, are not included. Such causes, fortunately, are not very widespread. The approximation method may also cover some of the idiopathic forms of disability through representation of some multicausal or idiopathic deaths in the residual categories.

Although the residual approximation method for disability could bias DFLE and DALE upwards, coidisability may bias the results downwards. The GBD estimates are built up from a disease perspective. Disability prevalence, DFLE, and DALE are based on the total number of disabling sequelae of each class. By implication, we assume that the severity weight for a coidisability is simply the sum of the disability weights for the various disabling sequelae. Further research is required to define the extent of dependent and independent coidisability in different populations more accurately. Disability weights for combinations of disabilities could also be developed by expanding the application of the methods used in this study.

The GBD has provided a rare opportunity to examine the cross-sectional relation between life expectancy and the prevalence of disabilities. Despite the uncertainty associated with particular estimates, the GBD has provided a uniquely standardised database that can be used to explore the compression of morbidity and other hypotheses. Based on the available data on disability, our results suggest that populations with higher mortality have a higher prevalence of disability. The proportion of the expected lifespan with disability declines as life expectancy rises, from a high of nearly 15% in sub-Saharan Africa to around 8% in established market economies. At age 60, evidence for compression is even stronger: in sub-Saharan Africa, men are expected to spend 53% of their remaining lifetime with a disability, whereas the figure is only 22% in established market economies. In other words, if the cross-sectional regional patterns observed can be generalised to temporal trends, a 1-year improvement in life expectancy could be accompanied by slightly more than a 1-year improvement in DALE. The regional pattern of DALE and life expectancy in our study is consistent with the compression of morbidity hypothesis. However, more definitive evidence from time-series data on DALE based on observed measures of non-fatal health outcomes is required before the compression hypothesis can be confirmed.

Although life expectancy for women exceeds that for men in all regions, some studies have claimed that the prevalence of disability is higher among women than men.27 In the established market and formerly socialist economies of Europe, Latin America and the Caribbean, and sub-Saharan Africa regions, men not only live on

<table>
<thead>
<tr>
<th>Region*</th>
<th>Life expectancy</th>
<th>% of remaining life</th>
<th># of remaining life</th>
</tr>
</thead>
<tbody>
<tr>
<td>At age 60 years</td>
<td>DFLE at age 60</td>
<td>DALE at age 60</td>
<td>Severity-adjusted expectation of disability at age 60</td>
</tr>
<tr>
<td>M F M F M F M F</td>
<td>M F M F M F M F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EME</td>
<td>19.0 24.1</td>
<td>15.5 19.9</td>
<td>3.5 4.2</td>
</tr>
<tr>
<td>FSE</td>
<td>15.8 20.4</td>
<td>12.5 16.5</td>
<td>3.3 3.9</td>
</tr>
<tr>
<td>CHN</td>
<td>15.2 18.0</td>
<td>11.3 13.5</td>
<td>4.0 4.5</td>
</tr>
<tr>
<td>LAC</td>
<td>18.5 21.3</td>
<td>17.7 16.2</td>
<td>4.8 5.1</td>
</tr>
<tr>
<td>OAI</td>
<td>16.2 18.6</td>
<td>12.0 14.2</td>
<td>4.2 4.4</td>
</tr>
<tr>
<td>MEC</td>
<td>16.3 18.6</td>
<td>12.4 14.3</td>
<td>3.9 4.3</td>
</tr>
<tr>
<td>IND</td>
<td>15.1 16.3</td>
<td>11.2 12.2</td>
<td>3.9 4.1</td>
</tr>
<tr>
<td>SSA</td>
<td>14.7 15.9</td>
<td>11.6 13.1</td>
<td>5.1 4.9</td>
</tr>
</tbody>
</table>

*Abbreviations for regions as in table 2.

Table 5: Life expectancy at age 60 years with and without disability and proportion of life affected by disability

Figure 2: Proportion of expected lifespan lived with disability adjusted for severity by region and sex

*Abbreviations for regions as in table 2.
average shorter lives than females, but they also spend a higher proportion of their life disabled. In China, other Asia and islands, the middle eastern crescent, and India, women live longer but spend a higher proportion of their life disabled than men. However, the combined effect of life expectancy and the prevalence of severity-weighted disability is such that in all regions, DALE is higher for women than men.

Estimation of the life expectancy lived with different classes of disability is another useful way to summarise information on disability from all causes. These expectations can be used to calculate a variety of DFLE estimates. The results in table 3 clearly show that a change in the threshold definition of disability for the calculation of DFLE can have a dramatic effect on the results. This methodological issue alone may explain the wide variation in cross-sectional results reported in national studies. National-level estimates of DFLE for different countries can be compared only when detailed information is available about the severity of disabilities included in the calculations and when a standardised threshold to define disability has been used. Those proponents of DFLE who are opposed to the use of severity weights incorporated into health-adjusted expectancies such as DALE, may be interested to note that DALE consistently falls between DFLE with disabilities of class IV or V in all regions.

As a summary measure of the burden of disability from all causes in a population, DALE has several advantages. The concept of a lifespan without disability is easy to explain to a non-technical audience. DALE is also easy to calculate by the Sullivan method, which relies on prevalence data. An alternative would be the multistate life-table method of calculating DALE, which uses data on incidence and remission of disability to calculate a period health expectation. Since estimates of the incidence and duration of each disabling sequela have been developed as part of the GBD, DALE could technically be estimated by the multistate life-table method. However, although this approach would be scientifically interesting, we do not believe our estimates by region based on the Sullivan method would differ much from the estimates based on the multistate life-table approach. Third, because severity weights are used for disability, DALE would be much less sensitive to variation across space or time in the definitions used to define disability.

Although DALE and the life expectancy in different classes of disability are useful summary measures for a population, years lived with disability, years of life lost, and their sum, DALYs, are preferable when the burden of non-fatal health outcomes and premature mortality needs to be broken down into the burden attributable to various diseases, injuries or exposures (see the third part in this series in the next issue). This situation is analogous to the relative utility of life expectancy and cause-specific death rates as measures of mortality. Use of a measure such as DALYs also facilitates direct comparisons between the measurement of the burden of disease and the cost-effectiveness analysis of different interventions.

This work was supported by the Edna M Cc Constructors Clark Foundation, the Rockefeller Foundation, the World Bank, and WHO. The views expressed are entirely those of the authors and do not reflect the opinions, policies, or standards of WHO. WHO considers that DALYs and the burden of disease approach discussed in these papers are potentially useful for health situation assessment but require further research.

References