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Methods Published and unpublished data were systematically reviewed to estimate the incidence, prevalence, and duration of 483 disabling sequelae of 107 diseases and injuries.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 disabiity 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

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Introduction

In this second instalment of a four-part series on the findings of the Global Burden of Disease Study (GBD)[1] 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,[2] 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.[3] Some investigators have examined trends in health expectancies in only one country to try to reduce such discrepancies.[4–6] 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.[7–9]

Trends in life lived with disability that have accompanied the rise in life expectancy during this century have been subject to extensive debate.[10–12] There are three types of theories about the changes in disability that go with longer life expectancy. Fries and colleagues[13,14] 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[15] and Kramer[16] 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[17–20] 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;[21] 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.[4] Several data sources suggest that the prevalence of disability in the USA is rising.[10]

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 sequela were all compatible with each other. As discussed in more detail elsewhere,[22] 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 epidmeiological 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 respondents should be interviewed.[23–26] At the start of the GBD, no comparable set of health-state preferences or disability weights was available. To fill this gap, a protocol for disability severity-weight measurement was developed.[22] Five aspects of the protocol are noted here. 22 indicator conditions were defined to encompass a wide range of disability severities and different health states. Based on available data,[24] the person-trade-off method was primarily used to elicit health-state preferences from a group of representatives that covered all of the study regions. Two forms of the person-trade-off method were used to avoid framing effects, by which the way a question is phrased may influence results. The protocol was a group exercise for between eight and 12 participants lasting 10 h. Individuals made their own assessment of health states, but discussion was an important component of the process. Alternative measurement methods, such as time trade-offs, visual analogue, and ordinal rankings of disorders, were also used to encourage respondents to think carefully about their preferences.

The protocol was applied to a group which convened at the WHO offices in Geneva, Switzerland. Spearman's rank order correlation coefficients between participants were all more than 0·86. Despite varied backgrounds, the participants reached a consensus on many of the disability severity weights for the 22 indicator disorders. This protocol was then applied to eight other groups, consisting of participants from more than 25 countries. The severity weights for the 22 indicator disorders were highly consistent; the lowest correlation coefficient among the other eight exercises was 0·873; six of the eight exercises had a Pearson's correlation coefficient greater than 0·9, and seven of the eight exercises had a Spearman's rank order correlation coefficient greater than 0·9.

Based on the results from the person-trade-off protocol, the spectrum from perfect health (0) to death (1) was divided into seven arbitrary disability classes (table 1). Each class is exclusively defined by the range of disability weights and contains two or three indicator disorders that act as benchmarks for the definition of each class. A simpler approach was used to estimate the severity weight for each of the other disabling sequelae included in the GBD. The participants in Geneva were asked to use a rating scale to decide the distribution of each disorder in treated or untreated forms across the seven disability classes. Each participant decided a distribution individually, then shared the results with their colleagues, discussed discrepancies between results, and revised their distributions. When treatment was judged to change the distribution of severity by class, and not simply to affect the incidence, duration, or case-fatality rate of a disorder, the group developed separate distributions for untreated and treated forms. For example, the disability severity weights for untreated and treated angina were 0·227 and 0·095, respectively, on our scales of 0–1.

Disability class	Severity weights	Indicator of conditions
I	0–0·020	Vitiligo on face, weight-for-height less than 2 SDs
II	0·021–0·120	Watery diarrhoea (five episodes per day), severe sore throat, severe anaemia
III	0·121–0·240	Radius fracture in a stiff cast, infertility, erectile dysfunction, rheumatoid arthritis (morning stiffness and pain in interphalangeal, metacarpophalangeal, and wrist joints with metocarpophalangeal deformity), angina (reproducible 5/10 chest pain walking 50 m)
IV	0·241–0·360	Below-knee amputation, deafness
V	0·361–0·500	Rectovaginal fistula, mental retardation (IQ 55–70), Down's syndrome
VI	0·501–0·700	Unipolar major depression, blindness, paraplegia
VII	0·701–1·000	Active psychosis, dementia (memory impairment, aphasia, and apraxia), severe migraine (bed-ridden with severe pain), quadriplegia

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

Prevalences of disability by class

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.[22] 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.

Calculation of DFLE

Seven forms of DFLE were defined—life expectancy free of class I (or worse) disability (DFLE-I), life expectancy free of class II (or worse) disability (DFLE-II), and so on. To calculate DFLE-I, the proportion of each age-group without any disability ($H_{1\chi}$) is calculated first.

$$H_{1\chi}=(1-P_{1\chi})(1-P_{2\chi})(1-P_{3\chi})(1-P_{4\chi})(1-P_{5\chi})(1-P_{6\chi})(1-P_{7\chi})$$

where P is the prevalence of a particular class of disability in age-group χ (in the equation classes are given in Arabic rather than Roman numerals for clarity). H_1 is multiplied by the L_χ column in a life table and standard life tables are used to calculate DFLE.

DFLE for class II disability is calculated in a similar way

$$H_{2\chi}=(1-P_{2\chi})(1-P_{3\chi})(1-P_{4\chi})(1-P_{5\chi})(1-P_{6\chi})(1-P_{7\chi})$$

In the same way, other values of H (the proportion without disability of a particular class of each age-group) can be applied to calculate DFLE for each of the other classes. For the calculaton of DFLE, we assume that the prevalence of a

Age	Males								Females							
	EME	FSE	IND	CHN	OAI	SSA	LAC	MED	EME	FSE	IND	CHN	OAI	SSA	LAC	MEC
Class I																
0–4	65·1	137·3	451·9	224·8	357·5	403·6	224·6	365·9	60·2	139·8	455·2	226·2	365·4	393·6	237·5	364·5
5–14	63·6	110·6	329·2	282·5	297·5	467·4	208·1	293·8	57·1	105·3	333·6	281·8	297·0	417·9	215·2	284·6
15–44	87·1	140·6	337·8	278·3	338·3	463·4	221·4	287·8	111·3	156·4	494·0	267·9	450·8	538·9	321·4	503·2
45–59	163·9	261·1	401·3	311·5	411·3	550·9	327·4	392·5	195·7	268·8	615·5	360·5	535·7	689·0	407·4	622·4
⩾60	341·4	414·8	556·6	394·1	562·5	656·3	482·6	553·4	337·6	400·3	679·7	405·3	621·4	728·7	527·5	706·3
Class II																
0–4	71·2	118·5	237·0	196·5	203·2	248·9	179·3	260·2	71·4	123·4	237·8	200·3	207·9	248·3	189·9	260·2
5–14	59·3	79·3	213·0	158·6	164·2	258·7	176·7	181·9	58·6	82·1	216·7	159·4	161·0	243·2	182·0	175·5
15–44	90·3	144·4	258·2	182·2	242·9	441·2	210·5	205·9	88·4	125·3	326·8	172·9	263·0	379·8	214·1	284·4
45–59	172·8	301·1	386·7	267·9	404·2	668·9	344·8	395·8	180·6	263·4	463·7	284·4	400·8	521·2	327·9	451·8
⩾60	378·8	490·2	643·6	465·0	749·8	927·6	629·7	705·4	389·2	483·3	705·6	469·5	725·0	800·3	649·5	781·7
Class III																
0–4	21·2	33·1	64·6	47·0	55·9	69·9	48·9	60·4	21·3	34·2	65·0	48·6	56·1	70·9	50·7	60·0
5–14	17·9	21·2	43·0	28·7	33·2	45·9	43·5	33·5	17·2	20·9	38·2	28·8	31·1	44·2	40·6	30·1
15–44	59·9	78·4	77·5	47·6	78·6	139·9	111·3	57·6	47·9	88·3	160·9	52·1	129·2	251·6	122·5	106·5
45–59	81·2	136·2	126·9	89·2	122·1	203·1	161·7	106·7	65·9	96·1	97·2	81·7	86·6	122·1	110·1	78·4
⩾60	169·0	215·8	225·0	200·4	230·3	300·4	282·2	203·1	145·0	183·7	173·4	171·3	164·2	213·9	229·8	157·2
Class IV																
0–4	8·5	13·2	28·6	17·1	25·1	33·9	20·8	24·7	8·8	13·7	28·7	17·7	25·0	34·5	21·9	24·4
5–14	8·4	10·4	24·3	13·1	17·1	21·6	16·0	17·4	7·4	9·1	20·3	13·3	14·8	20·1	15·8	14·8
15–44	35·2	44·8	38·2	24·7	40·6	63·6	57·5	37·8	20·5	25·7	31·0	21·2	25·3	40·2	31·8	28·0
45–59	43·7	72·6	65·7	53·5	62·3	99·4	78·1	63·8	31·8	44·5	50·0	46·1	42·4	65·7	51·5	49·0
⩾60	90·7	111·5	119·9	137·5	122·6	153·0	132·5	121·3	72·8	87·7	90·9	115·2	84·0	114·3	104·6	93·9
Class V																
0–4	4·8	8·0	16·5	11·4	14·1	16·2	11·3	13·4	4·7	7·9	16·2	11·0	13·8	16·3	11·5	13·0
5–14	4·7	5·9	15·2	7·2	9·8	11·5	9·0	10·4	4·2	5·1	12·9	7·4	8·5	10·6	8·9	8·9
15–44	17·6	20·7	22·6	14·9	21·2	26·3	27·2	20·6	11·8	13·5	19·9	13·4	15·4	20·8	18·2	16·3
45–59	21·9	32·5	37·7	34·3	32·0	39·0	35·8	29·0	17·5	21·9	30·8	31·2	24·1	29·0	26·7	27·1
⩾60	55·0	57·5	70·5	99·1	64·3	64·5	68·4	61·1	49·8	50·5	59·0	90·6	53·0	53·0	60·3	53·3
Class VI																
0–4	1·9	4·7	8·1	6·6	7·2	10·2	5·3	6·5	1·9	4·5	8·5	6·2	7·2	10·7	5·6	6·5
5–14	2·0	3·0	10·4	4·4	6·3	10·4	4·9	5·9	1·8	2·5	8·5	4·7	5·3	9·9	4·5	5·0
15–44	25·6	32·1	38·2	32·0	36·0	46·0	35·6	37·6	34·6	41·0	47·5	45·7	45·9	53·2	45·8	49·4
45–59	30·1	42·0	65·1	47·0	55·9	90·8	46·7	55·9	35·1	41·7	68·4	60·6	64·6	88·2	50·5	66·8
⩾60	54·9	58·7	118·6	100·3	98·6	193·7	86·9	103·0	56·9	56·5	126·8	112·7	110·7	199·3	90·3	113·7
Class VII																
0–4	1·1	3·3	4·3	4·6	3·7	2·7	2·7	3·7	1·1	3·1	4·3	3·8	3·7	2·8	2·8	3·7
5–14	1·2	1·7	5·7	2·6	3·4	2·3	2·6	3·4	1·1	1·6	4·9	2·9	3·0	2·1	2·4	3·1
15–44	7·3	10·3	12·1	8·3	11·8	11·1	10·8	11·0	5·4	6·5	9·8	7·1	8·7	6·9	7·7	8·3
45–59	13·4	21·1	18·1	17·8	19·2	19·3	18·3	15·8	10·4	12·6	16·0	15·2	14·2	11·4	13·0	12·6
⩾60	46·0	46·9	36·3	52·0	41·1	34·7	42·9	29·9	47·5	44·5	33·3	46·9	37·5	25·0	40·0	25·0

EME=established market economies; FSE=formerly socialist economies of Europe; IND=India; CHN=China; OAI=other Asia and islands; SSA=sub-Saharan Africa; LAC=Latin America and the Caribbean; MEC=middle eastern crescent.

Table 2: **Prevalence per 1000 for seven classes of disability for age, sex, and region**

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 by modifying the L_x column from a life table so that: $HL_x=L_x(1-\Sigma P_{jx}\ D_{jx})$ where HL_x is the number of years of healthy life lived at age $_x$; L_x is the number of years of life lived at age χ from a life table; P_{jx} is the prevalence of disabling sequelae j at age χ; and D_{jx} is the disability severity weight for disabling sequelae j at age χ. DALE is calculated in the same way as DFLE at birth, except that the HL_x column is used instead of the L_x column. The prevalence of a disabling sequela is, again, assumed to be constant within each of the five age-groups.

Results

Table 2 shows summarised prevalences of each of the seven classes of disability by 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 15–44 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 obstuctive 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.

As expected, class I and class II disabilities are substantially more prevalent than the higher classes in all regions. More specifically, among the elderly (60 years and older), class II disabilities tend to be the most common, with typically 40–50% of the elderly population affected in established market and formerly socialist economies of Europe, and 70–80% in developing regions.

Region*	Males							Females						
	DFLE-I	DFLE-II	DFLE-III	DFLE-IV	DFLE-V	DFLE-VI	DFLE-VII	DFLE-I	DFLE-II	DFLE-III	DFLE-IV	DFLE-V	DFLE-VI	DFLE-VII
EME	45·2	51·8	60·7	65·7	68·6	70·2	72·2	47·7	56·1	67·3	72·3	74·8	76·4	79·1
FSE	34·6	41·9	52·3	57·8	60·9	62·5	64·6	38·3	47·6	60·2	66·6	69·3	70·9	73·6
CHN	29·5	41·5	53·7	57·8	60·5	62·4	65·1	30·0	42·7	56·0	60·4	63·0	65·0	68·7
LAC	26·1	34·9	48·6	56·1	60·0	62·0	64·7	25·0	37·1	53·4	61·0	64·0	65·8	69·2
OAI	21·0	32·4	47·5	52·7	55·6	57·2	59·8	18·5	33·0	50·4	56·5	58·8	60·2	63·6
MEC	22·5	33·4	48·0	52·4	55·2	56·7	59·4	16·4	31·1	50·0	55·2	57·7	59·1	62·6
IND	19·4	30·8	44·9	49·8	52·5	54·2	57·0	14·0	27·5	44·7	51·1	53·4	54·9	58·2
SSA	10·1	18·8	34·6	40·4	43·4	44·7	47·8	9·9	20·7	35·7	43·3	45·6	46·8	50·5

*Abbreviations for regions as in table 2.

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

At younger ages, class I disabilities are the most common, ranging from 7–14% of males aged 0–44 years in established market and formerly socialist economies of Europe, to 30–40% of males at these ages in developing regions. These patterns can be largely explained by cumulative incidence and effects of disease and injury being more common in poorer countries.

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 (China) to 16·1 years (Latin America and the Caribbean) in males and 11·8 (established market economies) 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 DALE. 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 DALE 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 DALE 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 disablity. 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

Region*	Life expectancy							
	At birth		DALE		Severity-adjusted expectation of disability		% of life lived with severity-adjusted disability	
	M	F	M	F	M	F	M	F
EME	73·4	80·5	67·4	73·9	5·9	6·6	8·1	8·3
FSE	65·7	74·8	59·4	67·8	6·3	7·0	9·6	9·4
CHN	66·2	69·8	59·5	62·2	6·7	7·6	10·1	10·9
LAC	65·8	70·3	57·6	61·9	8·1	8·4	12·4	12·0
OAI	60·8	64·9	53·7	56·9	7·1	7·6	11·6	11·8
MEC	60·3	63·4	53·6	55·8	6·6	7·5	11·0	11·9
IND	57·9	59·1	51·0	51·5	6·9	7·6	11·9	12·9
SSA	48·4	51·0	41·0	43·4	7·4	7·6	15·3	14·9

*Abbreviations for regions as in table 2.

Table 4: **Life expectancy at birth with and without disability and proportion of life affected by disability**

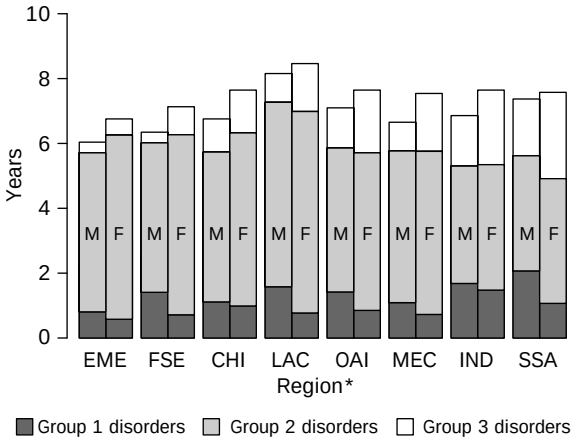

Figure 1: **Expectation of disability at birth adjusted for severity by disorder groups, region, and sex**
*Abbreviations for regions as in table 2.

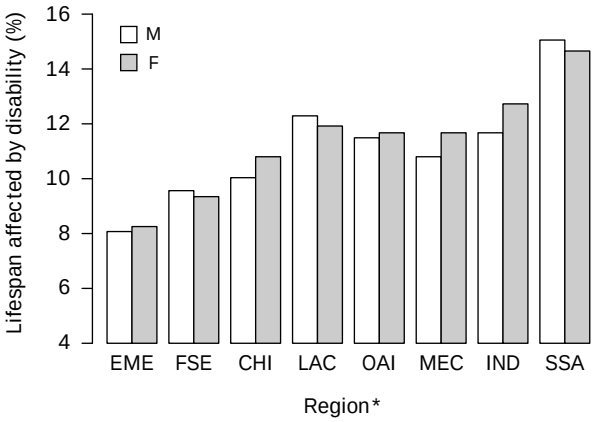

Figure 2: **Proportion of expected lifespan lived with disability adjusted for severity by region and sex**
*Abbreviations for regions as in table 2.

formerly socialist economies of Europe, Latin America and the Caribbean, and sub-Saharan Africa, whereas the opposite is true in China, other Asia and islands, the middle eastern crescent, and India. The differences between the sexes, however, are not substantial. Since women live longer than men after the age of 60, when the prevalence of disablity is more common, the expectation at birth of years lived with disability adjusted for the severity of disability is greater for women than for men in all regions, the differences vary from 0·3 years in Latin America and the Caribbean to 0·9 years in the middle eastern crescent.

Table 5 summarises the estimates of DFLE and DALE at age 60. There is less variation in life expectancy at age 60 among regions compared with life expectancy at birth. Nevertheless, expectancy at 60 years for men is still 20% higher in established market ecomonies than in sub-Saharan Africa and 29% higher for women in these regions. At these older ages, the proportion of the expected lifespan lived with disability ranges from about 20% in established market economies to nearly 50% in sub-Saharan Africa. Reduction in disability, as well as reduction in mortality, must, therefore, be common goals for health development in sub-Saharan Africa and other developing regions.

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.

Region*	Life expectancy							
	At age 60 years		DALE at age 60		Severity-adjusted expectation of disability at age 60		% of remaining life at age 60 lived with severity-adjusted disability	
	M	F	M	F	M	F	M	F
EME	19·0	24·1	15·5	19·9	3·5	4·2	22·4	21·1
FSE	15·8	20·4	12·5	16·5	3·3	3·9	26·7	23·6
CHN	15·2	18·0	11·3	13·5	4·0	4·5	35·3	33·2
LAC	18·5	21·3	13·7	16·2	4·8	5·1	34·7	31·3
OAI	16·2	18·6	12·0	14·2	4·2	4·4	34·8	30·7
MEC	16·3	18·6	12·4	14·3	3·9	4·3	31·8	30·0
IND	15·1	16·3	11·2	12·2	3·9	4·1	35·0	33·2
SSA	14·7	15·9	9·6	11·1	5·1	4·9	52·7	44·2

*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**

Although the residual approximation method for disability could bias DFLE and DALE upwards, codisability 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 codisability 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 codisability in different populations more accurately. Disablity 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

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 disabilty 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.[3] 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 advantges. 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.[30] 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.[22] 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 each class of 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 McConnell 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.

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