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Healthy life expectancy in 191 countries, 1999

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We describe here the methods used to produce the first estimates of healthy life expectancy (DALE) for 191 countries in 1999. These were based on estimates of the incidence, prevalence, and disability distributions for 109 disease and injury causes by age group, sex, and region of the world, and an analysis of 60 representative health surveys across the world. We used Sullivan's method to compute healthy life expectancy for men and women in each WHO member country. Japan had the highest average healthy life expectancy of 74·5 years at birth in 1999. The bottom ten countries are all in sub-Saharan Africa, where the HIV-AIDS epidemic is most prevalent, resulting in DALE at birth of less than 35 years. Years of healthy life lost due to disability represent 18% of total life expectancy in the bottom countries, and decreases to around 8% in the countries with the highest healthy life expectancies. Globally, the male-female gap is lower for DALE than for total life expectancy. Healthy life expectancy increases across countries at a faster rate than total life expectancy, suggesting that reductions in mortality are accompanied by reductions in disability. Although women live longer, they spend a greater amount of time with disability. As average levels of health expenditure per capita increase, healthy life expectancy increases at a greater rate than total life expectancy.

For the first time ever, the WHO has assessed the performance of health systems of its 191 member countries in achieving three main goals for the health system: health, responsiveness, and fairness in financing.[1] The primary summary measure of population health used is disability-adjusted life expectancy, or DALE, which measures the equivalent number of years of life expected to be lived in full health, or healthy life expectancy. We describe the methods and data sources used to prepare the DALE estimates for the 191 member countries of WHO, and the results. In constructing these estimates, we sought to address some of the methodological challenges regarding comparability of health status data across populations and cultures.

In the past two decades, considerable international effort has been put into the development of summary measures of population health that integrate information on mortality and non-fatal health outcomes' and international policy interest in such indicators is increasing.[2–7] The Global Burden of Disease (GBD) project developed two such summary measures,[8–12] the disability-adjusted life year and DALE. Disability-adjusted life years measure the gap between a population's actual health and some defined goal, whereas DALE belongs to the family of health expectancies, summarising the expected number of years to be lived in what might be termed the equivalent of full health.

As a summary measure of the burden of disability from all causes in a population, DALE has two advantages over other summary measures. The first is that it is fairly easy to explain the concept of an equivalent healthy life expectancy to a non-technical audience. The second is that DALE is measured in units (expected years of life) that are meaningful to and within the common experience

of non-technical audiences (unlike other indicators such as mortality rates or incidence rates).

During the 1990s, disability-free life expectancy and related measures were calculated for many countries.[13–14] However, these measures incorporate a dichotomous weighting scheme in which time spent in any health state categorised as disabled is assigned arbitrarily a weight of zero (equivalent to death). Thus disability-free life expectancy is not sensitive to differences in the severity distribution of disability in populations. By contrast, DALE adds up expectation of life for different health states with adjustment for severity weights. DALE has been calculated in the Global Burden of Disease Study for eight regions of the world,[10] for Canada based on population prevalence data for health states together with measured utility weights[15] and for Australia using prevalence data from the Australian Burden of Disease Study and preference weights based on the Global Burden of Disease valuation methods.[16]

Disability-free life expectancy estimates based on self-reported health status information are not comparable across countries because of differences in survey instruments and cultural differences in reporting of health.[17] Despite considerable international efforts to standardise health status measurement,[18–21] fundamental problems with the crossnational comparability of self-report data remain.[22] We have analysed over 60 representative national health surveys and demonstrate how these comparability problems relate not only to differences in survey design and methods, but much more fundamentally to unmeasured differences in expectations and norms for health. For example, the cutpoints of scales for a given domain such as mobility might have very different meanings across different cultures or across socioeconomic groups within a society. Analyses of surveys containing both selfreport and objective measurements of health status have documented systematic biases in selfreport data according to age, sex, socioeconomic disadvantage, and other measures of social disadvantage within populations.[22]

Because of these problems with the comparability of population health survey data, we have developed an analytical approach for this first analysis of DALE for all WHO member countries, which combines the condition-

specific approach based in burden of disease analysis with the use of available representative population health survey data.

Life expectancy and causes of death
We developed new life tables and detailed cause of death distributions for all 191 WHO Member States starting with a systematic review of all available evidence from surveys, censuses, sample registration systems, population laboratories, and national vital registration systems on levels and trends of child and adult mortality.[23] In countries with a substantial HIV epidemic, separate estimates were made of the numbers and distributions of deaths due to HIV/AIDS and these deaths were incorporated into the life table estimates.[24] We analysed cause of death patterns to take into account incomplete coverage of vital registration in countries and the likely differences in cause of death patterns that would be expected in the low coverage areas of countries with incomplete data.[25]

Disability prevalence from burden of disease analysis
WHO is currently updating and revising estimates of the Global Burden of Disease for 14 mortality subregions of the world for the year 2000. These revisions draw on a wide range of data sources, and various methods have been developed to reconcile often fragmented and partial estimates of epidemiological variables that are available from different studies.[10,26] These analyses are used to calculate years lost due to mortality, years lived with disability, and total disability-adjusted life years by age, and sex for 130 causes of disease and injury.

For causes where mortality is responsible for a significant proportion of the total burden (years lived with disability/years lost due to mortality ratio less than five), regional estimates of years lived with disability/years lost due to mortality ratios by age and sex together with country level estimates of years lost due to mortality, and average health expenditure per capita, were used to estimate years lived with disability. For other causes, regional estimates of years lived with disability rates per 1000 population by age and sex were used together with country-level population distribution to estimate country-level years lived with disability. These incidence years lived with disability were then used to estimate undiscounted and non-age-weighted prevalence years lived with disability by age, sex, and cause. The years lived with disability/years lost due to mortality ratios were quite insensitive to health expenditure; in Europe, for example, a 10% increase in health expenditure per capita was associated with around 0·2% increase in the overall severity-weighted prevalence of disability.

Summation of prevalence years lived with disability over all causes would result in overestimation of disability prevalence because of comorbidity between conditions. We correct for independent comorbidity between major cause groups as follows:

$$D_{s,x} = 1 - \prod_g (1 - PLYD_{s,x,g})$$

where $PYLD_{s,x,g}$ is the prevalence years lived with disability per 1000 population for sex s, age x, and cause g, and $D_{s,x}$ gives the overall severity-weighted prevalence of disability by age and sex.

Disability prevalence from health surveys
We analysed 64 household interview surveys which included nationally representative health status and disability data for 46 countries. To improve the comparability of health status data derived from surveys with different designs and numbers and types of questions, we used confirmatory factor analysis to estimate one general underlying latent construct, non-fatal health status.[22] There were some countries, such as Ireland, Greece, and the USA (men only) where the latent health factor scores were in reasonable agreement with the prior disability estimates based on burden of disease analysis. However, for many countries there were substantial differences in the latent health factor scores due to differences in norms and expectations of health. Figure 1 shows results for the USA (NHANES III) and for India (National Integrated Household Survey 1995–96). US women report substantially worse health at older ages than men in comparison with previous estimates, whereas in India, as in many other less-developed countries, few people reported poor health or disability, resulting in quite low mean values for the latent health factor scores compared with the prior disability estimates.

We developed numerical models for estimating and adjusting for these factors, using prior estimates of disability distributions based on the burden of disease analyses. We described the relation between the latent health factor score and the true underlying health state (both scaled to range from 0 to 1), using a three variable model. The first variable specifies the disability weight for the worst health state observed in the health survey, the second variable specifies the latent health factor score above which all health states are equivalent to good health, and the third variable specifies a power transformation which allows the latent health factor score to decrease with increasing severity faster or slower than the true disability weight. We used this model to rescale latent health factor scores by age and sex for all the available health surveys in each region using generalised reduced gradient non-linear optimisation methods to estimate variable values which kept the overall average difference between the age-sex specific prior disability estimates and the rescaled factor score to a minimum. This procedure enabled us to incorporate all data from household surveys into our estimates of average levels of severity-weighted disability for countries. The health survey data results in moderate changes in the level and age trends of disability prevalences for the European countries, and somewhat larger changes for many less-developed countries.[27] For countries where we were not able to obtain appropriate household survey data, we used the disability prevalences derived from the country-level burden of disease analyses.

Sullivan's method[27] was used to compute DALE. This method multiplies the L_X values (total years lived between exact ages x and x+5) from the abridged country life table by the severity-weighted prevalence of disability (adjusted for comorbidity) in the age range (x, x+5) to estimate the equivalent healthy years of life lost to disability in the age range. Subtraction of this from the total years lived, L_X, gives the number of years of healthy life lived between ages x and x+5, and summation over subsequent ages allows the computation of healthy life expectancy.

The uncertainty distributions of the DALE estimates for each member state were quantified by developing a total of 1000 DALE life tables for each member state which simultaneously sampled the uncertainty in the life table variables and the disability prevalences. Uncertainty in the DALE ranks for countries was also estimated. This is not only a function of the uncertainty of the DALE measurement for each country, but also the uncertainty of the measurement of adjacent countries in the ranking table.
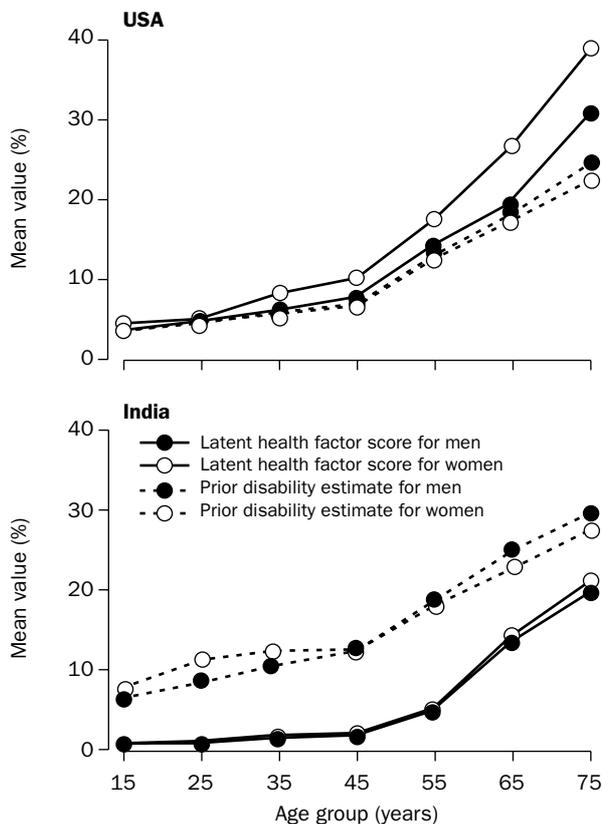
Figure 1: **Comparison of latent health factor scores and previous disability prevalences from condition-specific analyses in USA and India in 1999**

We examined the relation between DALE and other indicators such as total life expectancy and average health expenditure per capita using linear regression. The classic linear regression model assumes that all uncertainty (characterised as error) has zero mean and is independently and identically distributed across observations, and is estimated from the sample of observations. This does not take into account the estimated uncertainty distribution of each observation. Because practical analytical methods are generally lacking, it is almost universal to ignore this layer of uncertainty. To account for uncertainty surrounding DALE in the regression analyses, for each country, one DALE observation was drawn from the uncertainty distribution of DALE for that country—that value of DALE, for each of the 191 countries, was regressed against the observations of the X values (health expenditure per capita or total life expectancy). The process was repeated 1000 times, sampling without replacement from the DALE distribution for each country, each time running a new set of regressions of DALE on the X values. This resulted in 1000 estimates of the regression slope, which allowed for estimation of its 90% CI.

Global patterns of healthy life expectancy

Japan leads the world with an estimated average healthy life expectancy of 74·5 years at birth in 1999 (table). Healthy life expectancy in Japan was 77·2 years for women and 71·9 years for men in 1999. After Japan, in second and third places, are Australia and France, followed by a number of other industrialised countries of Western Europe. Canada is in twelfth place with an uncertainty range of 8–14 in ranking and the USA in 24th place (70·0 years with a ranking range of 22–27).
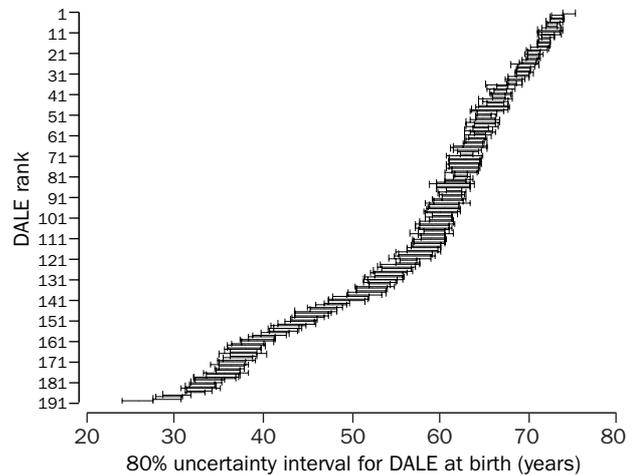

Figure 2: **Uncertainty in DALE vs mean DALE at birth in 191 countries ranked by DALE in 1999**

Other countries with reasonably high healthy life expectancies in the Americas include Dominica, Chile, Cuba, Uruguay, Argentina, and Costa Rica. Note that there is a considerable range of uncertainty in the ranks for most countries (figure 2), resulting in an 80% uncertainty range of around 6–10 ranks for many countries.

China has a healthy life expectancy above the global average, at 62·3 years, 63·3 years for women, and 61·2 for men. Other countries in the Asian region such as Vietnam and Thailand have a lower DALE. Healthy life expectancy in Myanmar is substantially behind its southeast Asian neighbours.

In Russia, healthy life expectancy is 66·4 years for women, 3 years below the European average, but just 56·1 years for men, 7 years below the European average. This is one of the widest sex gaps in the world and reflects the sharp increase in adult male mortality in the early 1990s. Similar rates exist for other countries of the former Soviet Union.

The ten countries with the lowest DALE are all in sub-Saharan Africa, where the HIV-AIDS epidemic is most prevalent. Life expectancy in several countries in southern Africa has been reduced by 15–20 years in comparison with life expectancy without HIV. Other African countries have lost 5–10 years of life expectancy because of HIV.[23] Full details of male and female DALE, together with uncertainty ranges are available in the World Health Report 2000.[1]

Overall, global life expectancy at birth in 1999 was 64·5 years, an increase of almost 6 years over the past two decades. Global healthy life expectancy at birth was 56·8 years, 7·7 years lower than total life expectancy at birth. Healthy life expectancy at the global level was 57·8 years for women, 2·0 years higher than that for men at 55·8 years. Figure 3 shows global estimates of DALE, DLE (expected years lost due to disability), and life expectancy for 1999 at 15 year age intervals. DALE at birth in 1999 ranged from a low of 37 years for African men to a high of almost 70 years for women in the low mortality countries of mainly western Europe. This is an almost two-fold difference in healthy life expectancy between major regional populations of the world. The difference between DALE and total life expectancy is DLE, which at birth ranges from 18.9% (of total life expectancy at birth) in Africa to 8.8% in European regions.

There is a reasonably close correlation across countries between total life expectancy and DALE at birth

Rank	Member State	DALE (years)	Rank	Member State	DALE (years)	Rank	Member State	DALE (years)
1	Japan	74·5	65	Azerbaijan	63·7	129	Guatemala	54·3
2	Australia	73·2	66	Qatar	63·5	130	Maldives	53·9
3	France	73·1	67	Cook Islands	63·4	131	Mongolia	53·8
4	Sweden	73·0	68	Kuwait	63·2	132	Sao Tome and Principe	53·5
5	Spain	72·8	69	Estonia	63·1	133	Bolivia	53·3
6	Italy	72·7	70	Ukraine	63·0	134	India	53·2
7	Greece	72·5	71	Paraguay	63·0	135	Vanuatu	52·8
8	Switzerland	72·5	72	Oman	63·0	136	Nauru	52·5
9	Monaco	72·4	73	Turkey	62·9	137	North Korea†	52·3
10	Andorra	72·3	74	Colombia	62·9	138	Bhutan	51·8
11	San Marino	72·3	75	Tonga	62·9	139	Myanmar	51·6
12	Canada	72·0	76	Sri Lanka	62·8	140	Bangladesh	49·9
13	Netherlands	72·0	77	Suriname	62·7	141	Yemen	49·7
14	United Kingdom	71·7	78	Mauritius	62·7	142	Nepal	49·5
15	Norway	71·7	79	Dominican Republic	62·5	143	Gambia	48·3
16	Belgium	71·6	80	Romania	62·3	144	Gabon	47·8
17	Austria	71·6	81	China	62·3	145	Papua New Guinea	47·0
18	Luxembourg	71·1	82	Latvia	62·2	146	Comoros	46·8
19	Iceland	70·8	83	Belarus	61·7	147	Laos‡	46·1
20	Finland	70·5	84	Algeria	61·6	148	Cambodia	45·7
21	Malta	70·5	85	Niue	61·6	149	Ghana	45·5
22	Germany	70·4	86	Saint Kitts and Nevis	61·6	150	Congo	45·1
23	Israel	70·4	87	El Salvador	61·5	151	Senegal	44·6
24	USA	70·0	88	Republic of Moldova	61·5	152	Equatorial Guinea	44·1
25	Cyprus	69·8	89	Malaysia	61·4	153	Haiti	43·8
26	Dominica	69·8	90	Tunisia	61·4	154	Sudan	43·0
27	Ireland	69·6	91	Russian Federation	61·3	155	Côte d'Ivoire	42·8
28	Denmark	69·4	92	Honduras	61·1	156	Cameroon	42·2
29	Portugal	69·3	93	Ecuador	61·0	157	Benin	42·2
30	Singapore	69·3	94	Belize	60·9	158	Mauritania	41·4
31	New Zealand	69·2	95	Lebanon	60·6	159	Togo	40·7
32	Chile	68·6	96	Iran, Islamic Republic of	60·5	160	South Africa	39·82
34	Slovenia	68·4	98	Guyana	60·2	162	Kenya	39·3
35	Czech Republic	68·0	99	Thailand	60·2	163	Nigeria	38·3
36	Jamaica	67·3	100	Uzbekistan	60·2	164	Swaziland	38·1
37	Uruguay	67·0	101	Jordan	60·0	165	Angola	38·0
38	Croatia	67·0	102	Albania	60·0	166	Djibouti	37·9
39	Argentina	66·7	103	Indonesia	59·7	167	Guinea	37·8
40	Costa Rica	66·7	104	Micronesia, Federated States of	59·6	168	Afghanistan	37·7
41	Armenia	66·7	105	Peru	59·4	169	Eritrea	37·7
42	Slovakia	66·6	106	Fiji	59·4	170	Guinea-Bissau	37·2
43	Saint Vincent & Grenadines	66·4	107	Libyan Arab Jamahiriya	59·3	171	Lesotho	36·9
44	Georgia	66·3	108	Seychelles	59·3	172	Madagascar	36·6
45	Poland	66·2	109	Bahamas	59·1	173	Somalia	36·4
46	Yugoslavia	66·1	110	Morocco	59·1	174	Congo, Democratic Republic	36·3
47	Panama	66·0	111	Brazil	59·1	175	Central African Republic	36·0
48	Antigua and Barbuda	65·8	112	Palau	59·0	176	United Republic of Tanzania	36·0
49	Grenada	65·5	113	Philippines	58·9	177	Namibia	35·6
50	United Arab Emirates	65·4	114	Syrian Arab Republic	58·8	178	Burkina Faso	35·5
51	Republic of Korea	65·0	115	Egypt	58·5	179	Burundi	34·6
52	Venezuela, Bolivarian Rep. of	65·0	116	Viet Nam	58·2	180	Mozambique	34·4
53	Barbados	65·0	117	Nicaragua	58·1	181	Liberia	34·0
54	Saint Lucia	65·0	118	Cape Verde	57·6	182	Ethiopia	33·5
55	Mexico	65·0	119	Tuvalu	57·4	183	Mali	33·1
56	Bosnia and Herzegovina	64·9	120	Tajikistan	57·3	184	Zimbabwe	32·9
57	Trinidad and Tobago	64·6	121	Marshall Islands	56·8	185	Rwanda	32·8
58	Saudi Arabia	64·5	122	Kazakhstan	56·4	186	Uganda	32·7
59	Brunei Darussalam	64·4	123	Kyrgyzstan	56·3	187	Botswana	32·3
60	Bulgaria	64·4	124	Pakistan	55·9	188	Zambia	30·3
61	Bahrain	64·4	125	Kiribati	55·3	189	Malawi	29·4
62	Hungary	64·1	126	Iraq	55·3	190	Niger	29·1
63	Lithuania	64·1	127	Solomon Islands	54·9	191	Sierra Leone	25·9
64	TFYR Macedonia*	63·7	128	Turkmenistan	54·3			

*The Former Yugoslav Republic of Macedonia. †Democratic Peoples Republic of Korea. ‡Lao People's Democratic Republic.

DALE at birth in WHO member states in 1999

(figure 4). The gap between life expectancy and DALE corresponds to DLE and there is a small but significant decline in DLE at birth as life expectancy increases. Taking the uncertainty of the life expectancy and DALE estimates into account in the regression analysis, we estimate that the decline in DLE with increasing life expectancy differs significantly from zero at $p=0.10$ for both men and women with regression slopes of -0.053 and -0.035, respectively.

Healthy life expectancies at birth are higher for women than men in most regions in the world and the difference between sexes generally increases as average life expectancy increases. Russia has one of the widest sex gaps in healthy life expectancy in the world: 66·4 years for women at birth but just 56·1 years for men. The most common explanation is the high incidence of male alcohol abuse, which led to high rates of accidents, violence, and cardiovascular disease. From 1987 to 1994, the risk of premature death increased by 70% for Russian men. Since 1994, life expectancy has been improving for men. Similar rates exist for other major countries of the former
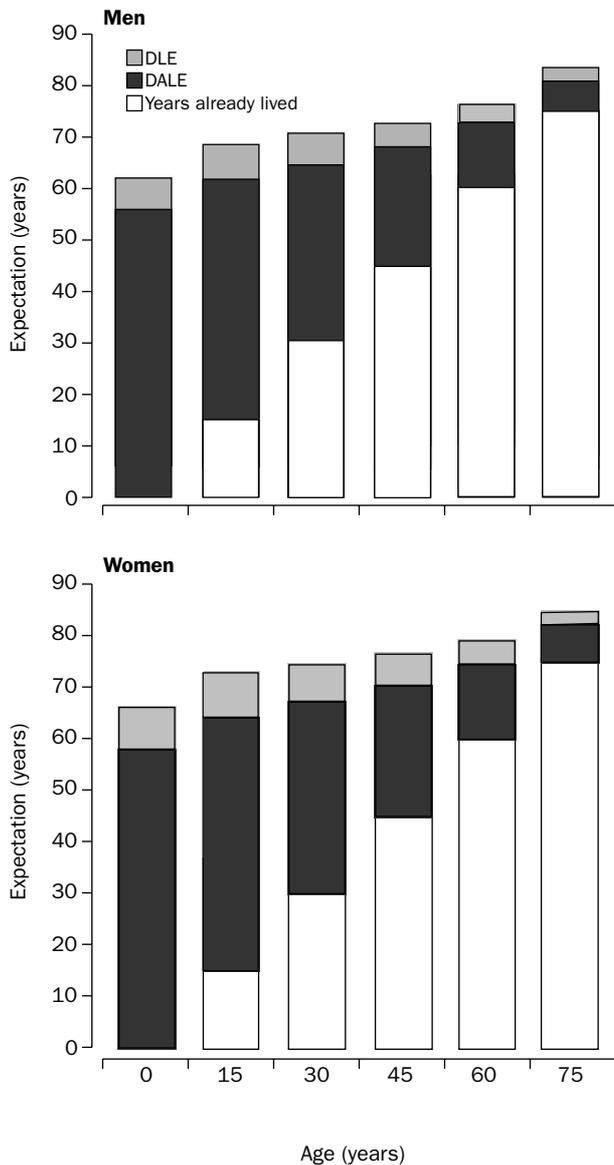
Figure 3: **Global DALE, global healthy years lost due to DLE and global life expectancy by age in 1999**

Figure 4: **DALE by total life expectancy at birth by sex in 191 countries in 1999**

Some conclusions

Despite the fact that people live longer in the richer, more developed countries, and have greater opportunity to acquire non-fatal disabilities in older age, disability has a greater absolute (and relative) impact on healthy life expectancy at birth in poorer countries. Separating life expectancy into equivalent years of good health and years of lost good health thus widens rather than narrows the difference in health status between rich and poor countries. Cross-sectionally, at the the global level, higher life expectancy at birth is associated with a compression of mordidity: fewer expected years of good health are lost due to the non-fatal consequences of diseases and injury as mortality rates decline. There is some evidence to suggest that compression of morbidity may be occurring over time in some low mortality countries as mortality rates at older ages continue to decline.[29–30]

Looking across countries, as average levels of health expenditure per capita increase, healthy life expectancy increases at a greater rate than total life expectancy. Although this result might be due to compression of morbidity with increasing life expectancy, it is also possible that health systems contribute to a lowering of disability levels. Further developments in the methods used by the WHO to analyse the contribution of health systems to average levels of population health may shed more light on this question.[1]

At a global level, women live on average 3.9 years longer than men, but lose the equivalent of 1·9 extra years of good health to the non-fatal consequences of diseases and injuries. In other words, although women live longer, they spend a greater amount of time with disability. However, this global average disguises enormous variations across the world in the sex difference in healthy life expectancy. The male-female gap in healthy life expectancy varies from a high of 10 years in some former Soviet Union countries to a low of −1·5 years for some Middle Eastern countries.

As with any innovative approach, there are substantial limitations and gaps in the information base required for estimating healthy life expectancy for all countries of the

Soviet Union (such as Latvia, Estonia, Belarus, and Kazakhstan). In North Africa and the Middle East, men and women have similar healthy life expectancies, which is unusual. In Saudi Arabia, for example, the healthy life expectancy at birth is 65·1 years for men compared with 64·0 years for women. Similarly in Qatar, male DALE at birth is higher than female: 64·2 years for men and 62.8 years for women. Contributing to these sex differences are higher female infant and child mortality rates, and higher risks of maternal mortality than in other countries, reflecting the position of women in these societies.

As shown in Figure 5, there is a striking relation across countries between DALE at birth in 1999 and average health expenditure, measured for each country for 1997 in US$ per capita using purchasing power parity exchange rates.[28] For countries with expenditure of over $100 per capita in 1997, the regression slope of DALE against the log of health expenditure per capita is 11·6, compared with 10·9 for a comparable regression of total life expectancy at birth. The difference in these two rates is significant at the 90% level.
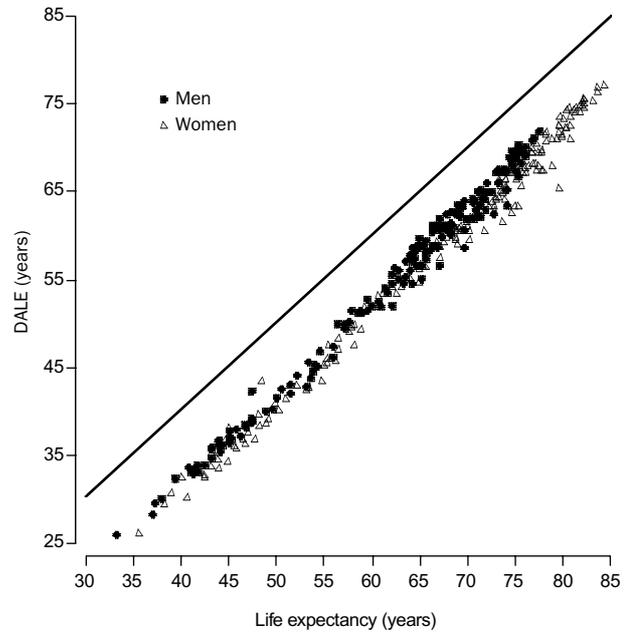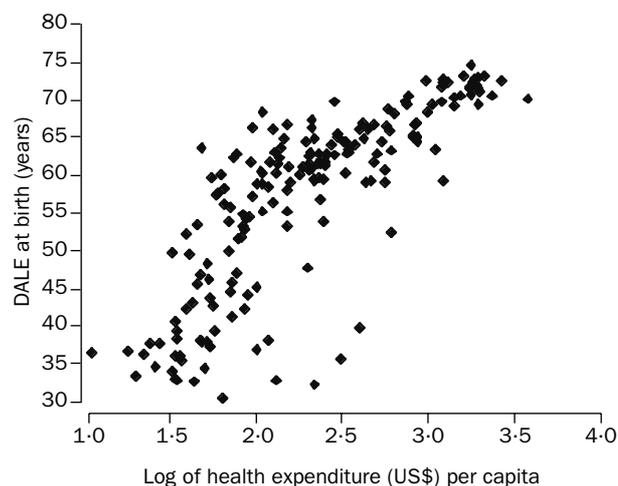
Figure 5: **DALE at birth in 1999 by average health expenditure per capita in 1997 in 191 countries**

world. We have attempted to maximise the comparability of the data derived from available nationally representative health surveys, but conclude that the valid comparison of self-report health status data across countries is limited due to non-random reporting differences even where the survey methods and data collection approaches are standardised. For the estimates reported here, we have used additional cross-population comparable information on health status derived from analysis of epidemiological data sources to improve comparability.

Since the publication of the World Health Report 2000, a substantial effort has been invested in improving the methods and in developing and refining data sources used for estimating healthy life expectancy. WHO has developed a standardised description of health states for use in population surveys and health state valuation, together with calibration methods that can be used in household and postal surveys, to improve the cross-population comparability of self-report data. A variant of item response theory has been developed to enable the cross-population calibration of self-report data for health domains.[31] The collection of population health data in over 70 countries using the WHO instrument will assist in improving the estimation of healthy life expectancy for the year 2000. Another objective for the ongoing WHO population survey work is to facilitate reliable and valid measurements of valuations of time spent in health states in populations across the world. The aim is to obtain large scale empirical assessment in many different countries to inform health state valuations for the calculation of healthy life expectancy. In addition, WHO is investing considerable resources in the revision of the Global Burden of Disease estimates for the year 2000. These estimates will also contribute to improved estimation of healthy life expectancy, which will in turn assist in monitoring global health trends and the performance of national health systems.

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Uses of error: the wrong research costs lives

Pneumonia is the commonest cause of death among children, and over 98% of the deaths occur in developing countries. This might not be the case if we had done a large controlled trial of the polysaccharide pneumococcal vaccine in the 1980s.

In the 1970s, many different viruses and bacteria were thought to cause pneumonia and little could be done to prevent children dying.[1] However, many clinicians working in developing countries suspected that most severe pneumonia was caused by bacterial infection - clearly, we needed more information. Bob Douglas persuaded me to do lung aspirates to obtain reliable information about the cause of pneumonia in children in Papua New Guinea. The results were available by the early 1980s, and they confirmed that almost all very severe cases were caused by *Streptococcus pneumoniae* or *Haemophilus influenzae*.[2] Thus, mortality from pneumonia could be reduced by giving antibiotics. However, antibiotics would clearly be only a short-term solution—they would be hard to deliver to the poorest children, who needed them most, and resistance would develop quickly. We really needed vaccines.

Polysaccharide capsular vaccines against pneumococcus had been available for many years, but the conventional wisdom was that these vaccines were not effective in children less than about 2 years of age—and most of the deaths occur in this age group. However, Ian Riley had done a small controlled trial of polysaccharide pneumococccal vaccine in Papua New Guinea in 1974-77.[3] The results were not statistically significant, but mortality among children aged less than 2 years at vaccination was 21·1 per 1000 person years in the placebo group and only 14·1 in the vaccine group. More children were studied in controlled trials in Tari and Asaro in Papua New Guinea in 1981-85.[3] In Tari, mortality was again lower in the vaccine group, but there was a trend towards a higher mortality with the vaccine in Asaro. When the three trials were combined, the vaccine reduced total mortality by 25% in children younger than 2 years of age, but the reduction was not significant (95% CI -6 % to 47%).[3]

This finding was very controversial—it conflicted with the conventional wisdom that the vaccine does not work in children younger than 2 years of age, it was really three separate trials combined, and the reduction in total mortality was substantial but not statistically significant. The controversy occurred in the late 1980s, when it seemed that polysaccharide-protein conjugate vaccines against pneumococcus would be available in just a few years. I argued, as did many others, that it was not worth doing further trials of the polysaccharide vaccine in young children—we should just wait for the conjugate vaccine.

This was a serious mistake. The first conjugate vaccine was not licensed until 14 years after the Papua New Guinea study was published. In addition, the conjugate vaccines are difficult to make, so that they are likely to be far too expensive for developing countries for many years—perhaps another 14 years, judging by past experience.[4] On the other hand, the polysaccharide vaccine is easy to produce in large quantities, and it is inexpensive and safe. Substantial reductions in mortality might be achieved if we gave the vaccine to women in late pregnancy (to protect the baby in the first months of life[5]), and to the infant at 8-9 months of age.

In 1998, I belatedly argued that there is still a need for another controlled trial of the polysaccharide pneumococcal vaccine.[6] If the vaccine really does reduce total mortality by 25%, and an average of 12 million children died each year for the past 14 years, 42 million deaths might have been prevented. Even if the vaccine reduces total mortality by only 10%, 17 million children have died unnecessarily.

Mistakes in setting research priorities can have a much greater effect than errors in the clinical management of individual patients—and this is especially true in developing countries, where mortality rates are so high and the resources available for research are so limited.

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