Chapter 26

Healthy Life Expectancy

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Historical Development

Historically, mortality data have been used to monitor the health of populations, because they are relatively easily collected and comparable across countries. Thus, decreasing mortality rates have been seen as reflecting improving population health. While this was a reasonable assumption when the burden of ill-health was due to acute, infectious diseases, the substantial increases in life expectancy that have taken place over the previous century, but particularly in the last 30 or 40 years, have seen a shift to more long-standing, chronic diseases, such as heart disease, stroke, and dementia, as our populations age. So mortality rates no longer correlate as well with the burden of ill-health in the population, necessitating new measures, such as health expectancies, that capture the quality rather than or as well as the quantity of life.

During the 1970s, a number of theories began to emerge on the relationship between the quantity and quality of remaining life. Kramer (Kramer 1980) reasoned that the increases in life expectancy were a result of medical technology prolonging the life of the frail and sick who would previously have died, resulting in an expansion of morbidity. Fries (1980, 2000), on the other hand, proposed that there was a natural limit to life and that prevention could delay the onset of disease and disability to minimize the gap between the morbidity and mortality curves (Fig. 26.1). The consensus is that there is no evidence thus far to suggest that a natural limit exists, since in most countries life expectancy gains are not slowing down. A third, intermediate scenario was later put forward that suggested that although morbidity/disability might increase, its severity on average would be reduced (Manton 1982).

Definition of Health Expectancy

Health expectancies divide life expectancy into years lived in different health states. They are a natural extension of life expectancies and were developed in response to exploring which of the "aging scenarios" was true. Life expectancies are the average number of years of life remaining at a particular age, considering current mortality. For example, in 2006 the female life expectancy at birth in the United Kingdom was 81.6 years, so a baby girl born in 2006 could expect to live to age 82, assuming that the conditions of 2006 prevailed over her whole life. By considering not only mortality, but also ill-health at particular ages, we can divide this remaining number of years into years spent in good and bad health; these are then health expectancies. The notion of health expectancy was first introduced in 1964 by Sanders, and 5 years later Sullivan (1971) documented its calculation.

One can question what extra information is brought by health expectancies, since the amount of ill-health in a population is often measured by the prevalence alone. However, because our populations are getting older, with more people surviving to the oldest age

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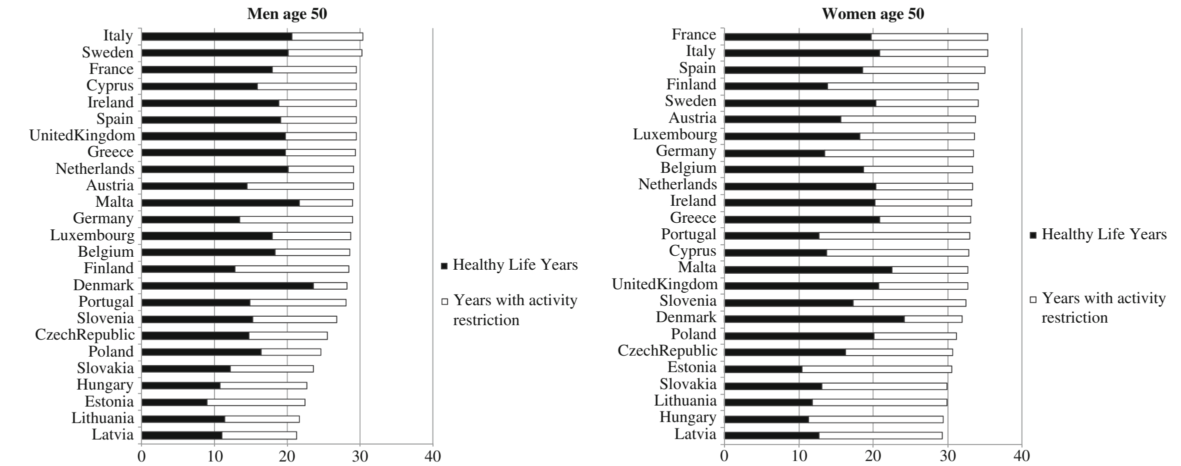


Fig. 26.1 Healthy life years at age 50 for EU countries. Source: EU-SILC 2005

groups, and older people are more likely to suffer from disability and multiple comorbidities, overall prevalence may increase in a population without individuals being more at risk of ill-health than previously. Health expectancies take into account both the changes in living with ill-health and the changes in mortality, which are responsible for the increase in life expectancy. Therefore, improving population health in an aging population leads to an increase in the part of life expectancy spent in good health despite an increase in the overall prevalence of ill-health due to more people being at risk. Health expectancy is therefore a potent tool to identify the interaction among health, ill-health, and mortality.

The scenarios of compression and expansion of morbidity and dynamic equilibrium have now been more clearly defined in terms of health expectancies by further concepts of absolute and relative compression/expansion (Nusselder 2003; Robine and Mathers 1993). *Absolute* compression of morbidity (or disability) occurs if the total years spent with morbidity decrease, whereas a *relative* compression of morbidity occurs when the years lived with morbidity decrease as a proportion of total life expectancy. An absolute compression of morbidity generally coincides with a relative compression, but an absolute expansion of morbidity can coincide with a relative expansion, equilibrium, or compression of morbidity, depending on how total life expectancy and life expectancy free of morbidity are increasing relative to each other. We explore this later in the chapter with examples from different countries.

Types of Health Expectancy

As health expectancies combine mortality with a health measure, there are as many health expectancies as health measures. The most popular indicator is disability-free life expectancy (DFLE), but it is also possible to construct many other indicators that might measure healthy life. A number of countries routinely monitor life expectancy "in good perceived health" (often known as healthy life expectancy) (Bronnum-Hansen 2005; White 2009). However, a limited number of "disease-free" life expectancies have also been estimated, for example, dementia-free life expectancy (Perenboom et al. 1996; Ritchie et al. 1994; Roelands et al. 1994; Sauvaget et al. 1997), life expectancy free of cognitive impairment (Dubois and Hebert 2006; Lievre et al. 2008; Matthews et al. 2009; Sauvaget et al. 2001; Suthers et al. 2003), life expectancy without diabetes (Jonker et al. 2006; Laditka and Laditka 2006), and life expectancy without cardiovascular disease (Crimmins et al. 2008; De Laet et al. 2003; Franco et al. 2005, 2007; Mamun et al. 2004; Pardo Silva et al. 2006).

Calculation Methods

Health expectancy calculation broadly follows life expectancy calculation, with the numbers of individuals in each age interval of the life table partitioned according to the age-specific probabilities of being in each of the health states under consideration. In life expectancy, the age-specific probabilities of dying are derived from the registered number of deaths and are thus *flow* data collected over a defined period. The age-specific probabilities of being in each of the health states for the health expectancy should be derived similarly, which means from the incidence rates of entry into and exit from the health state. Practically, this is difficult, since data on transitions in and out of health states, unlike data on mortality, are not collected regularly. As a consequence, direct calculation of the incidence rates is often difficult, and the "period prevalence" associated with the states under study is estimated as the proportion of the population in the state over a specific period of time. Three main methods for calculating health expectancy exist, and these correspond to the different approaches to estimate the transition rates or "period prevalence:" cross-sectional or observed prevalence life table methods (the Sullivan method); increment–decrement or multistate life table methods; and multiple-decrement life table methods.

Cross-Sectional Methods

The Sullivan method remains the most popular method of calculating health expectancies, since the only data required are the prevalence of ill-health within age groups (usually 5- or 10-year age groups) and by gender from a cross-sectional survey of the population, and a period life table for the population for the same time period as the survey. The prevalence of ill-health is then applied to the person-years lived (L_x) to produce the years lived in bad health. The life table is then constituted in the usual way, although the end product is now life expectancy in bad health. Life expectancy in good health is formed from the total life expectancy at a particular age minus the life expectancy in bad health. The period prevalence has been estimated therefore by the observed prevalence, providing an approximation of true period conditions. This has been shown to be a reasonable approximation provided that the health transition under study is stable over time or evolves regularly (Mathers and Robine 1997). More recent research has provided a statistical underpinning to the method and shown that the Sullivan estimator of DFLE is unbiased and consistent under the less stringent assumptions of stationarity (Imai and Soneji 2007). Further details of the Sullivan method, together with a training manual (Jagger 1999) and Excel spreadsheets for the calculation, can be found online at www.ehemu.eu. A Bayesian formulation of the Sullivan method has also been developed (Lynch and Brown 2005).

Health expectancies are usually formed with two states—for instance, with and without disability—but more levels of severity may be included and indeed are necessary to address the dynamic equilibrium scenario. Although health expectancy calculation apportions only a binary weighting (zero or one) to the health or disability state, it is possible to include a weighting system based on severity levels, similar to that of quality adjusted life years (QALYs), thus obtaining a disability-adjusted life expectancy (DALE) or health-adjusted life expectancy (HALE), such as disability-adjusted life years (DALY) (Murray and Lopez 1997b).

Health expectancies using the Sullivan method have now been calculated for over 50 countries (Robine et al. 1999), many by members of the International Network on Health Expectancy and the Disability Process (REVES) (www.reves.net). The obvious benefits of the Sullivan method are the relative availability of data, its requirements being only a population life table and the prevalence of ill-health from a cross-sectional survey. It is also the preferred method for assessing trends in health expectancies, information that is essential for determining whether countries are undergoing compression or expansion of morbidity. Though more and more countries have national health surveys conducted regularly, relatively fewer countries have good time series on health expectancies (Robine et al. 2003). We summarize these later in this chapter, but it is worth noting here the key elements necessary to compare health expectancies either between or within countries over time as follows:

- The *general design of the surveys* used to derive prevalence should be identical, as estimates of the prevalence of ill-health can be sensitive to the method by which the data are collected (e.g., face-to-face interview, telephone interview, postal questionnaire) as well as to any change in the questionnaire itself (Cambois et al. 2007).
- The *definition of health* used in the calculation of prevalence of health should be identical, since differences between health expectancies calculated for different countries have been explained by differences in the measurement instruments used

to collect the prevalence data (Buratta and Egidi 2003).

- If possible, health expectancies should be compared on *total populations*. Life tables generally include total populations, but surveys from which the prevalence of the health states are derived often exclude people in institutions. Omitting these may produce bias, particularly for older populations and for certain health conditions associated with admission to institutional care, such as dementia (Ritchie 1994). It is therefore preferable that either the prevalence survey include those in institutions or a separate survey of those in institutional care be undertaken to estimate prevalence and be combined with the prevalence outside institutions by weighting. If these requirements are impossible to meet, then with knowledge of the size of the population in institutions, assumptions can be made about the prevalence, and these can then be combined using appropriate weighting.
- The *final age group in the life table* should be the same when the Sullivan method is used, since the age distribution of this group may be substantially different between surveys, also affecting the comparability of health expectancies.

Multistate Methods

While prevalence reflects past and present incidence and survival, and therefore the Sullivan (1971) method implicitly includes past transitions to and from ill-health, multistate life tables explicitly apply incidence, recovery, and mortality rates to a population to estimate the years spent in good or bad health by age. The essential component for multistate life tables is longitudinal data, and this has been the reason why these methods are less well-used than the Sullivan method and have been increasing in popularity only over the last two decades, alongside the increase in large-scale longitudinal studies (Crimmins et al. 1994; Rogers et al. 1989).

Though theoretically a person can make multiple movements in and out of states within a time period (Schoen 1988), and the incidence rates reflect this fact, the nature of longitudinal surveys, with relatively long intervals between interviews, means that states are observable only at the ends of intervals, and multiple movements between these states are unobserved. It is generally assumed, therefore, that individuals make only one transition between interviews; hence the method underestimates the number of transitions, and this may be particularly acute at older ages (Laditka and Hayward 2003; Wolf and Gill 2009).

Multistate life tables have two major advantages over the Sullivan method. First, health expectancies allow comparison of the evolution of health status between different subpopulations, often defined by region, gender, education, or race. The Sullivan method is limited since such analyses require life tables to be available for subgroups, and for many countries only regional life tables are easily accessible. Multistate methods, on the other hand, can more readily incorporate covariates to define subpopulations for comparison. Second, since the incidence rates to and from ill-health and to death are explicitly estimated, their relative contributions to the prevalence of ill-health can be ascertained, and this can be important in explaining differences between subpopulations (Jagger et al. 2007b).

One disadvantage of longitudinal data is that they are often subject to attrition between survey waves and, in some cases, the intervals between survey waves are unequal. Microsimulation techniques have been developed in software such as interpolated Markov chain (IMaCH) (Lievre et al. 2003), and these have been key in the analysis of irregularly spaced data, a particular feature of the Medical Research Council Cognitive Function and Ageing Study (MRC CFAS) (Jagger et al. 2007a, b; Peres et al. 2008). Programs for multistate life tables have been written for STATA (see http://www.ssc.wisc.edu/~mweden/), for SAS (Cai et al. 2006), and using Bayesian techniques (van den Hout and Matthews 2009). A further issue is that if the interval between waves is long, then transitions may be missed, though intervals of 1–2 years are thought to be sufficient to accurately estimate active and disabled life expectancy (Gill et al. 2005).

Multiple-Decrement Methods

Multiple-decrement life tables are a special case of multistate life tables that include transitions to ill-health and death but not the return to the initial state (that is, recovery of health). The probabilities of survival by age in the initial (active) state can be estimated from two waves of data collection, and these are then applied, age by age, to a hypothetical cohort to obtain the active life table of the survey population. Katz et al. (1983) used a multiple-decrement life table to calculate active life expectancy using longitudinal data, but this method is of particular interest for states (often disease states) where recovery is impossible, for instance stroke-free or dementia-free life expectancy. In certain instances, for example, cognitive impairment, transitions to improved states are assumed to be impossible, though educational bias (and learning or practice effects) with cognitive measurement scales may result in apparent improvement. Recent advances in statistical modeling have dealt with these by assuming that such transitions are misclassification errors (van den Hout and Matthews 2008).

Relevance of Health Expectancies

This section reviews how health expectancies have been used to identify inequalities between spatial groupings (country, region) and social groupings within populations defined by gender, race, and social disadvantage (education, social class, income, deprivation). Though these analyses may go some way to address the important issue of compression of morbidity by identifying whether the extra years lived by one group are years of healthy life, definitive answers can come only from comparable time trends within countries. We review the few countries that have these data. Finally, we detail how health expectancies, in particular disability-free life expectancy, have allowed a fuller exploration of the public health impact of both fatal and nonfatal disease.

Spatial Comparisons

Global estimates of health expectancy. Estimations of health expectancies (disease-free, disability-free, or healthy life expectancy) were available for 67 countries in the REVES database (available at www.reves.net) as of April 2009 (see Table 26.1). These were predominantly European (29) and Asian (15) countries,

Table 26.1 List of the 67 countries for which at least one estimation of health expectancy was available in the REVES database by April 2009

Africa (9)	Asia (15)	Europe (29)	Europe (contd.)
Botswana*	Burma*	Austria	Slovak Rep.
Egypt*	Cambodia	Belgium	Slovenia
Ethiopia*	China (mainland)	Bulgaria	Spain
Ghana	India	Cyprus*	Sweden
Mali*	Indonesia	Czech Republic	Switzerland
Mauritius*	Japan	Denmark	United Kingdom
South Africa	Korea (North)*	Estonia*	
Sudan	Korea (South)*	Finland	*Oceania (2)*
Tunisia	Malaysia*	France	Australia
	Pakistan*	Germany	New Zealand
America, North (2)	Philippines	Greece*	
Canada	Singapore	Hungary	
USA	Sri Lanka*	Ireland	
	Taiwan	Italy	
America, Central (4)	Thailand	Latvia*	
Mexico		Lithuania*	
Antilles (Nether.)	*Middle East (4)*	Luxemburg*	
Cuba	Bahrain*	Netherlands (the)	
Trinidad and Tobago*	Israel*	Norway	
	Jordan*	Malta*	
America, South (2)	Kuwait*	Poland	
Brazil		Portugal	
Venezuela*		Russian Fed.	

*Indicates countries part of international studies not having independent national published values or studies.

but there are also estimates for almost all the countries of North and Central America, as well as Oceania. Indeed, the REVES bibliography database contained, by April 2009, 207 studies for the United States, 74 for Canada, 73 for the United Kingdom, 72 for the Netherlands, 65 for France, 51 for Japan, 42 for Spain, 36 for Denmark, 32 for Australia, 29 for China, 27 for Belgium, 25 for Italy, 11 for Taiwan, and 6 for Brazil.

Setting aside China, Taiwan, and Brazil, most studies report values for the most advanced western and Japanese economies. However, the REVES database contains health expectancy estimates for some less-developed and developing countries, for instance Cambodia, Cuba, Ghana (including working life expectancy), India, Indonesia, Philippines, the Russian Federation, Singapore, South Africa, Sudan, Thailand, Tunisia, the Caribbean in general, and the Netherlands Antilles. In total, the database contains estimates from independent national published values or studies for 43 countries (4 in Africa, 2 in North America, 3 in Central America, 1 in South America, 9 in Asia, 22 in Europe, and 2 in Oceania). In addition, estimates of health expectancies have been produced in ten developing countries in the context of international studies: for Bahrain, Egypt, Jordan, and Kuwait in a study of the elderly in eastern Mediterranean countries (Lamb et al. 1994); for Bahrain, Egypt, Ethiopia, Mali, and Pakistan in a study of aging and disability in the third world (Romieu and Robine 1994); for Botswana, Mauritius, Trinidad and Tobago, and Venezuela in a study by the United Nations (Haber and Dowd 1994); for five Asian countries (Burma, Malaysia, North Korea, South Korea, and Sri Lanka) in the framework of an international training on health expectancy calculation organized by Asia-REVES (Saito et al. 2003); for Israel in the framework of a European study (Minicuci et al. 2004); and for seven European countries (Cyprus, Estonia, Greece, Latvia, Lithuania, Luxemburg, and Malta) by Eurostat and the European Health Expectancy Monitoring Unit (EHEMU) (Jagger et al. 2008).

As the majority of these estimates were computed independently, they are poorly comparable, mainly because of differing methods of calculation, health measures, survey design, year, and starting age for the health expectancies. Even the few studies conducted internationally rarely provide satisfactory comparison among the countries studied because they use preexisting data collected separately within each of the countries involved.

Harmonization of national health surveys is very difficult to achieve, but considerable progress has been made within Europe with the advent of healthy life years (HLY), a new European Union (EU) structural indicator. HLY is a disability-free life expectancy based on a global measure of activity restriction, known as the GALI (Robine et al. 2003), and is calculated using the Statistics of Income and Living Conditions (SILC) survey conducted in all 25 EU countries. The range in HLY at age 50 (HLY50) in 2005 was 14.5 years for men, from 9.1 years (Estonia) to 23.6 years (Denmark), and 13.7 years for women, from 10.4 years (Estonia) to 24.1 years (Denmark), wider than the range in total remaining years of life at age 50, which was 9.1 years for men and 6.1 years for women (Jagger et al. 2008) (Fig. 26.1). Figure 26.1 also clearly shows that countries with the highest life expectancies at age 50 were not necessarily those with the highest HLY, and rankings of countries according to life expectancy at age 50 were not the same as rankings for HLY. Furthermore, differences between the new EU10 countries (predominantly eastern European countries) and the existing EU15 countries were particularly marked. Metaregression techniques demonstrated that some of the variation among the 25 countries could be ascribed to differences in other structural indicators reflecting wealth, employment, and education (Jagger et al. 2008); for example, the gross domestic product (GDP) in Estonia was 63, half that of Denmark (GDP in 2005 = 126.8). Though this is the most comparable data to date for European countries, harmonization of the underlying activity limitation measure was suboptimal, particularly for Denmark.

Subregional estimates of health expectancy. Countries that have regularly estimated health expectancies at the regional level, often to assist internal resource allocation, include Canada, England and Wales, France, and Spain. As a concise summary of findings to 2003 has been produced by Bebbington and Bajekal (2003), we include here only results published after this. In Italy, DFLE and life expectancy in good perceived health have been regularly computed by region, with a gradient of longer DFLE in the northern and central regions than in the south (Burgio et al. 2009). In Mexico, older people in regions with the longest life expectancy tended to spend a lower proportion of remaining life active (Reyes-Beaman et al. 2005), suggesting that social, economic, technological, and medical developments have focused on extending the lives of older people who are already dependent, echoing the "pandemic" scenario of Kramer (1980). Similar results have also been found in Spain (Gispert et al. 2007). Although the Netherlands appears a relatively small, homogeneous country, substantial regional differences have been found in healthy life expectancy (Groenewegen et al. 2003).

A study of five centers in the United Kingdom found that only for healthy life expectancy (self-perceived health) did the centers rank similarly to the way they ranked for life expectancy, while the centers ranked differently for DFLE and life expectancy free of cognitive impairment, confirming the existence of considerable differences in life experience across regions beyond basic life expectancy (Matthews et al. 2006a). Smaller area analyses for England, at the level of health authority and local authority, have been undertaken using 1991 and 2001 census data. In 1991, there was considerable variation in both LE and DFLE at birth at regional (local and health authority) levels across England, with greater variation in DFLE (men: 6.5 years men; women: 5 years) than in LE (men: 3 years; women: 2.5 years) (Bone et al. 1995). Almost all the variation in 1991 was explained by a small set of factors: unemployment rate, low social class, population sparsity (as a surrogate for access to services), retirement migration, and the size of ethnic minorities. Whynes (2009) has analyzed differences in HLE (based on self-rated health) between local authorities in 2001 using a more limited set of explanatory factors and found that the HLE observed in the most deprived areas was less than the regression model predicted. More recent studies in other countries have further confirmed the role of socioeconomic indicators in explaining regional variations, concluding that more favorable socioeconomic conditions lead to longer life expectancy, more years free of disability, and fewer years with disability (Kurimori et al. 2006; Van Oyen et al. 2005).

Although useful for resource allocation, such subregional analyses are not without methodological problems. For instance, the geographic areas need to be large enough to have the power to detect differences; Bebbington and Bajekal (Bebbington and Bajekal 2003) calculate that if two areas have a sample size of 1,000, then the difference in health expectancy required to qualify as significantly different at a 5% level of significance would be 5 years. A further issue is that subregional estimates are strongly affected by migration. Thus, differences between subregions may result from migration of certain subgroups of the population, e.g., into retirement areas, rather than the general "healthiness" of the area.

Temporal Comparisons Within Countries

In total, 16 countries have recently published at least one chronological series of health expectancies, including 4 countries outside Europe (China, Japan, Thailand, and the United States). There are no recent published series for Australia and Canada. Table 26.2 lists these series by country, indicating for each series the period concerned, the number of health expectancy estimations over time (n), the health domain under consideration, the method of calculation, and the main references for each study. The health domains used have been collated into seven categories: self-perceived health (SPH), chronic morbidity or long-standing illness (LSI), impairment (IMP), functional limitation (FL), activity limitation including basic and instrumental daily activities (AL), happiness (HAP), and well-being (W). Long-standing illness and disability have been combined in recent health expectancy calculations for the United Kingdom, forming a new category labeled LSI&D (Table 26.2). The methods of calculation used are the Sullivan method (Sullivan) or the multistate life table (multistate), though the majority have used the Sullivan method, demonstrating the difficulty of obtaining chronological series from longitudinal data.

Out of the 16 countries having a least one chronological series of health expectancies, 12 have series based on self-perceived health, 6 have series based on activity limitation, and 4 countries have series based on chronic or long-standing illness, other health dimensions being rarely used. General self-perceived health is a popular question available in almost all health surveys, following past recommendations of the World Health Organization for national health survey harmonization. Although often considered as more important for assessing the compression of morbidity and/or disability, data on long-standing illness and disability are less frequently available.

Table 26.2 Chronological series of health expectancies published since 2000

Country	Period	*N*	Domain	Method	References
Austria	1978–1998	4	SPH	Sullivan	Doblhammer and Kytir (2001)
Belgium	1997–2004	3	SPH, LSI, AL	Sullivan	Van Oyen et al. (2008)
China	1987–2006	2	IMP	Sullivan	Liu et al. (2009)
	1987–2006	2	IMP	Sullivan	Lai (2009)
Czech Rep.	1993–2002	4	SPH	Sullivan	Hrkal (2004)
Denmark	1987–2000	4	SPH, LSI, FL	Sullivan	Bronnum-Hansen (2005)
	1987–2005	5	SPH, LSI, FL	Sullivan	Jeune and Bronnum-Hansen (2008)
France	1980–2003	3	AL	Sullivan	Cambois et al. (2006) and Cambois et al. (2008a)
Germany	1984–1998	2	SPH, AL	Sullivan	Kroll et al. (2008)
Italy	1991–2000	3	SPH, AL	Sullivan	Burgio et al. (2009)
	1994–2005	3	SPH, AL	Sullivan	Egidi et al. (2009)
Japan	1986–2004	7	SPH	Sullivan	Yong and Saito (2009)
Lithuania	1997–2004	2	SPH	Sullivan	Kalédiené and Petrauskiené (2004)
Netherlands	1981–2007	27	SPH, LSI, FL	Sullivan	Bruggink et al. (2009)
	1989–2000	12	LSI, AL, W	Sullivan	Perenboom et al. (2004a, b, 2005)
Spain	1986–1999	2	AL	Sullivan	Sagardui-Villamor et al. (2005)
	1987–2003	4	SPH	Sullivan	Gomez Redondo et al. (2006)
Switzerland	1992–2002	2	SPH	Sullivan	Guilley (2005)
Thailand	1986–1995	2	SPH	Sullivan	Jitapunkul and Chayovan (2000)
USA	1970–1990	3	AL	Sullivan	Crimmins and Saito (2001)
	1982–1999	5	AL	Sullivan	Manton et al. (2006)
	1992–2003	2	AL	Multistate	Cai and Lubitz (2007)
	1982–1999	5	AL	Sullivan	Manton (2008)
	1982–2004	6	AL	Sullivan	Manton et al. (2008)
	1970–2000	4	HAP	Sullivan	Yang (2008)
	1984–2000	6	AL	Multistate	Crimmins et al. (2009)
United Kingdom	1980–1996	17	SPH, LSI	Sullivan	Kelly et al. (2000)
	1981–2002	22	SPH, LSI&D	Sullivan	Office for National Statistics (2006)
	2004–2006	2	SPH, LSI&D	Sullivan	Smith et al. (2008)
	2000–2006	7	SPH, LSI&D	Sullivan	Office for National Statistics (2008)

Several countries have computed a set of health expectancies to better describe the changes in the health status of their population, for instance Belgium, Denmark, Italy, the Netherlands, and the United Kingdom. These analyses are based on the premise that the main health domains (i.e., morbidity, functioning, and perceived health) may evolve differently.

Out of the 16 countries, 11 now have series made of three or more estimates over the studied period. The ranges of the series span 26 years in the United Kingdom and the Netherlands, 23 years in France, 22 years in the United States, 20 years in Austria, 19 years in China, 18 years in Denmark and Japan, and 16 years in Spain. However, forecasts of health expectancy values are still an exception (Manton et al. 2006).

Jagger et al. (2011) have computed a comparable series of health expectancies across 13 EU member states over the time period 1995–2001 using the European Community Household Panel (ECHP). They found consistent increases in life expectancy at ages 16 and 65 in all 13 countries over the period 1995–2001, but in the majority of countries this was not accompanied by a compression of disability. Only two countries (Austria and Italy) had strong evidence of compression of disability, while three countries (the Netherlands, Germany, and the United Kingdom) showed strong evidence of expansion of disability in the majority of age and gender groups, although these expansions were not accompanied by increases in years with severe disability, suggesting dynamic equilibrium. In contrast, in Greece there was a significant increase in the number of years with severe disability in all the age and gender groups (Table 26.3). There are a number of potential explanations for the fact that the majority of countries experienced an expansion of disability.

Table 26.3 Evidence for absolute and relative compression/expansion and dynamic equilibrium for men and women at ages 16 and 65

	Age 16			Age 65		
	Absolute compression/expansion	Relative compression/expansion	Dynamic equilibrium	Absolute compression/expansion	Relative compression/expansion	Dynamic equilibrium
Men						
Austria	Compression*	Compression*		Compression**	Compression**	
Belgium	Compression**	Compression**		Compression**	Compression**	
Denmark	Expansion*	Expansion*	Yes	Expansion*	Expansion**	Yes
Finland	Compression**	Compression**		Expansion**	Compression**	
France	Expansion**	Expansion**		Expansion**	Compression**	
Germany	Expansion**	Compression**		Expansion*	Expansion**	Yes
Greece	Expansion**	Expansion**		Expansion**	Expansion**	
Ireland	Expansion*	Expansion*	Yes	Expansion*	Expansion**	Yes
Italy	Compression*	Compression*		Compression**	Compression*	
Netherlands	Expansion*	Expansion*	Yes	Expansion*	Expansion*	Yes
Portugal	Expansion*	Expansion**	Yes	Expansion**	Expansion**	
Spain	Compression**	Compression**		Compression**	Compression**	
UK	Expansion*	Expansion*	Yes	Expansion*	Expansion*	Yes
Women						
Austria	Compression*	Compression*		Compression**	Compression**	
Belgium	Compression**	Compression**		Compression**	Compression**	
Denmark	Expansion**	Expansion**		Compression**	Compression**	
Finland	Expansion*	Expansion*	Yes	Expansion*	Expansion**	Yes
France	Expansion**	Expansion**		Expansion**	Compression**	
Germany	Expansion*	Expansion**	Yes	Expansion*	Expansion*	Yes
Greece	Expansion**	Expansion**		Expansion*	Expansion**	
Ireland	Expansion**	Expansion**		Expansion**	Expansion**	
Italy	Compression*	Compression*		Compression*	Compression*	
Netherlands	Expansion*	Expansion*		Expansion*	Expansion*	Yes
Portugal	Expansion**	Expansion**		Expansion*	Expansion**	Yes
Spain	Compression**	Compression**		Compression**	Compression**	
UK	Expansion*	Expansion*	Yes	Expansion**	Expansion**	

*Increase/decrease at 5% level.
**Nonsignificant increase/decrease.

Limitations of the data may be part of this: the ECHP, which provided the disability prevalence, did experience a falling response rate over time, although representativeness did not seem to have been adversely affected (Watson 2003); the underlying disability question in the ECHP was not optimally harmonized across countries, though this is less of a problem in comparing trends over time; and the ECHP included only the non-institutionalized population, so an apparent expansion of disability might result from changes in the care systems, allowing more older dependent people to remain at home rather than being admitted to a care home. If the expansions of disability are real, they confirm Kramer's (1980) hypothesis that medical and technological advances are keeping alive frail older people who previously would have died.

Social Inequalities in Health Expectancy

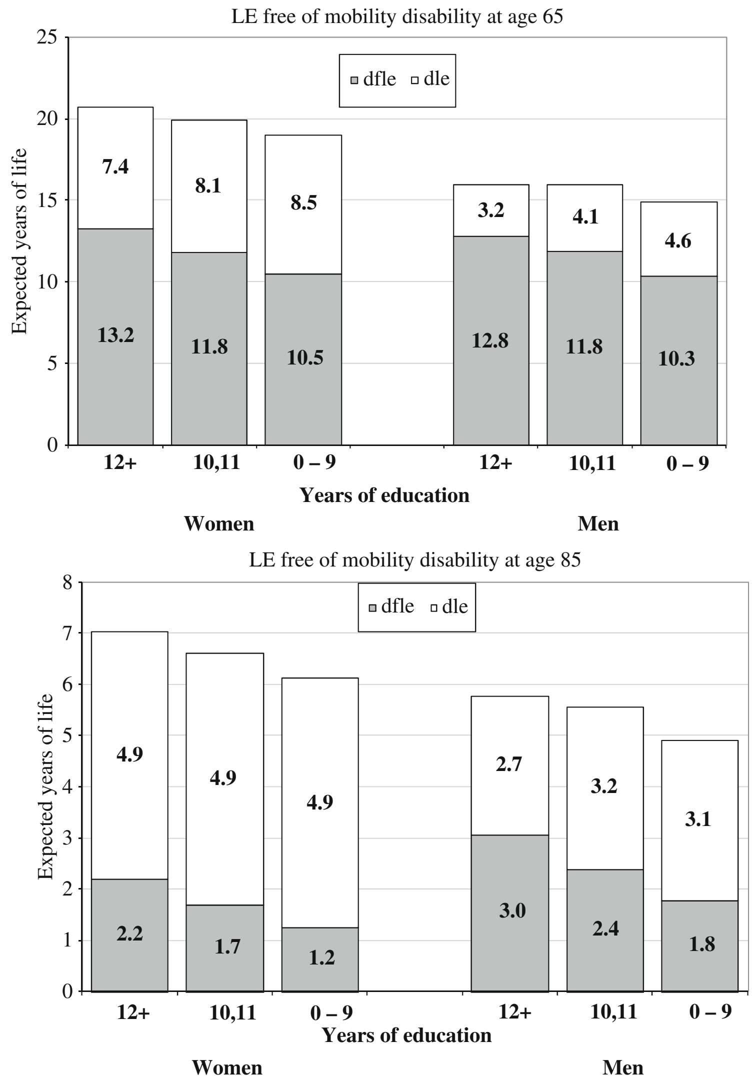
One of the major uses of health expectancy calculations has been to identify inequalities in the quality, not simply the quantity, of life between subgroups within the population. The subgroups explored by most countries are gender and socioeconomic status (defined by education, occupation, income, level of deprivation, or ethnicity). Although here we review each of these socioeconomic indicators separately, it should be remembered that they are not interchangeable, and they indicate inequity at varied points throughout the life course. Crimmins and Cambois (2003) have reviewed studies comparing socioeconomic groups up to 2003, so here we concentrate on more recent studies.

Gender. As life tables are generally available separately for men and women, most health expectancies are calculated by gender. Almost all studies, using either Sullivan or multistate methods, show that women live longer in total than men and have more years free of disability or ill-health, but that these latter years are a smaller proportion of remaining life expectancy. Thus, in general women live longer but spend a greater proportion of remaining life with disability or ill-health. This has been shown to be true even at the oldest ages in Denmark (Bronnum-Hansen et al. 2009), although recent findings from one city in Brazil suggest that from age 75 women spent a shorter proportion of remaining life with ill-health than did men (Camargos et al. 2008).

Education. As a measure of social inequity in health particularly at older ages, education has the advantage that it has been completed early in life and therefore is less likely to suffer from reverse causation than measures such as income or occupation. Comparisons of the absolute size of differentials between educational groups from different studies are difficult because both levels of education and the health measures are rarely the same. However, the consensus is that the highest education group has even more advantage over the lowest for healthy life than for total life. Thus, those in the lowest education group live shorter lives, have more years of ill-health, and enjoy fewer healthy years than those with the highest levels of education (Crimmins and Cambois 2003), although for life expectancy with cognitive impairment the burden for the highly educated is similar to that for the less educated (Matthews et al. 2009). Whether gaps between education groups have increased or decreased over time is debatable. In the Netherlands, between 1989 and 2000 educational differentials in morbidity-free life expectancy decreased by 2.5 years for men and 0.7 years for women, perhaps because of earlier diagnosis of chronic diseases in the less educated (Perenboom et al. 2005). However, for two countries, Denmark and the United States, the gaps between the educationally advantaged and disadvantaged have widened over time. Over the two decades beginning in 1970, the most educated in the United States experienced a compression of morbidity while the least educated continued to experience an expansion, so that the gaps between them widened (Crimmins and Saito 2001). In Denmark, the gaps in healthy life expectancy (based on self-rated health) and DFLE between the most and least educated increased between 1994 and 2005, despite the decrease in numbers of people with the lowest level of education (Bronnum-Hansen and Baadsgaard 2008).

In some countries, such as the United Kingdom, Sullivan's method cannot be used to generate health expectancies by educational status since life tables are not routinely available by education. Educational differentials in life expectancy free of mobility disability at age 65 have been estimated (Jagger et al. 2007b) from the Medical Research Council Cognitive Function and Ageing Study (see www.cfas.ac.uk), a large-scale longitudinal study of aging conducted at five centers in the United Kingdom. Differences in life expectancy between the least educated individuals

Fig. 26.2 DFLE at ages 65 and 85. Source: MRC CFAS



(0–9 years of education) and the most educated (12 or more years) were 1.7 years for women and 1.1 years for men at age 65, while differences in life expectancy free of mobility disability were considerably larger at 2.8 years for women and 2.4 years for men, and these persisted to age 85 years (Fig. 26.2). Despite the societal differences in China, similar gaps in active life expectancy (based on activities of daily living) have been found from a longitudinal study in Beijing (Kaneda et al. 2005). The United Kingdom differences appeared to arise from the least educated experiencing a significantly higher incidence of disability and lower rate of recovery, even after adjustment for the presence of comorbid conditions (Jagger et al. 2007b). Others have looked more specifically at the part that diseases and conditions play, finding that nonfatal conditions (arthritis, back complaints, and asthma/chronic obstructive pulmonary disease) explain a substantial part of differences in DFLE by education in Belgium (Nusselder et al. 2005), as do musculoskeletal diseases in Denmark (Bronnum-Hansen and Davidsen 2006; Bronnum-Hansen et al. 2006), since these diseases have a much greater impact on DFLE than on life expectancy.

Occupation. Occupation is often viewed as a measure of inequity in middle rather than early or late life. Health expectancies by occupation have been estimated for Finland (Kaprio et al. 1996), France (Cambois et al. 2008b; Cambois et al. 2001), Great Britain (Bebbington 1993; Matthews et al. 2006b;

Melzer et al. 2000), Sweden (Pettersson 1995), Italy (Spadea et al. 2005), and China (Kaneda et al. 2005). The majority of researchers use Sullivan's method and, as for education, all consistently find that those with the lowest occupational status live shorter lives, with more years of disability and fewer years disability-free.

Income and deprivation. Income and deprivation are more current measures of inequity. Social inequalities in health expectancies have been measured through income alone in Canada (Wilkins and Adams 1983), the United States (Katz et al. 1983), England (Matthews et al. 2006b), and China (Kaneda et al. 2005), and all studies again show that those with lower incomes have shorter lives with more disability. As with occupation, care must be taken since disability earlier in life might itself result in lower occupational status, more periods of unemployment and reduced incomes.

Deprivation is measured through area-level variables and is a common indicator for resource allocation in the United Kingdom. In the 1990s, those in the most deprived areas in the United Kingdom spent twice as many years in poor health as did those in the least deprived areas, and between 1994 and 1999 these gaps did not decrease (Bajekal 2005). An interesting analysis of the 2001 census in the United Kingdom demonstrated not only the unsurprising result that gaps between the most and least deprived areas were greater for healthy life expectancy (13.4 years for men and 11.8 for women at birth) and DFLE (14.1 years for men and 12.8 years for women at birth) than for life expectancy (7.6 years for men and 4.8 years for women at birth), but also "that for approximately equivalent levels of deprivation, the gap in health expectancies between the most and least deprived areas was widest in the northern regions and Wales and smallest in the East of England, London and the South West" (Rasulo et al. 2007). Significant reductions in DFLE and life expectancy in the most deprived areas compared to the least were found to persist in men, though not in women, at age 75 years (Matthews et al. 2006b).

Race/ethnicity. Comparisons of health expectancies by ethnic group are almost entirely confined to the United States, where racial differences (between white and African-Americans) in health expectancy are greater than those in life expectancy (Crimmins and Saito 2001; Crimmins et al. 1989), though gaps are age dependent (Crimmins et al. 1996; Guralnik et al. 1993). Ethnic inequalities in healthy life expectancy are, however, insignificant in highly educated groups and up to 6 years in those with the least education (Crimmins and Saito 2001). When ethnicity is further differentiated, the picture becomes more complex. Asian-Americans live longer and have relatively fewer years of disability than white Americans. African-Americans and Hispanics live shorter lives, but Hispanics have fewer years of disability (Hayward and Heron 1999). Two other countries, the United Kingdom and New Zealand, have estimated the impact of ethnicity on variations in healthy life expectancy. In New Zealand Maoris live shorter lives with more years of disability than Europeans, even within the same levels of deprivation (Tobias and Cheung 2003), while in the United Kingdom the proportion of ethnic minorities was found to contribute significantly to the variation in healthy life expectancy between local authorities (Bone et al. 1995).

Measuring the Burden of Disease by Disability-Free Life Expectancy

Most models of the disablement process place disease at the start of the process (Verbrugge and Jette 1994). A number of studies have estimated the impact on DFLE of individual diseases or conditions, such as depression (Peres et al. 2008; Reynolds et al. 2008) or diabetes (Jagger et al. 2003; Laditka and Laditka 2006), one of the benefits of health expectancies being that they provide the same metric for comparison of both fatal and nonfatal diseases. The original approach, and still the most common method, for comparing the impact of disease on DFLE has been through cause-deleted life tables. This method was first proposed in the 1980s (Colvez and Blanchet 1983), but other studies have followed (Bone et al. 1995; Mathers 1999; Nusselder et al. 1996), including the Global Burden of Disease study (Murray and Lopez 1997a). These studies have highlighted that elimination of such fatal diseases as cancer and cardiovascular disease not only increases DFLE, but also increases years with disability. Elimination of such nonfatal diseases as arthritis and psychiatric diseases increases DFLE and reduces years with disability.

Cause-elimination methods based on the Sullivan method rely on cause-of-death data. Nonfatal diseases, particularly dementia, are known to be

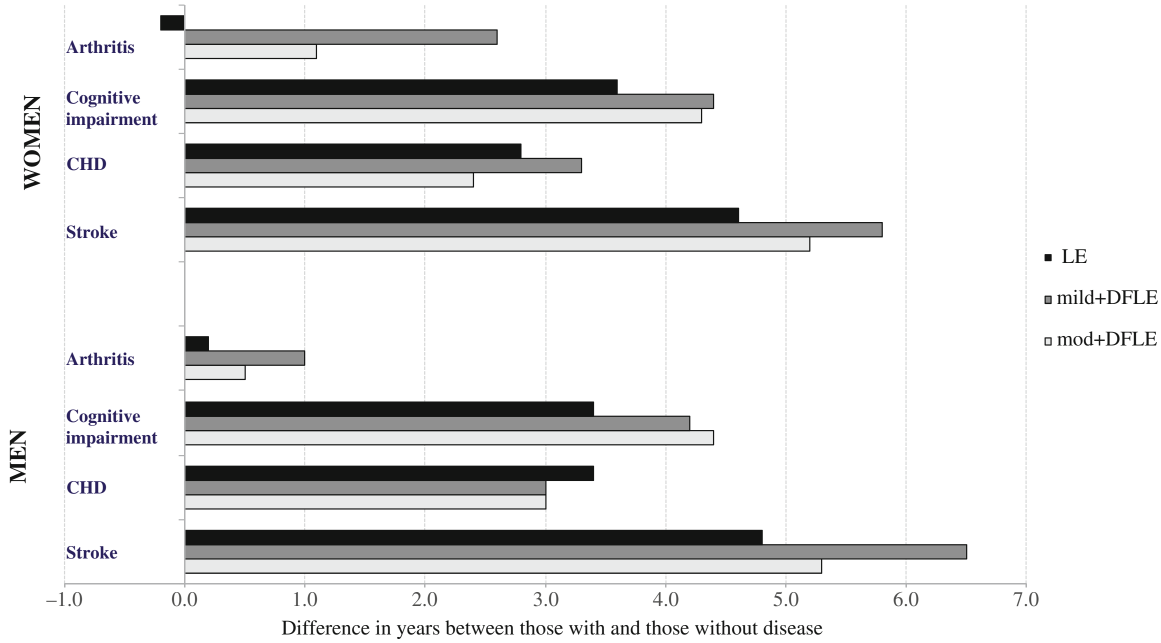


Fig. 26.3 Difference in years of life expectancy, free of any disability (Mild+) and free of moderate or severe disability at age 65 in participants with and without diseases at baseline. Source: MRC CFAS

underrepresented on death certificates, and for the oldest old, comorbidity is common, so it can be difficult to ascertain the main cause of disability. Multistate methods do not suffer from this problem, though disease in longitudinal studies is often self-reported, and a large study size is needed to assess the impact of less prevalent diseases such as diabetes. Only the MRC Cognitive Function and Ageing Study had sufficient size to compare a range of fatal and nonfatal diseases (Jagger et al. 2007a). The number of disability-free years gained in persons free of stroke, cognitive impairment, and arthritis at baseline was greater than the years gained in total life expectancy (Fig. 26.3) suggesting that eliminating these conditions would compress disability, in contrast to coronary heart disease (CHD), where, at least for men, the years gained in life expectancy exceeded those gained in DFLE.

Directions for Future Research

Future research in health expectancies is required both on harmonization of health measures and on methodology. Though considerable progress has been made within Europe in achieving comparability in disability measures with the healthy life years indicator, it is still impossible to compare national estimates of DFLE or trends among Europe, the United States, and Japan. A key concern for Europe is to ascertain whether different social groups within Europe are experiencing compression or expansion of disability, which requires life tables by social group. Methodological advances will focus on further extending methods to explain the variability in health expectancies between and within countries. Three ways are being pursued at present. Metaregression has begun to be used (Jagger et al. 2008), but more might be gained through the advances that have already been made in meta-analysis. Work is ongoing within the European Health and Life Expectancy Information System (EHLEIS) project (see www.ehemu.eu) on decomposition methods (Nusselder and Looman 2004). Finally, current software programs for longitudinal data, for example, IMaCH (Lievre et al. 2003) and SPACE (Cai et al. 2006), allow a very limited set of covariates, and further developments are required to allow adjustment for potential confounding factors—for instance, to better ascertain educational differences in healthy life expectancy after adjustment for comorbidity.

Conclusion

Since the development of health expectancy measures in the late 1960s, the use of these indicators to monitor population health and to identify health inequalities has burgeoned. The growth in the number of longitudinal studies of aging in both the developed and developing worlds affords greater possibilities for multistate methods to explore inequalities in health expectancies between social groups and discover which transitions and diseases contribute to inequalities. Moreover, the last 5 years have seen a real acceptance of the political importance of health expectancies within the EU with the addition of healthy life years (HLY), a DFLE, to the set of EU structural indicators.

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