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The Burden of Diseases on Disability-Free Life Expectancy in Later Life

Carol Jagger,[1] Ruth Matthews,[1] Fiona Matthews,[2] Thompson Robinson,[3] Jean-Marie Robine,[4] Carol Brayne,[5] and the Medical Research Council Cognitive Function and Ageing Study Investigators

Departments of [1]Health Sciences and [3]Cardiovascular Sciences, University of Leicester, United Kingdom.
[2]Medical Research Council Biostatistics Unit, Institute of Public Health, University of Cambridge, United Kingdom.
[4]Equipe Démographie et Santé, Institut National de la Santé et de la Recherche Médicale, Montpellier, France.
[5]Institute of Public Health, University of Cambridge, United Kingdom.

Background. The consequences of diseases in later life have been judged predominantly through mortality, resulting in an emphasis on the fatal rather than the nonfatal disabling conditions. We use a longitudinal study with follow-up at 2, 6, and 10 years to assess the impact of different diseases on both total life expectancy (TLE) and disability-free life expectancy (DFLE).

Methods. The Medical Research Council Cognitive Function and Ageing Study investigators interviewed 13,004 people aged 65 years and older from five U.K. centers starting in 1991. Persons aged 75 years and older were oversampled. Disability (mild, moderate, and severe) was assessed through basic Activities of Daily Living (ADL) and Instrumental ADL (IADL) scales at baseline and at follow-ups at 2, 6, and 10 years. TLE and DFLE were compared for persons with and without each of nine conditions.

Results. At age 65, men had a TLE of 15.3 years of which 12.1 (79%) were free of any disability, whereas women of the same age had an average TLE of 19.4 years, 11.0 years (57%) disability-free. Men (women) aged 65 years without stroke had 4.8 (4.6) more years of TLE and 6.5 (5.8) more years DFLE. Without diabetes, men (women) lived 4.4 (5.6) years longer and had 4.1 (5.1) years disability-free.

Conclusions. More disability-free years were gained than total life years in persons free of stroke, cognitive impairment, arthritis, and/or visual impairment at baseline. This finding suggests that elimination of these conditions would result in a compression of disability.

THE relative availability of mortality data makes this the usual means by which disease impact is measured in populations, though focus is then on fatal rather than nonfatal conditions. The increasing demand for healthy active life in old age is now changing the emphasis to outcomes such as disability that influence the quality of later life. The role of diseases on disability and functional decline in older people has been systematically reviewed (1,2). Conversely, evidence on the relative importance of different diseases remains scant, especially in the light of increases in life expectancy and the prevalence of certain diseases (3) yet decreasing trends in disability prevalence (4,5). A major reason for these contradictory trends is that most studies have viewed disability and mortality as separate outcomes but the size of study required to assess the contribution of less prevalent conditions is a further issue.

Disability-free life expectancy (DFLE) summarizes mortality and disability together, positioning fatal and nonfatal outcomes on a common metric. Such population health indicators have been instrumental in exploring whether the extra years lived have been spent in good or poor health (5–7). It was first proposed as a means of assessing the potential gains in health through the elimination of diseases 20 years ago (8). Other such studies have followed (9–12), the most comprehensive being the Global Burden of Disease Study (13). The common approach in these studies has been based on disability prevalence data and cause-deleted life tables. These methods are subject to a number of limitations: The accuracy of cause-of-death data is questionable and induces a bias towards the major fatal diseases; comorbidity, particularly prevalent in later life, is ignored; and the link between disease and disability has to be inferred, either through self-report of the major cause of disability or in the Global Burden of Disease study, through the opinions of health professionals (13).

Only a handful of studies have explicitly modeled transitions from disease through to disability and death with longitudinal data, and all have been limited to one or two diseases: heart disease (14), dementia (14,15), and diabetes (16). This article will be the first, to our knowledge, to use longitudinal data with 10 years of follow-up on both community-dwelling and institutionalised older people and to explore the impact of a range (nine) of diseases and impairments on life expectancy with and without disability of differing severity levels.

Methods

The Medical Research Council Cognitive Function and Ageing Study (MRC CFAS) is a population-based longitudinal study of health in the older population (http://www.cfas.ac.uk). Full methods have already been published (17), but relevant details are given here. Population-based samples, stratified to ages 65–74 years and 75 years and older, were taken from National Health Service primary care

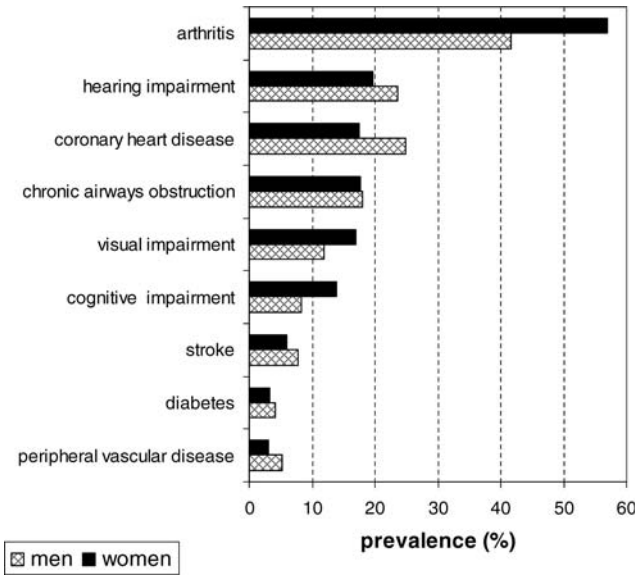

Figure 1. Prevalence (weighted by sampling design) of chronic conditions at baseline, by sex.

lists in three urban (Newcastle, Nottingham, and Oxford) and two rural centers (Cambridgeshire and Gwynedd) to achieve approximately 2500 interviews at each center. Individuals in long-stay hospitals and residential homes for the elderly were included in the sample.

Participants underwent a structured interview in their own homes during 1992–1994 (baseline) and at 2 and 10 years. In one center (Cambridge), participants were also reinterviewed at 6 years. The MRC CFAS data set version 8 was used for this analysis.

Measurement of Disability

The measure of disability had been previously developed (2) based on the hierarchy of basic Activities of Daily Living (ADL), Instrumental Activities of Daily Living (IADL) (18), and the concept of interval of need (19). Participants were classified as moderately to severely disabled if they were unable to perform at least one of the following five ADLs without human help: transfer to and from a chair (from interviewer assessment), put on shoes and socks, prepare a hot meal, get around outside, and have a bath or an all-over wash. Participants who were able to perform all five activities without human help but who required help with at least one of the two additional IADLs (shopping including carrying heavy bags and heavy housework) were classified as having mild disability.

Measurement of Disease

At baseline, participants were asked if they had ever suffered from a range of conditions (heart attack, diabetes, bronchitis, asthma, arthritis, stroke, hearing problems, eyesight problems). In addition to self-report, certain conditions were considered to be present if participants were under current treatment (diabetes); had been diagnosed (stroke); or interviewer observed (hearing problems, eyesight problems) (2). Diagnostic scales were used for angina and peripheral vascular disease (20) and for moderate or severe cognitive impairment (21) (Mini-Mental State Examination score $\leq$ 21). We defined coronary heart disease (CHD) as heart attack and angina and chronic airway obstruction as chronic bronchitis or asthma, excluding childhood asthma only. Death information was provided from the Office of National Statistics on all participants who underwent the baseline interview, and was complete through December 31, 2004.

Statistical Analysis

DFLE were calculated from the baseline and from 2-, 6-, and 10-year follow-up data using Interpolated Markov Chain (IMaCH) software version 0.98h (22). This technique partitions the time intervals between successive interviews into shorter steps and then models the resulting transition probabilities by multinomial logistic regression on age (and other covariates). We used a step length of 1 month to closely approximate the underlying continuous time process; the product of the 1-month probabilities thus provides the contribution to the likelihood for an observed transition. Missing interviews are easily accommodated as intervals between interviews do not have to be equal within or between individuals. Due to the low prevalence of some conditions and the scarcity of certain transitions, we used disability as a binary variable and performed separate analyses with any disability (mild, moderate, or severe) and moderate or severe disability only. Presence or absence of each condition at baseline was included as a covariate, and the difference in total life expectancy (TLE) and DFLE were calculated by gender, weighted for sample selection. Participants with missing data on a particular condition were excluded for that analysis only. Peripheral vascular disease (PVD) was missing for 3.2% of participants with the remaining conditions missing in 2% or less.

We explored how the presence of other diseases affected differences in TLE and DFLE with specific diseases in two ways. First, with the two most prevalent diseases, arthritis and CHD, in women only (due to small numbers in men) we compared: women reporting only CHD (or arthritis) with women free of all diseases and then compared women reporting CHD (or arthritis) in addition to other diseases with women reporting only other diseases. Second, we compared TLE and DFLE in participants reporting 0, 1, 2, 3, or 4+ diseases at baseline for men and women separately. All analyses were weighted to account for the oversampling of participants aged 75 years or older. Population data from each of the regions was ascertained from national statistics (www.ons.gov.uk) to calculate the oversampling proportion for each center and for the age groups 65–74 years and 75 years or older.

Results

A total of 13,004 individuals aged 65 years or older were interviewed at baseline, with 12,881 (99.1%) having a disability assessment at one or more of the major interview waves; this group formed the study population for analysis. Overall, 24.7% (N = 3181) were aged 65–69 years at baseline, 11.3% (N = 1455) were aged 85 years or older, and

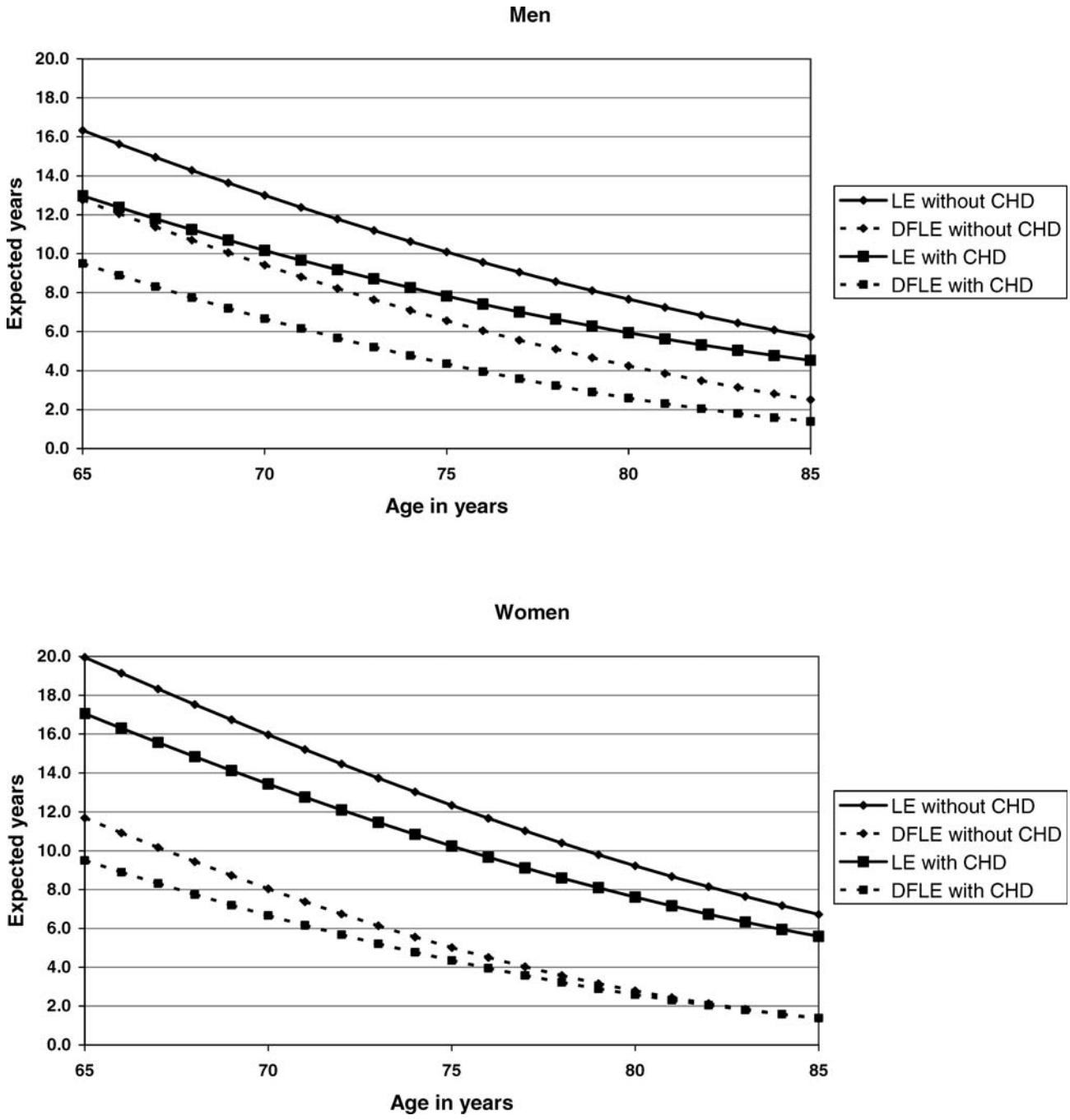

Figure 2. Life expectancy (LE) and disability-free life expectancy (DFLE) with and without coronary heart disease at baseline, by sex.

60.3% ($N = 7765$) were women. At baseline, 78% (3954/5100) of men compared with 63% (4865/7741) of women were free of any disability, and women were more likely to develop mild disability by the 2-year follow-up (women: 17.0% vs men: 10.3%). Men were more likely to have died from any state at baseline (data not shown). By the end of the study period, 7953 (61.7%) of participants had died.

Around one fifth (21.2%) of older people had none of the nine diseases and conditions at baseline. Arthritis was the most reported condition at baseline (51.3%) and diabetes the least (3.7%). The prevalence of arthritis, eyesight problems, and cognitive impairment was greater in women than men (Figure 1). Almost half (44.4%, $N=5418$) of participants reported two or more of the nine conditions at baseline and, of these, 73.2% had arthritis and at least one other condition.

TLE at age 65 for men was 15.3 years of which 12.1 years (79%) were DFLE and 13.4 years (88%) were free of moderate and severe disability (mod+DFLE). Women of the

Table 1. Life Expectancy at Age 65 Without and With Diseases at Baseline, Extra Years of Life Expectancy Without Disease and 95% Confidence Interval (95% CI), by Sex

Disease	Life Expectancy (Years) in Participants		Extra Years of Life Expectancy in Participants Without Disease (95% CI)
	Without Disease	With Disease	
Men			
Coronary heart disease	16.1	12.7	3.4 (2.7 to 4.1)
Stroke	15.6	10.9	4.8 (3.8 to 5.8)
Cognitive impairment	15.4	12.0	3.4 (2.3 to 4.6)
Diabetes	15.4	11.1	4.4 (3.2 to 5.6)
Peripheral vascular disease	15.4	12.6	2.8 (1.6 to 4.0)
Chronic airway obstruction	15.8	13.1	2.7 (1.9 to 3.4)
Arthritis	15.3	15.1	0.2 (−0.5 to 0.8)
Visual impairment	15.3	14.4	0.9 (0.0 to 1.9)
Hearing impairment	15.3	15.0	0.3 (−0.5 to 1.0)
Women			
Coronary heart disease	19.8	17.0	2.8 (2.0 to 3.5)
Stroke	19.6	15.0	4.6 (3.5 to 5.7)
Cognitive impairment	19.7	16.1	3.6 (2.7 to 4.6)
Diabetes	19.5	14.0	5.6 (4.3 to 6.9)
Peripheral vascular disease	19.5	16.1	3.4 (2.0 to 4.8)
Chronic airway obstruction	19.7	17.5	2.2 (1.5 to 2.9)
Arthritis	19.3	19.4	−0.2 (−0.7 to 0.4)
Visual impairment	19.5	18.0	1.5 (0.7 to 2.3)
Hearing impairment	19.3	19.2	0.2 (−0.6 to 0.9)

same age lived longer, 19.4 years, had longer mod+DFLE (16.0, 82%), but had shorter DFLE (11.0, 57%).

To assess the relative impact of different diseases, we calculated DFLE and mod+DFLE with and without each of the nine diseases. Although later we will focus on years lived from age 65, we show results for CHD across the age range as an example (Figure 2). The impact of CHD on TLE and DFLE reduced with age but was still evident. Thus 65-year-old men without CHD had 3.4 years (95% confidence interval [CI], 2.7–4.1) more in TLE and 3.3 years (95% CI, 2.5–3.6) more DFLE than did those men with CHD at baseline. The figures for 80-year-old men were 1.7 years (95% CI, 1.3–2.1) and 1.7 years (95% CI, 1.2–2.1), respectively.

Table 2. Expected Years Free of Any Disability and Free of Moderate or Severe Disability at Age 65 in Participants With and Without Diseases at Baseline and 95% Confidence Interval (95% CI), by Sex

Disease	Expected Years Free of Any Disability in Participants		Extra Years Free of Any Disability in Participants Without Disease (95% CI)	Expected Years Free of Moderate or Severe Disability in Participants		Extra Years Free of Moderate or Severe Disability in Participants Without Disease (95% CI)
	Without Disease	With Disease		Without Disease	With Disease	
Men						
Coronary heart disease	12.6	9.5	3.0 (2.3 to 3.8)	14.2	11.2	3.0 (2.3 to 3.6)
Stroke	12.3	5.8	6.5 (5.4 to 7.7)	13.9	8.5	5.3 (4.3 to 6.4)
Cognitive impairment	12.0	7.8	4.2 (2.6 to 5.8)	13.6	9.2	4.4 (3.1 to 5.8)
Diabetes	12.0	7.8	4.1 (2.8 to 5.4)	13.6	9.5	4.1 (2.9 to 5.3)
Peripheral vascular disease	12.0	9.2	2.8 (1.4 to 4.1)	13.6	10.9	2.7 (1.5 to 3.8)
Chronic airway obstruction	12.2	10.0	2.3 (1.4 to 3.1)	13.9	11.5	2.4 (1.6 to 3.1)
Arthritis	12.2	11.2	1.0 (0.3 to 1.7)	13.6	13.2	0.5 (−0.2 to 1.1)
Visual impairment	12.0	10.0	2.0 (0.9 to 3.1)	13.6	11.9	1.6 (0.7 to 2.6)
Hearing impairment	11.9	11.4	0.5 (−0.3 to 1.3)	13.5	13.0	0.5 (−0.2 to 1.3)
Women						
Coronary heart disease	11.6	8.3	3.3 (2.5 to 4.1)	15.9	13.5	2.4 (1.7 to 3.2)
Stroke	11.4	5.5	5.8 (4.5 to 7.1)	15.8	10.6	5.2 (4.1 to 6.4)
Cognitive impairment	11.3	6.9	4.4 (2.9 to 5.8)	15.8	11.5	4.3 (3.2 to 5.4)
Diabetes	11.2	6.1	5.1 (3.4 to 6.8)	15.7	10.6	5.1 (3.9 to 6.3)
Peripheral vascular disease	11.2	8.3	2.9 (1.5 to 4.3)	15.6	12.4	3.3 (1.8 to 4.7)
Chronic airway obstruction	11.6	8.9	2.8 (2.0 to 3.6)	15.9	13.7	2.2 (1.5 to 2.9)
Arthritis	12.5	9.9	2.6 (1.9 to 3.3)	16.1	15.0	1.1 (0.5 to 1.7)
Visual impairment	11.4	8.3	3.1 (2.1 to 4.0)	15.7	13.8	1.9 (1.1 to 2.7)
Hearing impairment	11.2	10.0	1.2 (0.3 to 2.1)	15.6	15.0	0.5 (−0.2 to 1.3)

Table 3. Expected Years of Life in Total, Free of Any Disability, and Free of Moderate or Severe Disability at Age 65 in Women With and Without Coronary Heart Disease (CHD) and Arthritis at Baseline Adjusted for Other Comorbidity

			Expected Years of Life	
Comorbidity at Baseline	*N**	Total	Free of Any Disability	Free of Moderate or Severe Disability
None	1447	21.4	15.1	18.3
CHD only	153	17.3	9.7	14.8
No CHD but other comorbidity	4582	19.3	10.4	15.2
CHD and other comorbidity	1180	16.9	7.9	13.2
Arthritis only	1555	21.5	12.2	17.4
No arthritis but other comorbidity	1664	17.1	9.9	13.9
Arthritis and other comorbidity	2710	17.8	7.9	13.1

Note: *Unweighted.

Impact of Diseases on Life Expectancy at Age 65

The greatest difference in TLE between participants with and without disease at baseline for men occurred with stroke (4.8 years, 95% CI, 3.8–5.8) and diabetes (4.4 years, 95% CI, 3.2–5.6). In women, diabetes (5.6 years; 95% CI, 4.3–6.9) and stroke (4.6 years; 95% CI, 3.5–5.7) resulted in the most years lost (Table 1). TLE was significantly reduced with all conditions except arthritis and hearing impairment (men and women) and visual impairment (men).

Impact of Diseases on DFLE at Age 65

Many of the diseases similarly affected DFLE and mod+DFLE (Table 2), suggesting that few years free of mild disability were gained without these diseases. However, the larger gains in DFLE than in mod+DFLE found without arthritis and hearing and visual impairment suggest that these conditions have a greater effect on mild disability. As for TLE, stroke had the greatest impact on DFLE with 6.5 years (95% CI, 5.4–7.7) shorter DFLE in men and 5.8 years (95% CI, 4.5–7.1) shorter DFLE in women. The years of DFLE gained without stroke, cognitive impairment, arthritis, or visual impairment exceeded TLE, suggesting that elimination of these disorders would result in a compression of disability.

Comorbidity

The effect of other conditions on results for arthritis and CHD in women is shown in Table 3. The relative size of differences in TLE and DFLE were unchanged, although differences were larger when the analysis was confined to women reporting CHD only compared with women reporting none of the diseases. We found reductions of 4.1 years TLE (95% CI, 2.1–6.1) and 5.4 years DFLE (95% CI, 3.5–7.3) for CHD alone compared to 2.4 years TLE (95% CI, 1.6–3.2) and 2.5 years DFLE (95% CI, 1.6–3.4) for CHD in conjunction with other diseases. Similar results were found for arthritis. This reduced effect of elimination when other diseases were present was further confirmed by analysis of TLE and DFLE by the number of diseases present at baseline (Table 4).

Table 4. Expected Years of Life in Total, Free of Any Disability, and Free of Moderate or Severe Disability at Age 65 by Comorbidity at Baseline and Sex

			Expected Years of Life	
Number of Diseases at Baseline	*N**	Total	Free of Any Disability	Free of Moderate or Severe Disability
Men				
None	1140	17.5	14.5	15.7
1	1667	16.0	12.4	14.4
2	1225	14.2	10.5	12.1
3	602	12.8	9.2	10.8
4 or more	292	11.1	6.9	9.1
Women				
None	1447	21.4	15.0	18.3
1	2525	20.1	11.8	16.5
2	1850	18.5	9.2	14.1
3	925	17.0	7.1	12.9
4 or more	524	16.5	6.5	12.0

Note: *Unweighted.

DISCUSSION

Our findings highlight the contribution of nonfatal conditions, such as arthritis and visual impairment, as well as fatal diseases to the burden of disability in older people. Without stroke, cognitive impairment, arthritis, or visual impairment, 65-year-old men and women gained more years free of disability than total years, thus disability was compressed into a shorter period of remaining life.

Since Fries (23) first proposed the compression of morbidity hypothesis, debate has been ongoing as to whether functional decline at the end of the ever-increasing life span can be postponed. The tendency in other studies to view mortality and disability as separate outcomes makes it difficult to judge whether disease prevention results in a compression of disability, where DFLE is increasing faster than TLE, or conversely, in an expansion of morbidity. Recent studies (24–26) have focused on improving lifestyle and health behaviors and have concluded that better nutrition, smoking cessation, less obesity, and more physical activity will reduce morbidity more than mortality. These are key factors in preventing stroke, CHD, and diabetes, conditions that we have shown greatly affect later life disability. Such improvements are pressing given that significant increases are predicted in stroke simply through the continued aging of our populations, particularly in developing countries (27).

Other studies have used cause-deleted life tables; therefore, cause of death may have underestimated the effect of conditions such as arthritis and mental and sensory disorders that rarely appear on death certificates. In contrast to Mathers (11), who found that the elimination of mental disorders had little effect on total years lived, our findings of over 3 years of life gained by those participants without cognitive impairment is much more in keeping with studies consistently reporting this as a predictor of reduced survival (28). We confirmed the position of cerebrovascular disease as a major contributor to reduced DFLE (10,11,13) and that elimination of CHD will extend TLE more than DFLE, at least for men (12). Reductions in the disabling effect of

arthritis were also found to be an important contributor to the improvement in functioning in U.S. older adults between 1984 and 1995 (29).

Previous studies (9–13) have required the principal cause of disability to be identified to map disability to disease, and have been limited in their ability to accommodate comorbidity. In our study, the disease–disability link is empirically established, in contrast to using either self-report of the cause of disability (8–10) or the judgments of experts (11,13). Our analysis of real individuals, rather than synthetic cohorts in the cross-sectional methods, means that individuals free of a specific disease will also tend to be free of associated conditions; hence, our results from the elimination of individual diseases are not additive. The frequency of comorbidity at older ages means that we could undertake analysis only by the number of conditions at baseline, although we also explored the presence of other conditions on the two most prevalent diseases, arthritis and CHD, in women. Previous conclusions were confirmed; although differences in TLE and DFLE were greater without other comorbid conditions, suggesting that our results on the impact of diseases may be conservative.

A limitation of this study is the restricted list of self-reported diseases. We compared the prevalence of conditions in women aged 70–79 years and found them similar to those reported in the Women's Heart and Health Study (30). Notably, cancer was omitted although others have shown cancer to have little impact on disability and to produce a relative expansion of morbidity, because gains in life expectancy are in persons with and without disability (9–11). We considered only conditions present at baseline rather than incident conditions so the temporal relationship between disease and disability could be inferred. Ignoring incident conditions may underestimate the impact of diseases that exert effects rapidly, as in the case of stroke, where only persons with less severe (and by definition nonfatal) stroke are represented in the baseline sample.

Our large U.K. epidemiological study with a 10-year follow-up has shown that targeting conditions such as stroke, coronary heart disease, diabetes, and cognitive impairment could have substantial consequences in years of disability saved in old age. For stroke in particular, the disability-free years gained exceed total years, suggesting that greater health care costs would not be incurred from the longer life expectancy (31). It is imperative that the effects of public health initiatives to reduce major cardiovascular risk factors are monitored in the future through mortality and disability outcomes.

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For information on the MRC CFAS Investigators, please go to http://www.cfas.ac.uk.

Correspondence

Address correspondence to Carol Jagger, PhD, Department of Health Sciences, University of Leicester, 22-28 Princess Road West, Leicester LE1 6TP, United Kingdom. E-mail: cxj@le.ac.uk

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