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Evidence for Significant Compression of Morbidity in the Elderly US Population

David M. Cutler, Kaushik Ghosh, and Mary Beth Landrum

Older Americans are living longer. Life expectancy at age sixty-five has increased about two years in the past two decades. But are we living healthier? This issue is vital for health policy and economic reasons. Longer life is valuable to people, but it is even more valuable if the additional years lived are in good health. For the public sector as well, the consequences of longer lives depend on their quality. Medical spending for healthy seniors is modest; spending for the severely disabled is much greater. Thus, if morbidity is being compressed into the period just before death, the impacts of population aging are not as severe as if additional life involves many years of expensive care.

This question of whether morbidity is being compressed into the period just before death has been at the center of health debates in the United States for some time. Fries (1980) first put forward the argument that the United States was undergoing a compression of morbidity. His work was provocative, and others took different views. Gruenberg (1977) argued that reduced disease mortality would extend unhealthy life, while Manton (1982) posited a dynamic equilibrium where both morbidity and mortality are fall-

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ing, leading to indeterminate impacts on disability-free and disabled life expectancy.

Empirical evidence on trends in morbidity is also unclear. Some authors argue that morbidity is being compressed into the period just before death (Cai and Lubitz 2007; Manton, Gu, and Lowrimore 2008), while others believe that the period of disabled life is expanding (Crimmins and Beltrán-Sánchez 2010) or that the evidence is more mixed (Crimmins et al. 2009).

There are three reasons for this disagreement. First, there is not a single definition of morbidity. Some studies look at whether people report specific chronic conditions, which have increased over time, while other studies look at functioning. As a result, studies differ in the morbidity trends they incorporate.

Second, it is often difficult to link health to the stage of life of the individual. If people are reporting more chronic disease, is that in the period just before the end of life, in which case the additional disease does not encompass many years? Or is the disease occurring in periods of time far from the end of life, in which case it represents many years of poor health? To answer this question, one needs data on quality of life matched to time until death. Most cross-section data sources do not have such a link, however, and thus they need to make assumptions about the disease process to generate lifetime disease-prevalence estimates. These assumptions can have large impacts on the results.

Third, the data samples that tend to be used often focus on a particular subset of the population; for example, the noninstitutionalized. Since there are changes in the residential location of the elderly population over time, focusing on population subsets can give biased results.

In this chapter, we examine the issue of compression of morbidity, addressing these three concerns. Our primary data source is the Medicare Current Beneficiary Survey, or (MCBS). We have MCBS data for a representative sample of the entire elderly population between 1991 and 2009. The sample sizes are large, over 10,000 individuals annually. Further, the MCBS data have been linked to death records through 2008, and hence all deaths can be matched. Importantly, this includes deaths that occur after the person has left the survey. Thus, we can form morbidity measures by time until death for a large, representative share of the elderly population.

We use these data in two ways. First, we examine trends in various measures of morbidity by time until death. We consider a number of different metrics: the presence of disease, whether the person reports activities of daily living (ADL) or instrumental activities of daily living (IADL) disability, and various summary measures of functioning that draw together nineteen different dimensions of health (Cutler and Landrum 2012). We show trends overall and by time until death.

As is well known, the MCBS data from the 1990s and 2000s show a reduction in the share of elderly people who report ADL or IADL limitations (Freedman et al. 2004, 2013). Our first result is that this reduction in disability is most marked among those with many years until death. Health status in the year or two just prior to death has been relatively constant over time; in contrast, health measured three or more years before death has improved measurably.

We then translate these changes into disability-free life expectancy and disabled life expectancy. We show that disability-free life expectancy is increasing over time, while disabled life expectancy is falling. For a typical person age sixty-five, life expectancy increased by 0.7 years between 1992 and 2005. Disability-free life expectancy increased by 1.6 years; disabled life expectancy fell by 0.9 years. The reduction in disabled life expectancy and increase in disability-free life expectancy is true for both genders and for nonwhites as well as whites. Hence, morbidity is being compressed into the period just before death.

The chapter is structured as follows. We begin in the next section by defining the compression of morbidity and showing how disability and mortality changes jointly affect disability-free and disabled life expectancy. The second section describes the data we use. The third section presents simple trends in health status by time until death. The fourth section calculates disabled and disability-free life expectancy. The last section concludes.

1.1 The Compression of Morbidity

The question we wish to examine is whether morbidity has been compressed into the period just before death, or whether it is accounting for a greater part of the life of elderly individuals. While this goal is clear, the empirical implementation needs a more precise definition. We consider two definitions of a compression of morbidity. One definition, dating back to Fries (1980), is whether the life table is "rectangularizing"—that is, whether disabled life expectancy is falling over time. A second definition is more modest: the share of remaining life that is nondisabled is increasing over time. Note that in this latter formulation, disabled life expectancy may be increasing as well, just not as rapidly as nondisabled life expectancy.

In situations where only morbidity or mortality is changing, these two measures will always move together. In situations where both mortality and morbidity are changing, however, trends in the two measures of compression of morbidity may be different.

To see this, consider a simple example presented in table 1.1 The first column depicts a person who lives for five years, the first three of which are without disability, and the fourth and fifth are with a disability. To be concrete, suppose that the person has heart disease in the fourth year and develops chronic obstructive pulmonary disease in the fifth, which results in death six months later. The specific diseases do not matter, but as is typical in the data, we reflect disability as occurring progressively over life and generally do not consider recovery.

Table 1.1 **Impact of mortality and morbidity on disabled and disability-free life expectancy**

Year	Baseline	Morbidity decline	Mortality decline	Morbidity and mortality decline
1	ND	ND	ND	ND
2	ND	ND	ND	ND
3	ND	ND	ND	ND
4	D	**ND**	D	**ND**
5	D	D	D	D
6	—	—	**D**	**D**
Life expectancy	4.5	4.5	5.5	5.5
Nondisabled life expectancy	3.0	4.0	3.0	4.0
Disabled life expectancy	1.5	0.5	2.5	1.5
Share of life expectancy that is nondisabled	67%	89%	55%	73%

Notes: ND is nondisabled and D is disabled. The table shows a hypothetical population and the impact of changes in mortality and morbidity. Morbidity changes alone increase nondisabled life, and mortality changes alone increase disabled life. Mortality and morbidity changes together extend disability-free life and have an ambiguous effect on disabled life.

In forming life tables, people who die during a year are assumed to die halfway through the year. Thus, the baseline life expectancy[1] is 4.5 years, of which the first 3.0 years is disability-free and the latter 1.5 years is disabled.

Now imagine that morbidity declines (column [2]). To be specific, suppose that because of improved medical treatment of cardiac risk factors, the person does not suffer a coronary event in the fourth year and thus is not disabled in that year. In year 5, however, the person still suffers lung disease and dies. As the last rows show, overall life expectancy is unchanged, but disability-free life expectancy has increased to 4.0 years and disabled life expectancy has fallen to 0.5 years. By either definition, disability has been compressed into the period before the end of life.

The third column shows the impact of a reduction in mortality. We imagine that the medical system gets better at treating the combination of heart disease and lung disease, and thus the person survives an additional year with both conditions, albeit they are still disabled. Total life expectancy has increased by one year in this example, all of which is associated with disability. Further, the share of life that is disabled has increased. Thus, there is an expansion of disability by either measure. Note that in this example, the person is still better off; it is just that the disabled part of life has increased.

The final column shows a combination of disability reductions (the per-

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[1] We refer to life expectancy even though this is a life table for a single person. It is easier to show the point this way than to consider a population distribution.

son does not suffer the coronary event) and mortality reductions (the person survives an additional year with lung disease). Life expectancy has increased by one year, relative to the baseline. The increase is entirely in disability-free life; disabled life starts one year later but ends one year later. In this scenario, whether morbidity has been compressed depends on the definition employed: disabled life expectancy has not declined, but a greater share of life is spent in the nondisabled state.

In general, the impact of combined morbidity and mortality changes on disability-free and disabled life expectancy depends on how rapid each change is and when in the course of life it occurs. All of this we need to evaluate empirically.

1.2 Medicare Current Beneficiary Data

Our primary data source is the Medicare Current Beneficiary Survey (MCBS). The MCBS, sponsored by the Centers for Medicare and Medicaid Services (CMS), is a nationally representative survey of aged, disabled, and institutionalized Medicare beneficiaries that oversamples the very old (age eighty-five or older) and disabled Medicare beneficiaries. Since we are interested in health among the elderly, we restrict our sample to the population age sixty-five and older.

A number of surveys have measures of disability in the elderly population (Freedman et al. 2004), including the National Health Interview Study and the Health and Retirement Study. Still, the MCBS has a number of advantages relative to these other surveys. First, the sample size is large, about 10,000 to 18,000 people annually. In addition, the MCBS samples people regardless of whether they live in a household or a long-term care facility, or switch between the two during the course of the survey period. Third, the set of health questions is very broad, encompassing health in many domains. Fourth, and most importantly, individuals in the MCBS have been matched to death records. As a result, we can measure death for over 200,000 people, even after they have left the survey window. Death data are available through 2008.

The MCBS started as a longitudinal survey in 1991. In 1992 and 1993, the only supplemental individuals added were to replace people lost to attrition and to account for newly enrolled beneficiaries. Beginning in 1994, the MCBS began a transition to a rotating panel design, with a four-year sample inclusion. About one-third of the sample was rotated out in 1994, and new members were included in the sample. The remainder of the original sample was rotated out in subsequent years. We use all interviews that are available for each person from the start of the survey in 1991 through 2009. We ignore the panel structure of the MCBS interviews and treat each survey year as a repeated cross section that has been linked to mortality information.

The MCBS has two samples: a set of people who were enrolled for the entire year (the Access to Care sample) and a set of ever-enrolled beneficiaries (the Cost and Use sample). The latter differs from the former in including people who die during the year and new additions to the Medicare population. The primary data that we use are from the health status questionnaire administered in the fall survey, which defines the Access to Care sample. We thus use the Access to Care data. We compute time until death from the exact date at which the Access to Care survey was administered to the person.

The MCBS population becomes older and less white over time, as the elderly population changes demographically. We do not want to show trends that are influenced by these demographic changes. We thus adjust survey weights so that the MCBS population in each year matches the population in the year 2000 by age, gender, and race. All of our tabulations are weighted by these adjusted weights.

Recall that our death dates are available through 2008. For each individual interviewed in 1991–2007, therefore, we can determine if they died in the next twelve months or survived that period. Similarly, we can categorize individuals through 2006 as dying between twelve and twenty-four months or not, and individuals through 2005 as dying between twenty-four and thirty-six months or not. Death at thirty-six months or beyond is also known for the population through 2005.

Trends in the distribution of time until death are shown in figure 1.1 The share of the population that is within one year of death is about 5 percent on average. Reflecting the overall reduction in mortality, this share is declining over time (this will be true of the population 1–2 years from death and 2–3 years from death as well). Between 1991 and 2007, the decline is 1 percentage point, or 18 percent. Correspondingly, the share of the population that is three or more years from death increased by about 3 percentage points, also shown in figure 1.1.

The MCBS asks extensive health questions. The first set of health questions are about medical events the person has experienced. These include cardiovascular conditions (heart disease, stroke), diseases of the central nervous system (Alzheimer's disease, Parkinson's disease), musculoskeletal problems (arthritis, broken hip), pulmonary disease, and cancer. For purposes of disability assessment, we divide these diseases into four groups, based on their likely association with death and disability (Lunney et al. 2003). The first disease is cancer. Once past the acute phase of cancer treatment, people with cancer tend to have a reasonably high quality of life until the last few months of life, when health deteriorates markedly. The second group is permanently disabling conditions that get progressively worse. Alzheimer's disease, Parkinson's disease, and pulmonary disease fall into this category.[2] The third group is acute conditions for which recovery is possible but not assured. This includes heart disease, strokes, and hip fractures.

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[2] Congestive heart failure is natural to add to this list but is only asked about from 2003 on.

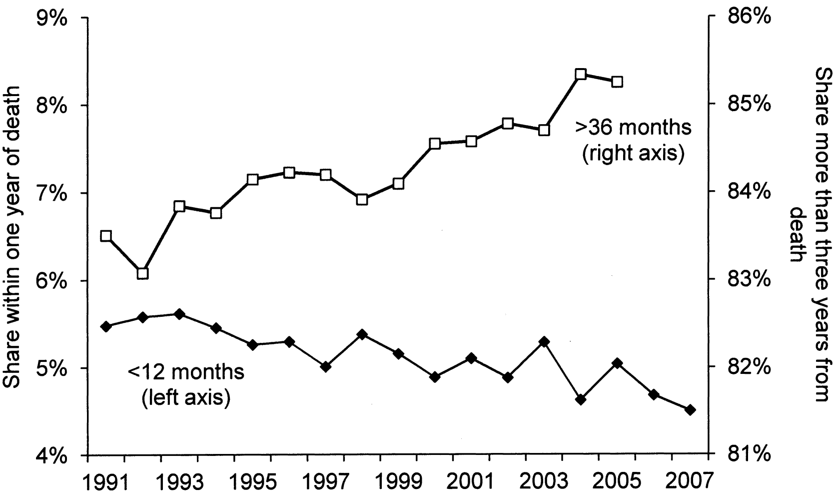

Fig. 1.1 Population distribution by time until death

Note: Data are from the Medicare Current Beneficiary Survey, 1991–2009, and are weighted to the population distribution in 2000 by age, sex, and race, as are all subsequent figures.

Finally, we group diabetes and arthritis as commonly disabling but generally nonfatal conditions.

Table 1.2 shows the prevalence of these conditions across all years of the survey, the annual percentage point change in the prevalence over time, and the disability rate conditional on having the disease (defined as whether the person reports an ADL or IADL limitation; see following). Nonfatal conditions are the most common. Over half of the elderly population reports a prior diagnosis of arthritis, the prevalence of which is increasing by 0.3 percentage points annually. Nearly one in five elderly people has diabetes. Acute conditions for which recovery is possible are the next most common, ranging in prevalence from 4 percent of the population (hip fracture) to 26 percent (ischemic heart disease). Perhaps owing to better prevention, the prevalence of both heart disease and heart attacks is declining over time. About 18 percent of the elderly population has a history of cancer, which is increasing over time. Degenerative diseases are relatively less common, though pulmonary disease affects about one-seventh of the elderly population. People with these conditions are extremely likely to report having an ADL or IADL impairment.

The MCBS also asks a number of questions about the impact of morbidity on a respondent's ability to function and perform basic tasks, shown in table 1.3. The first category of questions is about physical functioning, such as difficulty walking a reasonable distance (1/4 mile or 2–3 blocks) or carrying moderate-weight objects. Difficulty in these areas ranges from one-quarter to three-quarters of the elderly population.

Table 1.2 Medical event questions in the MCBS

Number	Ever told have . . .	Average prevalence (%)	Annual percentage point change (%)	Percent with ADL or IADL limitation (%)
1	Cancer	17.7	.13	50
	Chronic disabling conditions	19.5	.31	69
2	Alzheimer's disease	5.2	.12	91
3	Parkinson's disease	1.6	–.01	83
4	Pulmonary disease	14.0	.23	61
	Recoverable acute conditions	34	–.27	61
5	Acute myocardial infarction	13.9	–.07	59
6	Ischemic heart disease	25.6	–.32	59
7	Stroke	11.2	.04	71
8	Broken hip	4.1	–.08	77
	Nonfatal conditions	63.5	.45	52
9	Arthritis	56.5	.29	53
10	Diabetes	18.7	.52	58

Notes: Tabulations are from the MCBS Access to Care sample for 1991–2009 and use sample weights. The sample includes 251,872 observations.

The second and third categories are impairments in activities of daily living (ADL) such as bathing or dressing, and instrumental activities of daily living (IADL) such as doing light housework or managing money. Six questions are asked about each of the ADL and IADL limitations. Because limitations in these areas reflect more severe impairment, the share of the elderly population reporting difficulty in these areas is lower than the share reporting difficulty with functional limitations.

The final category is sensory impairments, including trouble seeing and hearing. In the case of vision, the difficulty also refers to correction such as glasses or contact lenses, and for hearing it is with hearing aid. The possible responses to the vision and hearing questions changed in 2002. Prior to 2002, the responses for each question were: *no trouble, a little trouble, and a lot of trouble*. Starting in 2002, a more severe category was added to each: *no usable vision* and *deaf*. After this change, more people reported less severe vision and hearing impairments—most likely, they judged themselves less severely disabled relative to the more severe categories now being offered as a response. The share of people reporting difficulty with vision and hearing each fell by 4 percentage points in 2002, far larger than in any other year.

To adjust for this, we create a counterfactual time series for difficulty with vision and hearing assuming that the trend in each variable in the year the survey changed was the same as the trend in the prior three years. We then extend this aggregate estimate back to 1991. At the individual level, we randomly choose individuals who reported that they had a little trouble seeing or hearing and recategorize their responses to having no trouble, to match

Table 1.3 **Health status questions in the MCBS, 1991–2009**

Number	Question	Prevalence (%)
	Functional limitation: Difficulty	
1	Stooping/crouching/kneeling	70
2	Lifting/carrying 10 pounds	39
3	Extending arms above shoulder	29
4	Writing/handling object	28
5	Walking ¼ mile or 2–3 blocks	47
	Activities of daily living: Reports difficulty doing the following activities by himself/herself because of a health or physical problem	
6	Bathing or showering	15
7	Going in or out of bed or chairs	15
8	Eating	5
9	Dressing	10
10	Walking	26
11	Using the toilet	8
	Instrumental activities of daily living: Reports difficulty doing the following activities by himself/herself because of a health or physical problem	
12	Using the telephone	10
13	Doing light housework (like washing dishes, straightening up, or light cleaning)	16
14	Doing heavy housework (like scrubbing floors or washing windows)	34
15	Preparing own meals	14
16	Shopping for personal items	18
17	Managing money (like keeping track of expenses or paying bills)	11
	Sensory problems	
18	Trouble seeing	32
19	Trouble hearing	38

Notes: Tabulations are from the MCBS Access to Care sample for 1991–2009 and use sample weights. Trouble seeing and hearing are adjusted to reflect questionnaire changes in 2002 and 2003. The sample includes 251,872 observations.

the adjusted aggregate totals. With these adjustments, about one-third of the elderly population reports vision and hearing impairments on average.

The health status questions are generally the same for the community population and the institutional population, with the exception that the institutionalized are not asked about three IADLs limitations—light housework, preparing meals, and heavy lifting. On average, 5 percent of people are in a nursing home. In order to utilize these questions, we assume that everyone in a nursing home has difficulty with these activities.[3]

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[3] With regard to the other IADLs, 61 percent of people living in institutions report difficulty using the telephone and 85 percent report difficulty shopping for personal items and managing money. Over 90 percent report difficulty with basic activities such as stooping, crouching or kneeling, or carrying a 10 lb. object (Cutler and Landrum 2011).

1.2.1 Summary Health Status Measures

The most common single measure of disability in the literature is any difficulty with ADL or IADLs. We follow this in our analysis and define disability as an ADL or IADL impairment.

While simple to implement, this measure lacks a rigorous theoretical foundation. Moreover, a binary measure does not capture heterogeneity in the population. For many purposes, we care about finer gradations in the distribution of health. There is a literature (e.g., Verbrugge and Jette 1994) arguing for a distinction between functional status (measures of specific physical functioning) and disability (the ability to engage in the activities typically expected of a person). Within this latter spirit, we examine the different dimensions of health among the elderly. In particular, we estimate a factor analytic model of the different domains of functioning and choose the number of domains that best summarize the data.

Formally, denote y_{ij} as the response to question j for individual i. Suppose there are J questions total ($J = 19$ in our setting). We imagine that these health states are a linear function of K different unobserved factors, denoted F_{ik}. We fit a factor analytic model of the form (e.g., Bartholomew 1987; Knol and Berger 1991):

$$y_{ij} = \gamma_{0j} + \gamma_{1j}F_{i1} + \gamma_{2j}F_{i2} + \gamma_{3j}F_{i3} + \ldots + \gamma_{Kj}F_{iK}, \tag{1}$$

where y_{ij} is a 0 or 1 outcome variable, γ_{0j} is a threshold parameter that accounts for varying prevalence of limitations in the population (for example, limitations climbing stairs are more common than limitations in bathing) and the γ_{kj}'s are factor loadings that describe the relationship between unobserved factor k and question j. Unobserved factors are assumed to follow a multivariate normal distribution. The latent variable model described by equation (1) is similar to the factor analyses and grade of membership models that have been previously used to describe dimensions of disability (Lamb 1996; Manton, Woodbury, and Tolley 1994; Manton, Stallard, and Corder 1998; Woodbury and Garson 1978).

We can fit this model provided $K < J$. Empirically, because the data tend to be highly correlated and we have nineteen dimensions of health, a small number of factors is associated with a wide range of variation in the data.

Table 1.4 shows the results of the factor analysis over the 1991–2009 time period. By the usual criterion of eigenvalues greater than 1, there are three significant factors. Together, these three account for 57 percent of the cumulative variation in the data. These three also have natural economic and demographic interpretations. We thus work with those three.

The predicted factor scores are positively correlated. Prior to rotation, the correlation between factors 1 and 2 is .501, between 1 and 3 is .246, and between 2 and 3 is .265. To aid in interpretation, we consider rotations of

Table 1.4 **Factor analysis for MCBS data**

	Eigenvalue	Proportion	Cumulative
1	7.978	0.420	0.420
2	1.779	0.094	0.514
3	1.122	0.059	0.573
4	0.872	0.046	0.619
5	0.851	0.045	0.663
6	0.809	0.043	0.706

Notes: The results are from factor analyses using the MCBS data for 1991–2009. The sample includes 251,872 observations.

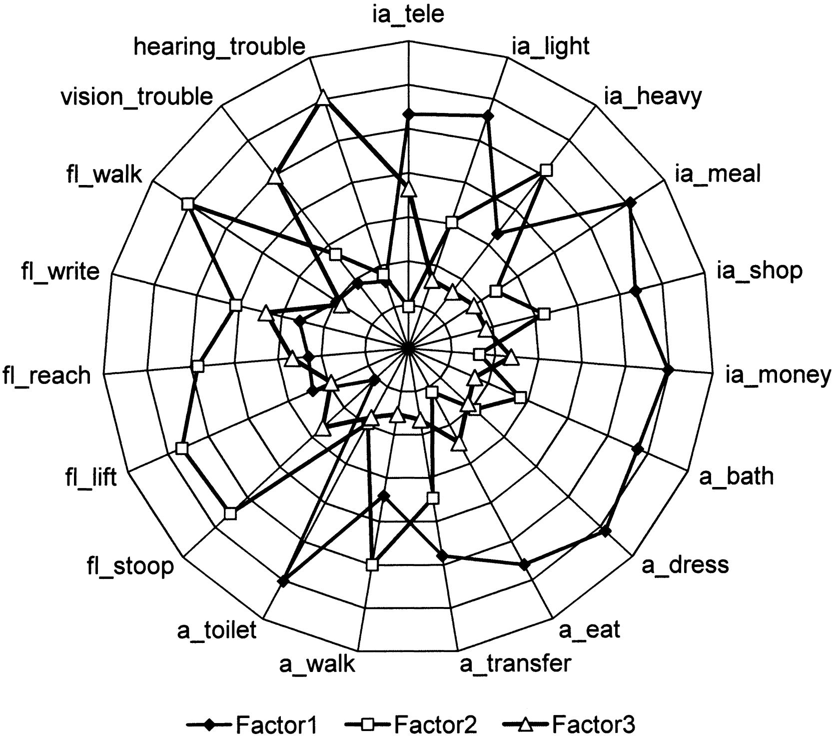

Fig. 1.2 Factor loadings

Note: The figure shows the factor loadings for the first three factors of the health status questions. Data are from the Medicare Current Beneficiary Survey, 1991–2009.

the factors that reduce the correlation between them. Specifically, we use an oblique rotation of the three factor scores (promax = 3).

Figure 1.2 shows a radar plot of the (rotated) factor scores. The first factor loads heavily on ADL and IADL limitations, including bathing, dressing, eating, managing money, and preparing meals. This is a very severely

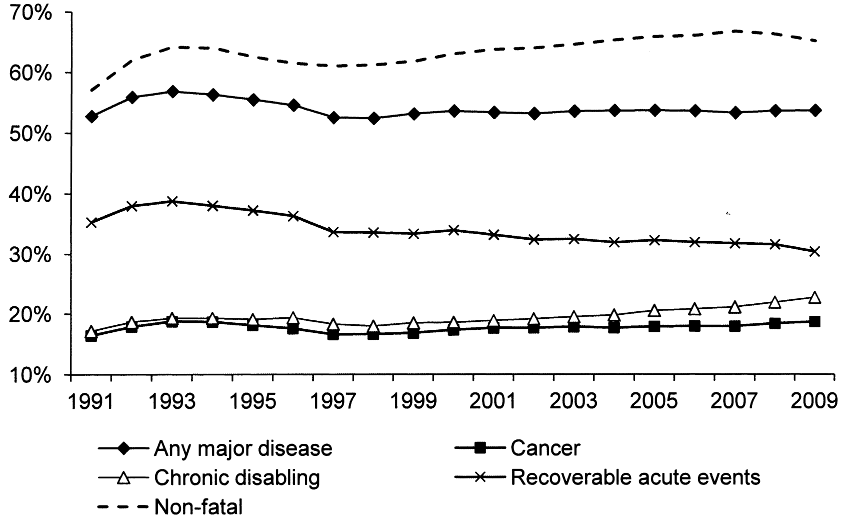

Fig. 1.3 Trends in disease prevalence

Note: Major diseases include cancer, chronic disabling conditions, and recoverable acute events. Specific conditions in the chronic disabling, recoverable acute event, and nonfatal condition categories are in table 1.2.

impaired population. The second factor is largely associated with functional limitations and related IADLs, including difficulty walking, lifting, stooping, reading, and doing heavy housework. This group is generally somewhat less impaired. The third factor is concentrated in sensory impairments, including both vision and hearing.

1.3 Trends in Health

Our goal is to examine health trends by time until death. We start with overall health trends in the population as a whole and then proceed to trends for the different subgroups by time until death.

1.3.1 Disease Prevalence

Disease prevalence is a first measure of health that we consider. Figure 1.3 shows the share of the elderly with the four categories of conditions over time: cancer, chronic degenerative diseases, recoverable acute conditions, and generally nonfatal conditions; individual trends are reported in table 1.2. There has been an increased prevalence of nonfatal disease over time, as more people report arthritis and diabetes. Major severe diseases as a whole have been relatively constant in prevalence. This constancy masks some differentiation by type of condition, however. Recoverable acute conditions have declined in prevalence over time, from about 40 percent of the

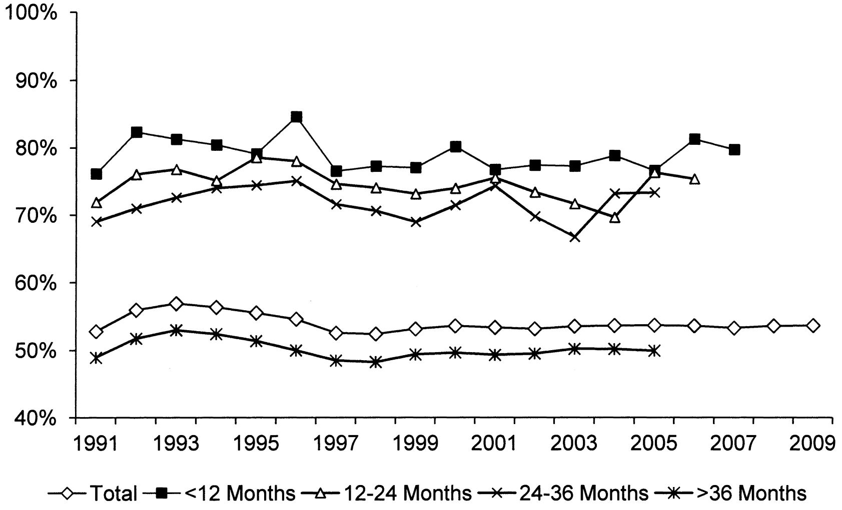

Fig. 1.4 Any major disease prevalence by time until death

Note: Major diseases include cancer, chronic disabling conditions, and recoverable acute conditions.

population in 1993 to about 30 percent in 2009. Chronic disabling conditions have increased (Alzheimer's and pulmonary disease), and cancer has been relatively constant.

We consider the major diseases as a group, since they are likely to have the biggest impact on health. Figure 1.4 shows the prevalence of any major disease by time until death. Since this figure is used repeatedly in the chapter, we describe it here in some detail. The second-to-the-lowest line of the figure is the overall prevalence of major conditions, analogous to the line in figure 1.3. Since this line is not conditioned on time until death, we can form this series through 2009. The upper line in the figure is the share of people within twelve months of death who have a major condition. That line extends through 2007, since we know twelve-month mortality for that group. The prevalence of major diseases is significantly greater in the population near death than in the overall population. About 80 percent of seniors near death have at least one major condition, and that share is relatively constant over time. The most common major disease in this group is heart disease (38 percent of the population, on average). Cancer affects about 25 percent of this population, as does Alzheimer's disease and pulmonary disease (chronic degenerative diseases) and heart attacks and stroke (recoverable acute conditions). Parkinson's disease has a lower prevalence (4 percent), as does hip fracture (9 percent).

The lines just below the top line are the prevalence rate for people 12–24 months from death and 24–36 months from death. For each line, we are

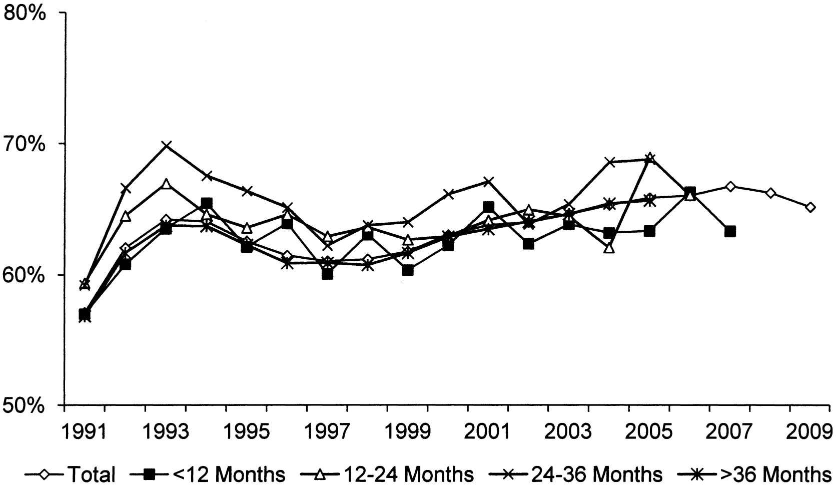

Fig. 1.5 Any minor disease prevalence by time until death

Note: Minor diseases include arthritis and diabetes.

restricted to data ending one year earlier, reflecting the fact that the mortality information is only available through 2008. The prevalence of major disease is slightly lower for these groups, but still high. In each case, the prevalence is 70–80 percent. As with the population within twelve months of death, major disease prevalence is not changing in the population 1–2 years and 2–3 years from death. The lowest line in the figure is the prevalence of major disease in people thirty-six or more months from death. This share is about 50 percent, and is flat after a rise and fall in the early to mid-1990s.

Figure 1.4 shows clearly that not only is major disease prevalence overall unchanged, but major disease prevalence is unchanged in each window of time until death. We return to lifetime disease-free years next.

The prevalence of minor diseases by time until death is shown in figure 1.5. There are five lines in the figure, but they are virtually indistinguishable. About 60–70 percent of elderly people have arthritis or diabetes, and that is independent of how close or far they are from death. Similarly, the prevalence of minor diseases increases over the years 2001 to 2009 for all groups.

1.3.2 Functional Limitations and Disability

We now proceed to functional limitations and ADL/IADL limitations, the latter of which is the most common metric of disability in the literature. Figure 1.6 shows the time series for any functional limitation, any ADL or IADL impairment, any ADL impairment, and any IADL impairment. The prevalence of functional limitations is high; about 60 percent of the elderly population reports some difficulty with the functional measures. ADL or

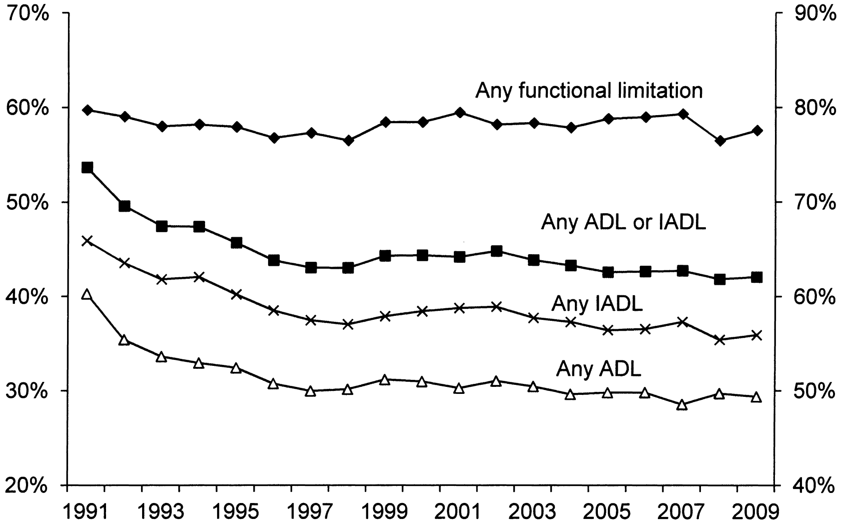

Fig. 1.6 Trend in functioning

Note: Specific questions used in functional limitations and ADL/IADL limitations are shown in table 1.2.

IADL impairment is lower but still high. Nearly half of the elderly population reports one or more ADL or IADL problems. Effectively, this means that about half of the life expectancy of the elderly is years lived with a disability.

Overall functional limitations are relatively constant over time, declining by 2.7 percent between 1991 and 2009. The prevalence of people with ADL or IADL impairments declined more dramatically, however. The overall reduction between 1991 and 2009 is 22 percent, with somewhat greater declines for ADL disability than IADL disability, but impressive declines in both. Most of the disability decline was in the 1991–1997 time period. Between 1997 and 2002, disability increased modestly, before declining again from 2005 to 2009.

Changes in disability may be influenced by demographic or disease factors. Although not the primary focus of our analysis, we consider this a little in understanding the change in disability over time. We start by relating disability in the early time periods of the sample (1991–1993) and the later time periods (2004–2006) to demographic and medical factors:

$$\text{Disability}_{it} = \text{Demog}_{it}\,\beta_{Dt} + \text{Clinical}_{it}\,\beta_{Ct} + \varepsilon_{it}. \tag{2}$$

where *i* denotes individuals and *t* denotes the time period (1991–1993 or 2004–2006). Demographics include five-year age-sex dummy variables, a dummy variable for nonwhites, a dummy variable for being married, and a dummy variable for having a high school degree or more. The clinical

Table 1.5 **Regressions explaining disability**

	1991–1993		2004–2006	
	Coef.	**Std. Error**	**Coef.**	**Std. Error**
Demographics				
Male 70–74	0.018	(0.010)	0.002	(0.009)
Male 75–79	0.080***	(0.011)	0.048***	(0.010)
Male 80–84	0.166***	(0.013)	0.157***	(0.012)
Male 85	0.313***	(0.015)	0.283***	(0.014)
Female 65–69	0.093***	(0.010)	0.073***	(0.009)
Female 70–74	0.116***	(0.010)	0.094***	(0.009)
Female 75–79	0.176***	(0.011)	0.150***	(0.009)
Female 80–84	0.278***	(0.012)	0.247***	(0.010)
Female 85	0.381***	(0.012)	0.375***	(0.011)
Nonwhite	–0.0421***	(0.008)	0.016*	(0.007)
Married	–0.055***	(0.006)	–0.038***	(0.005)
> = High school	–0.077***	(0.005)	–0.091***	(0.005)
Conditions				
Alzheimer's	0.246***	(0.012)	0.323***	(0.010)
Parkinson's	0.212***	(0.019)	0.253***	(0.018)
Broken Hip	0.149***	(0.011)	0.188***	(0.012)
Stroke	0.187***	(0.008)	0.156***	(0.007)
Pulmonary	0.160***	(0.007)	0.163***	(0.006)
IHD	0.139***	(0.006)	0.068***	(0.006)
Diabetes	0.134***	(0.007)	0.130***	(0.006)
Arthritis	0.152***	(0.005)	0.139***	(0.005)
Cancer	0.063***	(0.007)	0.044***	(0.006)
Constant	0.205***	(0.010)	0.187***	(0.009)
N	31,374		38,880	
R^2	0.250		0.218	

Note: The table shows regressions for reporting an ADL or IADL impairment in either 1991–1993 (the first columns) or 2004–2006 (the second columns).

covariates include dummy variables for the conditions in table 1.2. Both the demographic and clinical covariates are strongly associated with disability (table 1.5). Older age is associated with higher disability, as being nonwhite, being single, and having less education. All of the clinical covariates are associated with higher disability rates, as we would expect.

We then perform an Oaxaca decomposition to understand how much of the reduction in disability can be explained by changes in the X's (for example, the population becoming better educated or less likely to have heart disease) versus changes in the impact of each demographic and clinical factor on disability. We do this as in equation (3):

$$\text{(3)} \qquad \begin{aligned} \Delta\text{Disability} \approx {} & \{\Delta\text{Demog}\ \beta_{Dto} + \Delta\text{Clinical}\ \beta_{Cto}\} \\ & + \{\text{Demog}_{to}\ \Delta\beta_{D} + \text{Clinical}_{to}\ \Delta\beta_{C}\} \end{aligned}$$

Table 1.6 **Impact of demographics and medical conditions on health**

	Measure of health			
Health change (percentage points)	Disability (%)	F1	F2	F3
Total change	–7.4	–.138	–.091	–.201
Effect of changes in Xs				
Demographics	–1.4	–.025	–.034	–.026
Condition prevalence	0.5	.008	.014	.010
Effect of changes in βs				
Conditions	–2.9	–.185	–.083	–.063
Demographics	–2.1	–.084	–.074	–.039
Constant	–1.8	.148	.090	–.093

Notes: The table is a decomposition of changes in the measure of health indicated in the columns. For each health measure, we estimate equations of the form $H_{it} = X_{it}\beta_t + \varepsilon_{it}$, for two time periods (1991–1993 and 2004–2006). The first row, total change, shows the percentage point change in H_{it} over time. The remaining rows show the predicted percentage point change in H_{it} resulting from changes in the X variables, decomposed into demographics and condition prevalence, and changes in the βs, decomposed into those for conditions, those for demographics, and the constant term.

where t_o denotes the initial time period and Δ indicates the changes over time. The first term on the right-hand side of equation (3) is the impact of changing demographics and clinical condition prevalence, holding constant their health impact, and the second term is the impact of changes in the relationship between clinical and demographic factors and disability, holding constant their prevalence. There is no *i* subscript because we use averages of each explanatory variable in the relevant time period.

Table 1.6 shows this decomposition. The first column uses disability as the health outcome measure. As the first row shows, the overall reduction in disability was 7.4 percentage points. The next two rows show the impact of changes in demographics and condition prevalence between 1991–1993 and 2004–2006 on disability. Demographic changes imply a modestly healthier population over time,[4] while the clinical conditions have become somewhat more prevalent. Overall, the contribution of changes in the explanatory factors is modest.

The next rows show that the bulk of the impact comes from changes in the severity of demographic and clinical risk factors. Conditions have become less disabling over time (see table 1.5)–especially heart disease and arthritis—and this lowers disability by 2.9 percentage points. Older age is less disabling than formerly, even given the clinical conditions we measure. This accounts for another 2.1 percentage points. Finally, the constant term, reflecting other

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[4] Recall that age, gender, and race changes have already been factored out, by reweighting the data to the population distribution in 2000. Thus, the demographic change is only marital status and education.

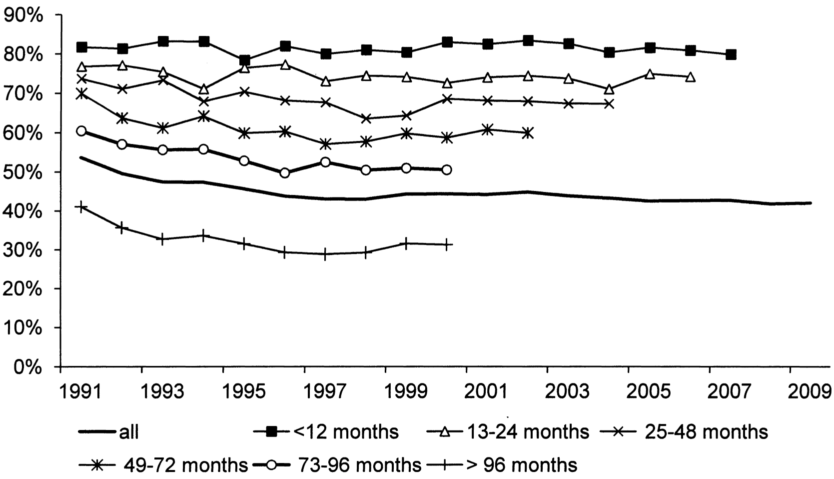

Fig. 1.7 ADL/IADL disability by time until death

Note: Specific ADL and IADL questions are defined in table 1.2.

factors not captured, shows a large decline in disability. The finding that conditions are less severely disabling than they were formerly motivates our focus on their relation to time until death, not on the incidence of conditions themselves.

Figure 1.7 shows the share of the population with an ADL or IADL limitation by time until death. Since disability defined in this way is the most common health metric in the literature, and it has fallen so much, this figure is in many ways the most crucial to understand population changes in health. Also for this reason, we decompose the change in disability by more periods of time: <12 months until death, 12–24 months until death, 25–48 months until death, 49–72 months until death, 73–96 months until death, and 97+ months until death.

Figure 1.7 shows clearly that the vast bulk of the reduction in disability is among people a few years away from death. Disability is high and has remained so for people within one year of death; about 80 percent of this population is disabled, and that has not changed over time. Indeed, more detailed analysis shows just how sick this population is. The average person in the last twelve months of life has 2.7 ADL limitations and 3.1 IADL limitations. Disability has declined marginally for those 12–24 months from death (2.8 percentage points over the period). Rather, the larger decline is for the population twenty-five or more months from death. Starting in the group three to four years from death, disability declines by 6 to 7 percentage points in each group.[5] Figure 1.8 shows this pattern graphically. The reduction in disability is greater the farther out from death one goes.

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[5] Each group is observed over a different time frame. However, since most of the disability decline occurred prior to the mid-1990s the differing observation windows has minimal effect.

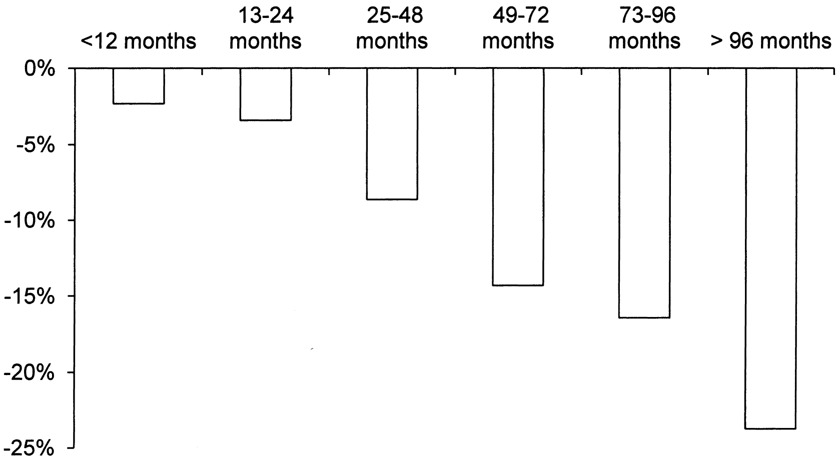


Fig. 1.8 Percent change in disability by time until death
Note: The data are based on figure 1.7 and represent changes from 1991 through 2000.

We can show the implications of these trends using a more formal analysis. Note that the average disability in the population can be expressed as the average of disability for people with different times until death, weighted by the share of people in that time-until-death category: $\text{Disability}_t = \Sigma_k \text{Share}_{kt} * \text{Disability}_{kt}$, where k references the buckets of time until death. Then, the change in the disability rate is approximately equal to the change in the mortality rates, weighted by initial disability rates, and the change in disability rates, weighted by the population share with that time to live:

$$(4) \quad \Delta\text{Disability} \approx \Sigma_k \, \Delta\text{Share}_k \, \text{Disability}_{kto} + \Sigma_k \, \text{Share}_{kto} \, \Delta\text{Disability}_{k.}$$

Table 1.7 shows the results of this decomposition. As the first row of the second column shows, disability declined by 6.3 percentage points. The next row shows the impact of mortality changes on the prevalence of disability. Because people are living longer, disability would have declined by 0.7 percentage points, even if all groups were just as disabled as in the early time period. The far bigger impact is of changes in disability for a given time until death. Disability declines particularly greatly for those two or more years from death. The decline is roughly similar in groups that far from death or longer. The largest share of disability decline occurred in the population eight or more years from death (almost 50 percent), though this group is about 60 percent of the population.

Given the importance of health trends by population subgroup, figure 1.9 shows the relationship between disability and time until death for different demographic groups, divided by gender (a and b), race (c and d), and education (e and f). The pattern in all cases is very similar. Disability declined only slightly near death, and much more the farther away from death one

Table 1.7 **Decomposition of disability over time, by time until death**

Measure	Disability change in group (%)	Decomposition of total change in disability (%)
Total change	—	–6.3
Effect of survival	—	–0.7
Change within time periods		
≤ 12 months	–0.4	–0.0
13–24 months	–3.7	–0.2
25–48 months	–10.0	–0.8
49–72 months	–9.4	–0.6
73–96 months	–12.3	–0.7
> 96 months	–15.9	–3.3

Notes: The first column shows the percent change in disability rate for people in each category of time until death. The change is taken from 1991–1993 to the latest three years available. The second column decomposes the total change in disability. The first row, total change, shows the percentage point change in disability over time from 1991–1993 to 1998–2000. The second row shows the change in disability resulting from changes in the share of people with different periods of time until death. The remaining rows show the change in disability resulting from changes in the disability rate in each time-until-death category.

gets. Indeed, even the magnitudes are similar. The decline in disability for those eight or more years from death is 20–25 percent in all cases. Thus, the results we find are quite robust across demographic groups.

Although functional status did not decline greatly in our data, we show the trend in functional limitations by time until death in figure 1.10. Almost everyone is functionally limited before death; in the last year of life, 95 percent of people have a functional limitation. This did not change greatly over time, however. Nor did it change meaningfully in any other population group.

1.3.3 Summary Measures of Health

We finally turn to our three summary measures of health, the factor scores from the factor analysis. We denote them F1, F2, and F3, corresponding to the three largest eigenvalues in table 1.4. We also identify them by the health measures that load on them most strongly: ADL and IADL limitations for F1, functional limitations for F2, and sensory impairments for F3. As is customary, we normalize each factor score to have a mean of 0 and a standard deviation of 1. A higher score indicates more "yes" answers to the impairments, and thus a greater level of sickness.

Figure 1.11 shows the trend in the three factor scores. All three decline over time. The greatest decline is for F3, the factor reflecting sensory impairments. The overall decline is approximately one-sixth of a standard deviation. F1, corresponding to ADL and IADL limitations declines the second largest, and F2, corresponding to functional limitations and related ADL and IADL limitations, declines the least.

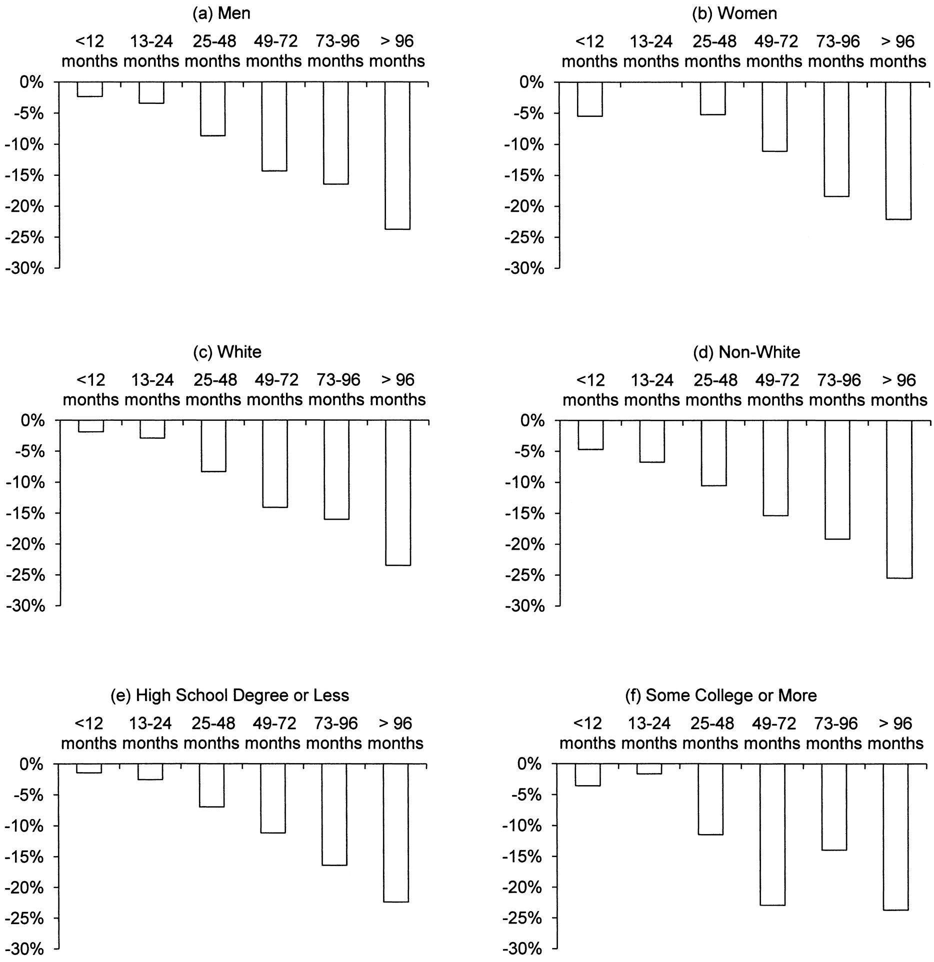


Fig. 1.9 Percent change in disability by time until death

Note: The data are for 1991–2000 and are based on data like those in figure 1.7.

Figure 1.12, in panels (a), (b), and (c), shows the changes for each factor score by time until death. Not surprisingly, there is enormous spread in the data. For those within 12 months of death, the average F1 score is about 1.5, the average F2 score is about 0.8, and the average F3 score is about 0.5. These decline somewhat as death moves away in time, but they remain high even for people 24–36 months from death. For that group, F1 and F2 are about 0.5.

Mirroring our results in the binary disability measure, the improvement in these health measures is particularly marked for those farther from death. Except for F3, these summary measures do not improve greatly for those in the three years prior to death. Rather, the vast bulk of the decline is in those

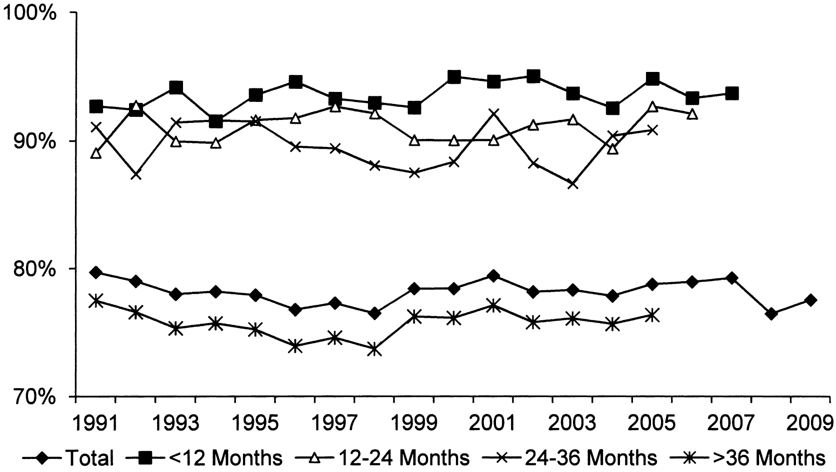


Fig. 1.10 Functional limitations by time until death
Note: Functional limitations are defined in table 1.2.

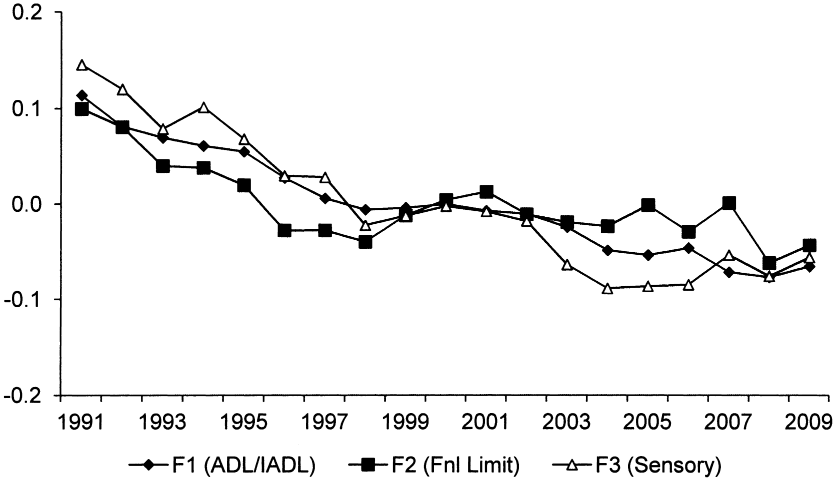


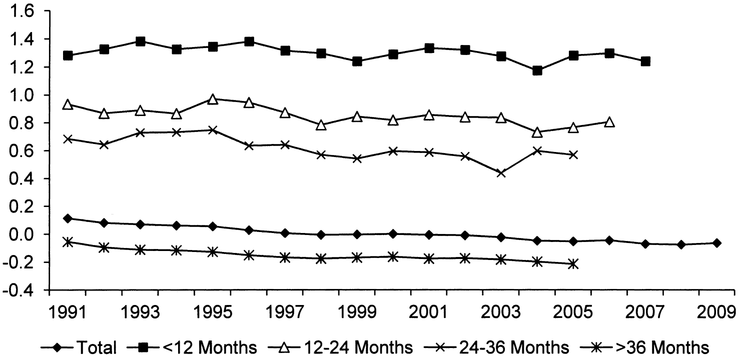
Fig. 1.11 Trend in factor scores
Note: F1, F2, and F3 are based on the factor analysis displayed in table 1.3.

with three or more years to live until dying. Sensory impairments, however, are declining in all groups, even those very close to death.

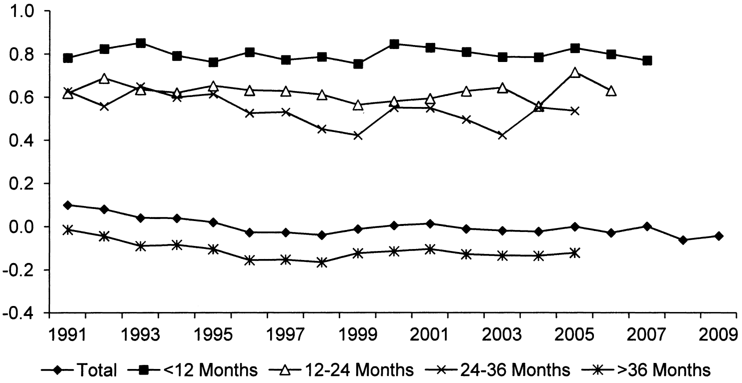
1.3.4 Summary

There are many measures of health, not all of which move in the same direction. As a result, there is no single conclusion we can draw. But there are some common trends that are important. Our major conclusion is that time spent in poor physical functioning is being increasingly compressed

(a) F1 (ADL/IADL impairments)



(b) F2 (Functional Limitations)



(c) F3 (Sensory)

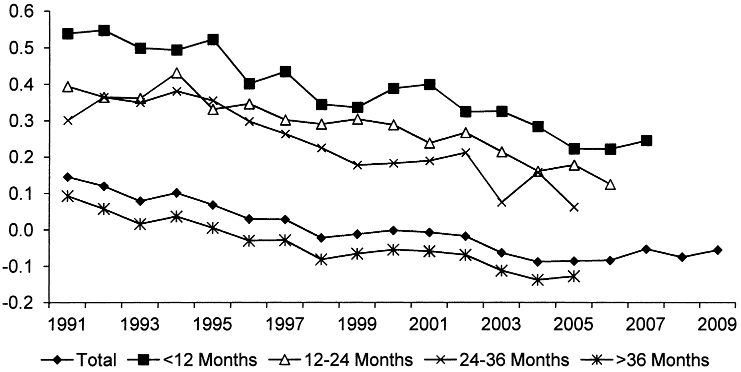


Fig. 1.12 Trend in factor scores by time until death

Note: F1, F2, and F3 are based on the factor analysis displayed in table 1.3.

into the period just before death. Limitations in very severe impairments such as ADLs or IADLs are falling for those not near the end of life, as are more severe functional limitations. Less severe functional limitations are constant, and overall disease prevalence is rising. People have more diseases than they used to, but the severe disablement that disease used to imply has been reduced.

The compression of morbidity into the period just before death means that disability-free life expectancy will be increasing. We explore changes in disability-free and disabled life expectancy quantitatively in the next section.

1.4 Disability-Adjusted Life Expectancy

Understanding the compression of morbidity is best done in the context of disability-adjusted survival. In this section, we turn our estimates of health changes into changes in disabled and disability-free life years. The starting point for our analysis is the standard measure of life expectancy:

$$(5)\quad \mathrm{LE}(a) = \Sigma_s \{\Pr[\text{Survive } a + s \mid \text{Alive } a] + .5^*\Pr[\text{Die at } a + s \mid \text{Alive } a]\}.$$

Starting at age a, every (probabilistic) year that the average person survives adds one year to life expectancy. A person who dies in a year is assumed to live half the year, and thus adds half that amount to life expectancy.

Mortality is calculated by the National Center for Health Statistics and routinely published in the National Vital Statistics Reports. We use their data for mortality.

To account for disability, we modify equation (5). For those in the last year of life, we weight the half year they expect to live by the share of the people in that half year who are not disabled. As figure 1.8 shows, this is on average 20 percent. Similarly, we weight the years lived by those one year away from death, two years away from death, three years away from death, and more than three years away from death by the share of population in those intervals who are not disabled. Adding this up over all future ages yields disability-free life expectancy. Disabled life expectancy is the difference between total life expectancy and disability-free life expectancy.

We can form disability-free life expectancy and disabled life expectancy for any year in which we have mortality and disability data. To match our results, we estimate these values in two time periods: 1992 and 2005. The mortality data are from those exact years. The disability data are from 1991–1993 and 2003–2005. We present all of our calculations for a person age sixty-five in those years.

Relative to our earlier calculations, we make one additional refinement. Where earlier we showed disability rates on an age-adjusted basis, here we need to disaggregate disability by age. For example, about 45 percent of people who are thirty-six or more months from death in 1991–1993 have an ADL or IADL impairment. But that share is about 30 percent for the young-

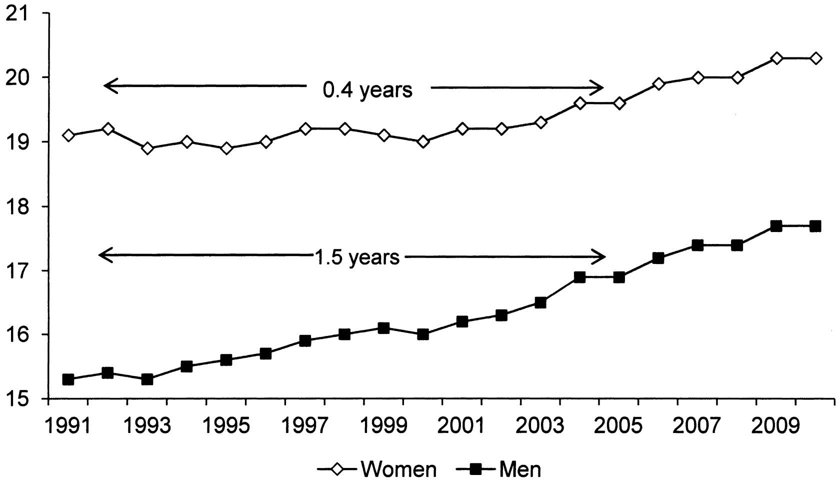


Fig. 1.13 Life expectancy at age sixty-five
Note: Data are from the National Center for Health Statistics.

est elderly and 80 percent for the oldest elderly. To account for this, we form an estimate of disability rates that is age specific. Rather than calculating means across single-year age by time-until-death cells, which would involve many small cells, we instead use regression analysis to smooth disability rates by age, and other demographic characteristics.

Specifically, we estimate a logistic regression model relating disability to age and its square, a dummy for females, and a dummy for nonwhite. We estimate this regression separately for 1991–1993 and 2003–2005 and for each category of time until death: < 12 months, 12–24 months, 24–36 months, and 36 months or more. We then predict the disability rates for each person and average the predictions across the relevant groups (e.g., single year of age). We match these to life tables in 1992 and 2005.

1.3.5 Results

We start with basic life expectancy calculations. Figure 1.13 shows the trend in life expectancy at age sixty-five, separately for men and women. Life expectancy is rising for both groups, but the increase is much greater for men than women. Between 1992 and 2005, life expectancy for a sixty-five-year-old male increased by 1.5 years, while life expectancy for a sixty-five-year-old woman increased by 0.4 years. Our life expectancy data differs from these calculations slightly, since the NCHS does not publish mortality tables beyond age 100. We thus assume everyone dies at that age. Effectively, this reduces our life expectancy increase by 0.2 years.

Figure 1.14 shows the trend in total life expectancy, disability-free life expectancy, and disabled life expectancy for the overall population at

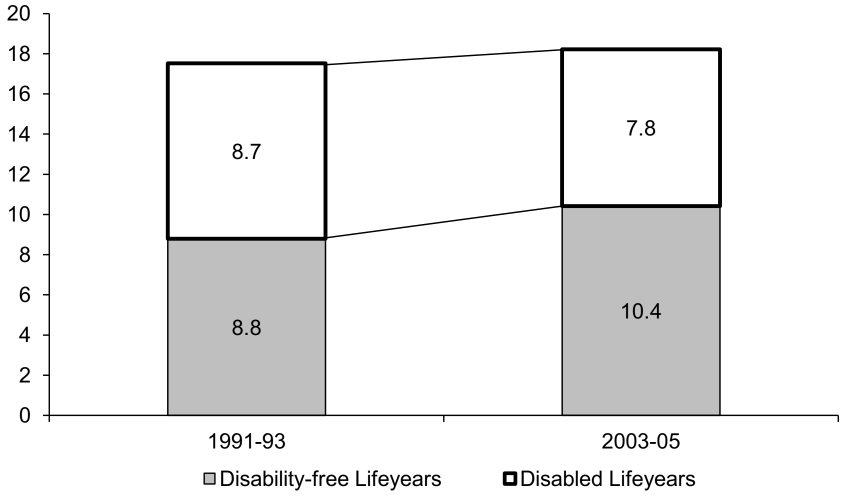


Fig. 1.14 Trend in disabled and disability-free life expectancy

Note: The figure combines life expectancy data from the NCHS with imputed disability rates by age and time until death.

age sixty-five. Table 1.8 shows specific numerical results. Life expectancy at age sixty-five was 17.5 years in 1992. This reflects the fact that about half the elderly population is disabled, and about half of those years were disabled.

Life expectancy increased by 0.7 years between 1992 and 2005. Because the fall in disability was so large, however, the increase in disability-free life expectancy was greater than the total increase in life expectancy—1.6 years in total. The residual was a reduction in disabled life expectancy of 0.9 years. Thus, both the metric of the change in disabled life expectancy as well as the share of life that is spent disability free, morbidity is being compressed into the time period just before death.

Figure 1.15 shows life expectancy, disability-free life expectancy, and disabled life expectancy by gender and race. In all four cases, the results are similar: overall life expectancy increased, and disability-free life expectancy increased by even more. As a result, disabled life expectancy fell in all cases. The decline in disabled life expectancy was greater for women than for men, but was similar by race.

In principle, we can estimate changes in life expectancy and disability-free life expectancy by education as well. In practice, while data on mortality by education are collected (since 1989), they are not routinely published.[6] In

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[6] Some authors have calculated life expectancy by education for particular years (e.g., Meara, Richards, and Cutler 2008), but they do not match the years we analyze for the other demographic groups.

Table 1.8 **Changes in disabled and disability-free life expectancy at age sixty-five**

	1991–1993			2003–2005			Change		
Group	Total	Disability free	Disabled	Total	Disability free	Disabled	Total	Disability free	Disabled
All	17.5	8.8	8.7	18.2	10.4	7.8	0.7	1.6	–0.9
Men	15.5	9.2	6.2	16.7	10.9	5.8	1.3	1.7	–0.4
Women	19.2	8.4	10.8	19.4	10.0	9.4	0.2	1.6	–1.4
White	17.6	9.0	8.6	18.3	10.6	7.7	0.7	1.6	–0.9
Nonwhite	15.8	7.0	8.9	16.7	8.8	7.9	0.9	1.8	–1.0

Notes: The table shows total life expectancy, disability-free life expectancy, and disabled life expectancy, in years. Disability is an indicator for the presence of an ADL or IADL limitation.

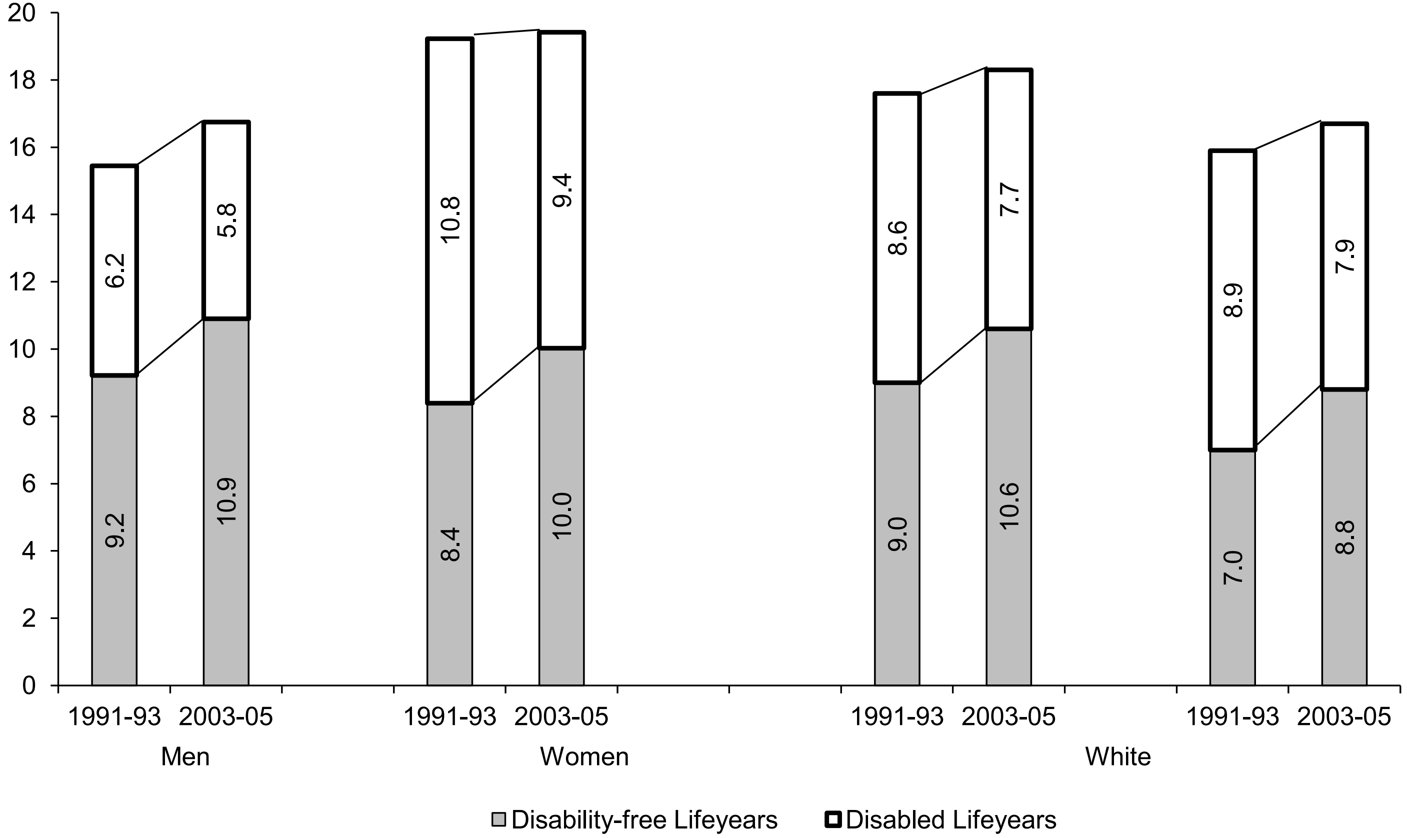

Fig. 1.15 Trend in disabled and disability-free life expectancy at sixty-five, by gender and race

Note: The figure combines life expectancy data from the NCHS with imputed disability rates by age and time until death.

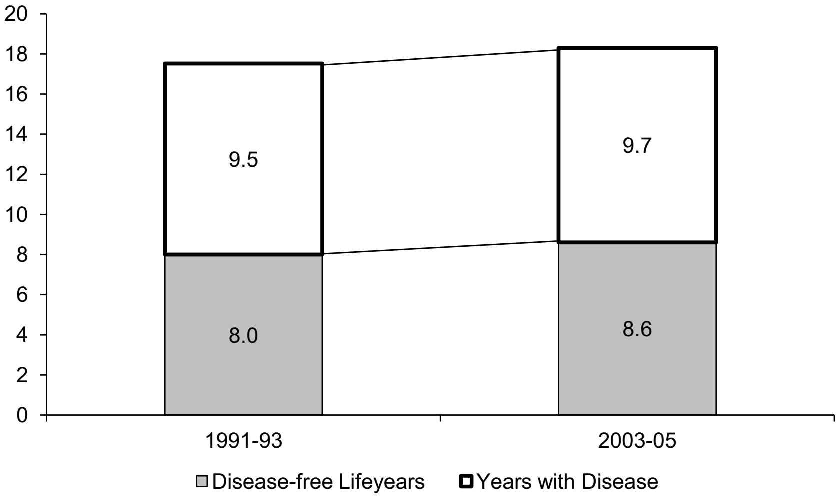

Fig. 1.16 Trend in disease-free life expectancy and life with disease
Note: The figure combines life expectancy data from the NCHS with imputed disease rates by age and time until death.

future work, we will construct relevant life tables from the micro data and calculate life expectancy by education.

Since so much of the literature has focused on disease-free survival, we have estimated disease-free survival trends as well. We focus on the major diseases in table 1.2, since they are the most consequential for health. Figure 1.16 shows the results. Disease-free survival increased over time, but so did life expectancy with disease. Of the total increase in life expectancy of 0.7 years, 0.6 years was associated with disease-free survival and 0.1 years was associated with additional life with major disease. The conclusion about the compression of morbidity thus depends on the definition used: the share of life that is disease free rose, but the length of life with major disease increased as well.

1.5 Conclusion

Our results show clearly that over the 1991–2009 period, disability has been compressed into the period just before death. Disability-free life expectancy rose, and disabled life expectancy declined. Thus, by either measure of compression of morbidity, morbidity is being compressed into the period just before death. Disease-free survival increased as well, although so did survival with a major disease.

The major question raised by our results is why this has occurred. How much of this trend is a result of medical care versus other social and environmental factors? Our results do not speak to this issue, but they give us a metric for analyzing the impact of changes that have occurred. We and others could usefully pursue the question about causality in subsequent research.

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Comment

Daniel McFadden and Wei Xie

There is a plausible conjecture that morbidity should be expanding among seniors: risks from early, quick killers like heart attacks and strokes are falling, leaving the elderly more exposed to risk from slow, disabling "killers of last resort" like senile dementia. Improved treatments have increased survival times after onset of some potentially mortal conditions such as kidney disease, and people living with such diseases are prone to other complications. If health research dollars and medical advances are tilted toward acute conditions and their treatment, people may live longer, but do so with burdensome disabilities. The chapter "Evidence for Significant Compression of Morbidity in the Elderly US Population" by David Cutler, Kaushik Ghosh, and Mary Beth Landrum presents persuasive evidence that this conjecture is wrong. They make clever use of data from the Medicare Current Beneficiary Study (MCBS), linked to 2008 National Death Index data, and find that while disease prevalence is rising for key conditions, functional disabilities are falling, and overall, morbidity measured by disabilities that cause substantial functional limitations is falling as a portion of the total life span. In conclusion, medical science is not creating a population of zombies. We compliment the authors on this research, and in this comment will also complement it with tabulations from a 20 percent sample of Medicare claims records.

To understand the authors' results, it is useful to clarify what "morbidity" means. The correlated but distinct aspects in figure 1C.1 seem important.

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