Mortality and Morbidity Trends: Is There Compression of Morbidity?

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Objective. This paper reviews trends in mortality and morbidity to evaluate whether there has been a compression of morbidity.

Methods. Review of recent research and analysis of recent data for the United States relating mortality change to the length of life without 1 of 4 major diseases or loss of mobility functioning.

Results. Mortality declines have slowed down in the United States in recent years, especially for women. The prevalence of disease has increased. Age-specific prevalence of a number of risk factors representing physiological status has stayed relatively constant; where risks decline, increased usage of effective drugs is responsible. Mobility functioning has deteriorated. Length of life with disease and mobility functioning loss has increased between 1998 and 2008.

Discussion. Empirical findings do not support recent compression of morbidity when morbidity is defined as major disease and mobility functioning loss.

Key Words: Compression of morbidity—mortality trends—morbidity trends.

RECENT decades have seen dramatic change in social science research on mortality and morbidity. Dramatic changes have occurred in the questions researchers and policy makers address, the data available to researchers, and the theoretical and empirical models that underlie these models. About the time the *Journal of Gerontology* began publication, the interests of science and policy turned toward health issues of the older population. Mortality at young ages and from infectious conditions was assumed to be a thing of the past; mortality at older ages and from chronic conditions began to dominate. At the same time, research frontiers shifted to heart disease and cancer, causes of mortality that were largely concentrated in advanced years. Then, in the 1960s, a period of remarkable progress began with improving mortality from heart disease and increasing life expectancy, especially at the older ages. Also Medicare became available for the longer lived older population, linking the health of the older population in the United States to national economic demands and well-being. These developments focused attention on the morbidity as well as the mortality of the older population and resulted in people asking a question that has guided significant amounts of research in recent decades. Is the population healthier now as well as longer lived?

In the following sections, we summarize what we have learned about recent trends in morbidity and mortality, primarily in the older population, as well as the interaction between mortality change and morbidity change. We begin with a discussion of the compression of morbidity hypothesis and then we discuss trends in morbidity and mortality. We provide empirical evidence of recent changes in morbidity and mortality and link these together to provide estimates of life expectancy with and without diseases and with

and without loss of mobility functioning. This provides a link between changes in parameters of population health and the expected life cycles of individuals.

The Compression of Morbidity

Thirty years ago, Fries (1980) introduced the idea of the "Compression of Morbidity," which provides a useful vehicle for discussing developments in research on trends in health among the older population. He proposed that the increased life expectancy would be accompanied by a shortening of the length of morbid life. Fries believed that the same forces that resulted in decreased mortality would be linked to a lower incidence of chronic disease and a higher age of onset of chronic disease (Fries, 2000, 2001, 2002). Increasing life expectancy has been accompanied by a rectangularization of the survival curve as survival until old age becomes almost universal. Fries believed that this would be accompanied by a rectangularization of the curve of onset for chronic disease or an increase in the age of onset of chronic disease. Because he felt that life expectancy had a limiting biological maximum, he postulated that the time with disease would be compressed into a shorter period at the end of life.

Not everyone held similar views, as some saw the processes of increasing life expectancy and disease onset as related in different ways. Gruenberg (1977) felt that the decline in mortality from chronic disease would be met with increased disease prevalence. He did not think that the decrease in mortality would arise from lowered disease incidence rates but rather from higher survival of people with health problems, resulting in more disease in the population, which he termed the failure of success. Manton (1982)

proposed a position somewhere between the two, which he called dynamic equilibrium. He felt that changes in the severity and progression of chronic disease would keep pace with mortality change so that the progression of disease would be halted at early stages, resulting in potentially more disease in the population but disease with decreased consequences, such as disability and imminent death. Since this time, these three scenarios linking the extension of life expectancy at older ages and changes in morbidity—expansion of morbidity, dynamic equilibrium, and compression of morbidity—have provided the hypotheses for much research on health trends (Cai & Lubitz, 2007; Robine & Michel, 2004).

Morbidity in the Compression of Morbidity

It is difficult to describe "morbidity" and change in population morbidity in a simple way. Morbidity is a multidimensional concept, and time trends in the different dimensions can vary (Crimmins, 1996). Increases in physiological dysregulation, disease onset, functioning loss, and frailty are all parts of the process of health change that can precede death (Crimmins, Kim, & Vasunilashorn 2010b; Martin, Schoeni, & Andreski, 2010; Martin, Freedman, Schoeni, & Andreski, 2010). These are related but not identical dimensions of health.

In addition, disability is a commonly used indicator of health problems or morbidity, which is influenced not only by physiological functioning but also by the environment in which it takes place. It is important to make this distinction because trends in many indicators of disability can be caused by changes in the environment, which reduce the barriers to functioning as well as to changes in innate functioning ability (Freedman, Agree, Martin, & Cornman, 2006). The compression of morbidity should indicate a reduction in the innate morbidity occurring within people in a population rather than an improvement in environmental conditions external to the individuals living in the environment. So while changes in the environment external to the person such as a reduction in smoking, a reduction in fat intake, or the provision of electric wheelchairs may be the cause of a reduction in morbidity, it would be the related reduction in respiratory conditions, obesity, and ability to walk that we would want to investigate to determine whether there has been a compression of morbidity. For this reason, we will discuss trends in physiological status, disease incidence and prevalence, and functioning ability.

Mortality, Survival, and Disease Incidence Trends

Mortality rates have been declining in most developed countries since the mid-1800s. Empirical evidence shows a steady upward trend in the highest life expectancy at birth with an average increase of about three months per year since 1840 (Christensen, Doblhammer, Rau, & Vaupel, 2009; Oeppen & Vaupel, 2002). In the early part of the 20th century, most of the increase in life expectancy was due to improvements in infant and childhood mortality; the period when mortality decrease among those over 60 made a significant contribution to increasing life expectancy began after 1960 (Vallin & Meslé, 2009). Thus, recent increases in life expectancy have depended on increasing survival among the older adult population, an age group more likely to be afflicted by chronic disease and disability.

Increases in life expectancy at older ages have characterized most low-mortality countries of the world but even the recent pattern of change shows significant variability (Glei, Mesle, & Vallin, 2010; Vallin & Meslé, 2009). For instance, Japan is the world leader in life expectancy with a life expectancy at birth of 83 and a life expectancy at age 65 of 21 years (Ministry of Health Labour and Welfare, 2010). On the other hand, the United States, which in 2006 had a life expectancy of 78 years at birth and of 18 years at age 65, is falling behind many other countries in recent years because of slower rates of mortality decline, particularly among women (Arias, Rostron, & Tejeda-Vera, 2005; Crimmins, Preston, & Cohen, 2010; Glei et al., 2010; Kung, Hoyert, Xu, & Murphy, 2008).

Large declines in mortality rates in recent decades have translated into sizeable increases in survival at older ages. For example, in the United States, the probability of a 65-year-old surviving to age 85 doubled between 1970 and 2005, from about 20% in 1970 to about 40% in 2005 (Bell & Miller, 2005). Similar or greater increases in survival at older ages have been reported in most developed countries among people aged 80 years or older since the 1970s (Kannisto, 1994, 1997; Vaupel, 1997). As life expectancy has increased, the modal age at death has steadily increased so that death in low-mortality countries most frequently occurs to people in their late 80s and 90s (Robine, 2010). Even death rates among people above age 100 have declined significantly in recent years leading to an increasing number of centenarians (Kannisto, Lauritsen, Thatcher, & Vaupel, 1994; Robine, Saito, & Jagger, 2003; Vaupel, 2010). This steady rise of life expectancy even at the oldest ages indicates that humans are not yet pushing up against a fixed limit, one that cannot be exceeded, which is a central tenet underpinning the compression of morbidity hypothesis.

In addition to major changes in the age when death is likely to occur, there have also been major changes in causes of death. In the early 1900s, infectious diseases accounted for the majority of deaths; in recent years, cardiovascular diseases (CVDs) and cancers account for more than half (58%) of all deaths in the United States in 2005 (Kung et al., 2008). This is a dramatic change as when people were saved from death from infectious disease, they lived their lives with relatively little observable effect of the condition. When chronic diseases dominate deaths, they develop over long periods of time and people often live with diagnosed disease and with treatment for long periods of time.

Over time, mortality can decrease because people never get disease, because the progress of the disease is arrested, or because very sick people are saved from death (Crimmins, Garcia, & Kim, 2010; Glei et al., 2010). Because we are linking mortality and morbidity, we examine trends in mortality and morbidity from a few of the major causes of death in order to be able to understand the processes in those diseases that should determine whether morbidity is compressed or not.

Trends in CVD Mortality and Morbidity

CVD has been the leading cause of death in the United States and most other low-mortality countries since the 1950s. CVD currently accounts for about a third of the deaths in the Untied States (32.5% in 2005; Kung et al., 2008). Mortality rates from CVD experienced a remarkable decline between 1970 and 2000 accounting for about 60% of the increase in life expectancy at birth during this period (Beltrán-Sánchez, Preston, & Canudas-Romo, 2008). About three quarters (77% in 2005) of CVD mortality is due to heart disease, and about two thirds of heart disease deaths are due to ischemic heart disease of which acute myocardial infarctions or heart attacks are the main component.

Examination of trends in incidence of and survival after myocardial infarction (MI) provide some idea of whether mortality is improving because people are less likely to have heart attacks or whether survival is increasing among those who have heart attacks, a reasonably well-defined cardiovascular event. Data are fairly consistent in providing evidence that survivorship after an MI event has been increasing over the last 50 years. Declines in case fatality rates immediately after the event and increases in survivorship have been reported consistently since the 1950s (Cutler, 2004; Ergin, Muntner, Sherwin, & He, 2004; Gerber et al., 2006; Goldberg, Yarzebski, Lessard, & Gore, 1999; McGovern et al., 2001; Muntner et al., 2006; Roger et al., 2002).

CVD is also a major cause of morbidity. Results from the Framingham Heart Study show that, at age 50, the lifetime risk for developing CVD was 51.7% for men and 39.2% for women (Lloyd-Jones et al., 2006). The Framingham Heart Study also shows that when methods of diagnosis are taken into account incidence rates for a first MI remained relatively stable between 1960–1969 and 1990–1999 (Parikh et al., 2009); however, trends differ by gender. For men, there was no clear trend in incidence of MI before 1980, but a decline characterizes most of the 1980s and 1990s, although two studies report small increases in incidence rates in the late 1990s (Greenlee, Naleway, & Vidaillet, 2002; Rosamond, Folsom, Chambless, & Wang, 2001). Incidence rates of MI for women are generally reported to have increased after the 1950s through the 1990s (Ergin et al., 2004; Roger et al., 2002). In the 1990s, however, a decline

in incidence rates set in (Greenlee et al., 2002; McGovern et al., 2001). Thus, the evidence indicates increased survival among those who have heart attacks; however, it is not until recently that there has been a decrease in the likelihood of actually having a heart attack by a given age.

Cerebrovascular conditions, primarily stroke, comprise the other major cause of CVD deaths. One of every five CVD deaths in 2005 was attributed to stroke (Kung et al., 2008). Nevertheless, mortality from strokes experienced one of the largest declines in both absolute death rates and age-standardized death rates between 1970 and 2002 (Jemal, Ward, Hao, & Thun, 2005). However, men benefited more than women from this decline. Men, but not women, experienced significant decline in the mortality rates occurring in the month after experiencing a stroke when comparing a period centered in the mid-1960s with one centered at the end of the 1990s (Carandang et al., 2006).

Stroke incidence does not appear to have changed consistently over the period, whereas mortality was declining. Stroke incidence was reported to be higher in the 1980s than the 1970s, and the 1990s appear to have been a period of some, but inconsistent, decline (Brown, Whisnant, Sicks, Ofallon, & Wiebers, 1996; McGovern, Shahar, Sprafka, & Pankow, 1993; Shahar et al., 1997). Evidence from the Framingham Heart Study shows that the age-adjusted incidence rate of first stroke declined slightly from the late 1960s to the late 1990s for both men and women (Carandang et al., 2006). Incidence rates are generally higher for men than women at younger ages, but the inverse is true in old age. For example, the male–female incidence rate ratio slightly declined from about 1.25 in people aged 55–64 years to about 0.76 for those aged 85 years or older (Lloyd-Jones et al., 2010). Thus, the evidence indicates increased survival among men who have a stroke with some decrease in the likelihood of having a stroke for both men and women.

As indicated previously, CVD incidence appears to be declining somewhat, at least recently, but many researchers have noted that the prevalence of heart disease and stroke survivors has increased in the population from the 1980s through the 1990s (Crimmins, 2004; Crimmins & Saito, 2000; Freedman & Martin, 2000) and for some age groups even more recently (Martin, Freedman, Schoeni, & Andreski, 2009). Cutler Richardson, Keeler, and Staiger (1997) estimated that the annual increase in the prevalence of heart disease was 2.2% from 1970 to 1990. However, one analysis of the period from 1997 to 2004 showed no significant change in the proportion of the population with heart disease (Freedman, Schoeni, Martin, & Cornman, 2007). There are a number of reports of increases in the prevalence of older persons who report they have had a stroke (Crimmins, 2004), although more recent analyses shows no increase among the old but increase in CVD among those approaching older age (Freedman et al., 2007; Martin et al., 2009).

Trends in Cancer Mortality and Morbidity

Cancer is the next most important cause of mortality after CVD accounting for about a quarter of deaths (22.8% in 2005; Kung et al., 2008). Overall mortality rates from cancer declined little until recent years (Kung et al., 2008). From 1970 to 2000, the decline in cancer mortality rates contributed to less than a third of a year in the increase in life expectancy (Beltrán-Sánchez et al., 2008); however, mortality rates from a number of important cancers have decreased in recent years (Jemal, Murray, et al., 2005; Preston & Ho, 2010). Cancer is really a number of different diseases with different risk factors, treatments, and trends. About 50% of all cancer deaths in 2005 in the United States were cancer of lungs, colon/rectum/anus, prostate, and breast so we focus on these cancers in our discussion (Kung et al., 2008).

Decrease in mortality after 1990 resulted from both decrease in incidence and increase in survival (Coleman et al., 2008). The decrease in lung cancer mortality is believed to be due to decreased cancer incidence related to reduced exposure to tobacco smoke. On the other hand, mortality decreases from a number of important cancers including breast, colorectal, and prostate result primarily from increased screening, earlier diagnosis, and therapeutic improvements (Cutler, 2008; Karim-Kos et al., 2008).

Because three of the most important cancers—breast, prostate, and colorectal—are often identified through screening rather than symptoms, it is hard to interpret general increases in incidence over time reported in cancer registries because they are affected by screening policies and programs (Garcia, 2010; Preston & Ho, 2010). For men, total cancer incidence in the United States appears to have leveled-off from 1995 to 2001, although incidence of prostate cancer slightly increased during this period (Jemal, Murray, et al., 2005). For women, there was a continuous increase in all cancer incidence of about 0.3% per year from 1987 to 2001, mainly due to increases in cancer of breast and lung and bronchus. After 2002, decreased use of hormone therapy among postmenopausal women appears to have contributed to some reduction in breast cancer incidence. It is clear that cancer survival has increased, but this has not resulted from major changes in cancer incidence, with the exception of lung cancer (Garcia, 2010; Preston & Ho, 2010). The pattern of lengthening survival from cancer with only recent decreases in incidence would lead to an increasing number of cancer survivors in the population, and data on the prevalence of cancer survivors show this (Crimmins, 2004; Freedman & Martin, 2000; Freedman et al., 2007; Martin, Freedman, et al., 2010).

Trends in Diabetes Mortality and Morbidity

Diabetes is the sixth leading cause of death in the United States (Kung et al., 2008). Age-adjusted death rates for diabetics are about twice that for people without diabetes, and about two to four times that for people with heart disease (Geiss, Herman, & Smith, 1995). Diabetes is also an important contributor to mortality from other conditions, and it is often listed as a contributing factor to deaths that are assigned to other causes (McEwen, Kim, Hann, & Ghosh, 2006). Age-adjusted death rates from diabetes declined from 1970 to the mid-1980s but increased substantially (about 47%) from 1987 to 2002 (Jemal, Ward, et al., 2005).

The lifetime risk of diabetes for Americans born in the year 2000 is estimated to be 33% for men and 36% for women (Narayan, Boyle, Thompson, Sorensen, & Williamson, 2003). Age-adjusted incidence rates of diabetes doubled between 1980 and 2008 for both men and women between the ages of 18 and 79 (Center for Disease Control and Prevention, 2010). There are numerous studies reporting an increasing prevalence of diabetes in the United States over the last few decades (Crimmins, 2004; Engelgau et al., 2004; Martin et al., 2009). Increasing prevalence and incidence of diabetes is assumed to be related to the growing problem of obesity, and it is projected to continue to increase (Honeycutt et al., 2003). Trends in diabetes mortality, incidence, and prevalence all point to growing population health problems from this condition.

Trends in Other Diseases and Conditions

We have started by examining the trends in major causes of mortality because trends in these causes should underlie any compression of morbidity. A number of conditions that are significant causes of functioning loss and disability are not important causes of mortality. Among these are arthritis, other musculoskeletal problems, depression, and dementia or cognitive loss. Trends in these conditions should not be as directly affected by forces affecting changes in life expectancy.

The reported prevalence of arthritis and musculoskeletal problems has generally been increasing (Reynolds, Crimmins, & Saito, 1998), although people report that the associated disability is reduced (Crimmins & Saito, 2001; Freedman et al., 2007). There are several reports of decreases in cognitive decline in the older population in the United States (Freedman, Aykan, & Martin, 2002; Freedman, Martin, & Schoeni, 2002; Langa et al., 2008), although not all research points to reduction (Hebert et al., 2010; Rodgers, Ofstedal, & Herzog, 2003). Trends in cognitive function may reflect early life experiences, especially education in this case, even more than a number of other conditions we have discussed.

Trends in Physiological Dysregulation

Many of the trends that we report previously reflect self-reports of disease. Trends in several measured indicators of physiological status can be examined over recent years to see if average functioning of multiple bodily systems has improved or deteriorated. Because these are measured

indicators, rather than self-reported presence of disease, they are sometimes thought to be more valid as indicators of trends in health. These indicators include a number of recognized risk factors for some of the conditions we discuss previously: heart disease, diabetes, and loss of cognitive functioning. These markers include high weight, high cholesterol, high blood pressure, glucose processing, and markers of inflammation.

The most adverse change in physiological status in recent years is the marked increase in obesity, which has occurred across the adult age range (Ogden et al., 2006). On the other hand, the evidence is that one marker of inflammation, C-reactive protein (CRP), and one marker of glucose regulation, glycosylated hemoglobin, have stayed roughly the same over the entire period from the late 1980s to about 2005 for persons aged 65 years and older (Crimmins et al., 2010b). The most promising trends for older persons have been in the reduction of high cholesterol and, more recently, a reduction in hypertension (Crimmins et al., 2005; Crimmins et al., 2010b). Both of these changes are due primarily to increased use and efficacy of prescription drugs not to reduction in the proportion of persons ever diagnosed with the condition. Martin, Schoeni, & Andreski (2010) have examined trends in biomarkers from 1999 to 2006 for the 40- to 64-year-old population and find more diagnosis and treatment of hypertension and high cholesterol, higher obesity, and higher CRP for males and higher glycated hemoglobin levels for females. So there is little evidence from trends in these measures that we are improving our physiological state as we approach old age.

Trends in Physical Functioning and Disability

The most consistent findings of improving health in the older population have been in decreases in indicators of functioning problems and reductions in disability. Again, there is far more evidence on prevalence changes than incidence changes based on longitudinal data. For older persons, there have been fairly regular reports of improved functioning from reports of the prevalence of problems from the 1980s through the present (Crimmins & Saito, 2000; Cutler, 2001; Freedman & Martin, 1998, 2000; Martin, Freedman, et al., 2010; Schoeni, Freedman, & Wallace, 2001). There have also been fairly consistent reports of decreases in recent disability prevalence both in the United States and in some other countries (Manton, Gu, & Lamb, 2006; Manton, Stallard, & Corder, 1995; Schoeni et al., 2001; Spiers, Jagger, & Clarke, 1996). However, there are a number of countries where disability has increased (Cambois, Clavel, Romieu, & Robine, 2008; Lafortune, Balestat, and the Disability Study Expert Group Members, 2007). One of the explanations for the decrease in disability has been that diseases have become less disabling as their progression has been halted before disability. This is true of both heart disease and arthritis, two of the most common causes of disability (Crimmins & Saito, 2000; Freedman et al., 2007). This reduction in disability associated with disease supports the dynamic equilibrium model of Manton.

We should note that recent reports on trends in prevalence of functioning problems and disability for the population less than 65 years in the United States have been less positive. A number of researchers have reported increasing disability and reduced functioning ability in newer cohorts of people approaching old age (Bhattacharya, Choudhry, & Lakdawalla, 2008; Fuller-Thomson, Yu, Nuru-Jeter, Guralnik, & Minkler, 2009; Lakdawalla, Bhattacharya, & Goldman, 2004; Martin, Freedman, Schoeni, & Andreski, 2010; Martin et al., 2009; Seeman, Merkin, Crimmins, & Karlamangla, 2010).

As indicated previously, data on changes in incidence of disability and functioning problems are scarce and generally limited to the older population. Several studies have reported significant decreases after the 1980s in the onset of disability or reductions in the transition from less severe to more severe disability (Cai & Lubitz, 2007; Crimmins, Hayward, Hagedorn, Saito, & Brouard, 2009; Crimmins, Saito, & Reynolds, 1997; Manton, Corder, & Stallard, 1993; Wolf, Mendes de Leon, & Glass, 2007). The evidence from the same studies on trends in recovery rates from disability is conflicting, although both Cai and Lubitz (2007) and Crimmins and colleagues (2009) report increased recovery in recent years in national samples of older Americans.

LINKING CHANGES IN MORTALITY AND MORBIDITY TO LIFECYCLE DISABILITY AND TIME WITH DISEASE USING RECENT DATA FROM THE UNITED STATES

How do recent mortality trends and recent morbidity trends interact to affect the length of lives people live with health problems? We can examine this using cross-sectional data on recent change in prevalence of disease and functioning loss along with mortality for the United States by employing the Sullivan approach to healthy life expectancy. This will allow us to investigate the implications of changes in the prevalence of conditions for changes in the length of life with and without functioning loss and disease in the life table population.

First we examine recent change in the prevalence of the four major diseases that are causes of death that we have discussed previously: heart disease, stroke, cancer, and diabetes. Self-reports of whether a person has been diagnosed with coronary heart disease, myocardial infarction, stroke, cancer, and diabetes are contained in the National Health Interview Survey. We examine these by age and sex for the noninstitutionalized population of the United States aged 20 years and older in 1998 and 2006. People also report whether they are unable to perform a set of functions in this survey. We have chosen an indicator of functioning problems based on four items (walking 1/4 mile, walking up 10 steps, standing or sitting for 2 hr, and standing, bending, or kneeling without using special equipment). If a person

Table 1. Prevalence (percent) of Self-reported Heart Disease and Stroke by Age and Sex for the Adult U.S. Population: National Health Interview Survey 1998, 2006

Age (years)	Coronary heart disease				Myocardial infarction				Stroke			
	Men		Women		Men		Women		Men		Women	
	1998	2006	1998	2006	1998	2006	1998	2006	1998	2006	1998	2006
20–29	0.28	0.23	0.13	0.09	0.36	0.24	0.17	0.06	0.16	0.30	0.15	0.11
30–39	0.39	0.46	0.33	0.52	0.36	0.21	0.29	0.25	0.09	0.51	0.43	0.37
40–49	1.38	1.68	0.89	1.06	1.83	1.03	0.74	0.81	0.83	1.11	0.74	1.30
50–59	5.83	6.78	2.67	3.26	5.85	4.91	2.23	3.21	2.54	2.51	1.99	2.04
60–69	13.32	15.14	5.86	6.33	11.42	12.21	5.33	4.23	7.46	6.35	4.63	4.92
70–79	17.44	18.93	10.55	12.21	15.15	15.72	8.80	7.39	9.22	9.86	7.08	7.75
80+	18.86	26.22	12.66	13.55	15.35	20.57	11.39	11.76	10.95	17.15	9.37	11.44

Note: Source: National Health Interview Survey 1998, 2006.

reports that he or she is unable to perform any of these tasks, she or he is classified as having a mobility functioning problem. We also examine mortality from official life tables for the U.S. population for 1998 and 2006 (Anderson, 2001; Arias, 2006).

There is no hint of a declining prevalence of disease over these eight years. The prevalences of cardiovascular conditions (heart, heart attack, and stroke) are shown in Table 1. The most striking change over the ten-year period is the increase in all the CVD conditions among older males; for females, the increase among the oldest group only occurs in the prevalence of stroke. Prevalences of cancer and diabetes are shown in Table 2. Older men and women show an increased prevalence of cancer. Diabetes increases are seen through much of the adult age range.

Table 3 shows the percentage of people with mobility difficulty increased markedly across the age range in this eight-year period. These large increases in functioning loss have not been previously reported across the age range, although Martin and colleagues (2009) reported recent increases in difficulty performing these functions for 50- to 64-year-olds. We have purposefully examined an indicator of functioning ability that represents fairly robust functioning and that is not likely to be significantly affected by environmental or social changes.

Mortality decline in the United States over the 1998–2006 period has been relatively slow, particularly for women. At age 20, life expectancy for men increased by 1.1 years from 55.0 to 56.1 years; for women, the increase was only 0.7 years from 60.3 to 61.0 years (Table 4). Men also gained more life expectancy at age 65 than women (1.0 vs. 0.5 years).

Robine and colleagues have been a leader in developing theory, methods, and data for examining whether a compression of morbidity exists (Robine & Jagger, 2005; Robine & Michel, 2004; Robine, Jagger, Mathers, Crimmins, & Suzman, 2003). They have operationalized the World Health Organization model linking survival, survival without disability or functioning loss, and survival without disease for France (Robine, Mormiche, & Cambois, 1996; World Health Organization, 1984). We follow this approach in examining change in survival and healthy survival in the United States between 1998 and 2006. Life table survival curves indicating the number of people surviving to each age out of the original 100,000 are commonly used in mortality studies. The data presented in Tables 1–3 can be used with the life tables for the two dates to indicate the number of survivors without functioning loss and the number who survive without at least one of the four diseases we examine. These curves provide a visual display of whether there has been compression of morbidity as the area under the

Table 2. Prevalence (percent) of Self-reported Cancer and Diabetes by Age and Sex for the Adult U.S. Population: National Health Interview Survey 1998, 2006

Age (yeara)	Any kind of cancer (excluding nonmelanoma skin cancer)				Diabetes			
	Men		Women		Men		Women	
	1998	2006	1998	2006	1998	2006	1998	2006
20–29	0.44	0.68	1.87	2.15	0.76	0.74	0.63	1.73
30–39	0.96	0.98	3.20	2.80	1.70	3.19	1.52	4.09
40–49	1.75	1.65	4.74	5.86	4.12	5.42	3.49	5.10
50–59	4.49	4.82	8.26	8.03	8.76	10.99	8.33	10.67
60–69	10.55	11.26	10.11	11.47	13.11	19.21	13.52	15.42
70–79	15.47	20.31	16.30	15.74	13.82	20.15	13.66	20.13
80+	15.62	28.18	16.06	19.85	9.72	19.87	12.39	14.24

Note: Source: National Health Interview Survey 1998, 2006.

curves indicates overall survival, survival without loss of mobility functioning, and survival without one of these major diseases. If the area increases, more of surviving life is spent in a healthy state.

Figure 1 shows the increase in overall survival from 1998 to 2006 as a move outward of the survival curve, indicating more survival time. For the curves representing both survivors without functioning problems and survivors without disease, later curves have shifted inward or leftward, indicating less survival without diseases and functioning loss. The fact that the curves indicating survival without disease are below those indicating survival without functioning loss indicates that these diseases occur at younger ages in the population than this type of functioning loss.

The overall impact of the age-specific changes on expected life cycle time with disease and mobility functioning loss at ages 20 and 65 is shown in Table 4 where total life expectancy is divided into life with and without diseases and functioning loss. At each age over the eight years, there is an increase in the life expectancy with disease and a decrease in the years without disease. The same is true for functioning loss, an increase in expected years unable to function and a decrease in years able to function.

Other Analyses of Change in Healthy Life Expectancy for the United States

Most other analyses of changes in healthy life for the United States have examined change in life expectancy with and without disability rather than disease or functioning loss. These analyses have generally shown increases in disability-free life expectancy, at least in recent decades. For instance, in the 1980s, increased life expectancy in the United States was concentrated in years without disability, although this followed a decade when this was not true (Crimmins, Saito, & Ingegneri, 1997). Two analyses of changes over time in disability -free life expectancy based

on multistate models and limited to the older population have arrived at the same conclusion. Cai and Lubitz (2007) using data from the Medicare Beneficiary Survey found increases in the length of nondisabled or active life and decreases in the length of life with disability between 1992 and 2002. The decline in disabled life is evidence of some compression of morbidity; however, they also found no change in age of disability onset, an inconsistency with compression of morbidity (but consistent with dynamic equilibrium). Crimmins Hayward, and Saito (1994) report fairly similar results comparing the 1984 and 1994 cohorts of the Longitudinal Studies of Aging. They find increases in the length of disability-free life and no change in the length of disabled life resulting from the decreases in the rates of disability onset and increases in rates of disability recovery. Again, there is some suggestion of compression of morbidity with the increase in the proportion of disability-free life and decrease in rates of onset of disability.

DISCUSSION

There is substantial evidence that we have done little to date to eliminate or delay disease or the physiological changes that are linked to age. For example, the incidence of a first heart attack has remained relatively stable between the 1960s and 1990s and the incidence of some of the most important cancers has been increasing until very recently. Similarly, there have been substantial increases in the incidence of diabetes in the last decades. Although we have examined the increased prevalence in a number of individual diseases, we should note that the proportion of the population with multiple diseases and the number of diseases co morbid in an older individual has also increased (Crimmins & Saito, 2000).

Although there have been declines in the proportion of people with high blood pressure and high cholesterol, they are not due to decreases in the diagnosis of these conditions

Table 3. Prevalence (percent) of Self-reported Mobility Functioning Loss[a] by Age and Sex for the Adult U.S. Population: National Health Interview Survey 1998–2006

Age (years)	Mobility disability			
	Men		Women	
	1998	2006	1998	2006
20–29	0.50	1.77	1.06	2.18
30–39	1.68	2.39	1.92	3.50
40–49	2.73	4.25	4.54	6.60
50–59	6.31	7.86	9.90	13.32
60–69	10.66	14.59	14.86	21.46
70–79	15.74	24.43	27.24	33.18
80+	27.68	41.74	42.84	51.26

Note: Source: National Health Interview Survey 1998, 2006.

[a] Mobility functioning loss is defined as unable to perform at least one of the following: walking 1/4 mile, walking up 10 steps, standing or sitting for 2 hr, and standing, bending, or kneeling without using special equipment.

Table 4. Life Expectancy, Life Expectancy With and Without Cardiovascular Disease, Cancer, or Diabetes, Life Expectancy With and Without Mobility Functioning Ability, 1998–2006 (years)

|	Men		Women	
	1998	2006	1998	2006
Age 20 years				
Life expectancy	55.0	56.1	60.3	61.0
With at least one disease	10.0	12.3	11.1	13.0
Without disease	45.0	43.8	49.2	48.0
Unable to function	3.8	5.8	7.3	9.8
Able to function	51.2	50.3	53.0	51.2
Age 65 years				
Life expectancy	16.0	17.0	19.2	19.7
With at least one disease	7.2	8.9	7.4	8.4
Without disease	8.8	8.1	11.8	11.3
Unable to function	2.9	4.5	5.8	7.3
Able to function	13.1	12.5	13.4	12.4
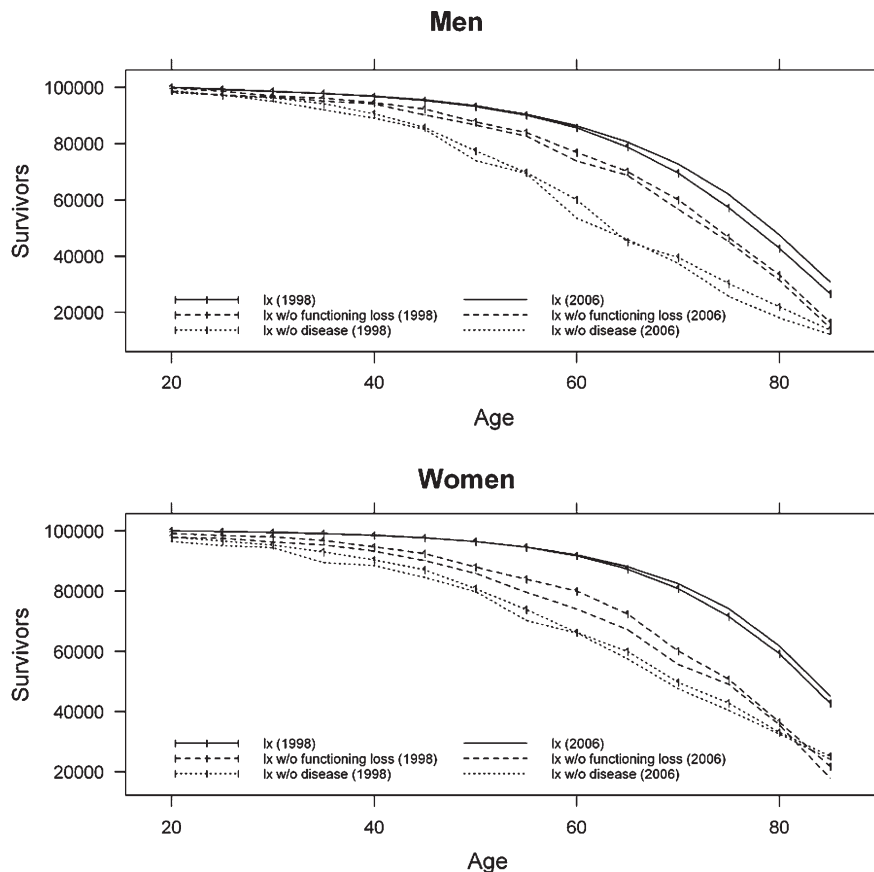
Figure 1. Survivors in the life table population, survivors without mobility functioning loss, and survivors without disease by sex: 1998 and 2006. Source: Prevalence of disease and functioning loss from National Health Interview Survey 1998, 2006; life tables from National Center for Health Statistics (1998, 2006).

but to the use of effective pharmaceutical treatments. There have been increases in the prevalence of many diseases, both diseases that are important causes of mortality and those that are less related to mortality. Increase in diabetes appears to be related to the increase in obesity that has been characterized as an epidemic. Some of the increases in both the prevalence of conditions, like heart disease, and the incidence of conditions, like cancer, may result from greater awareness among people of health problems and improved methods of diagnosis and screening. Our empirical results could be overstating the recent increase in disease as it is impossible to hold constant these factors.

On the other hand, substantial strides have been made in dealing with the consequences of disease. Diseases are both less lethal and less disabling; they have become more chronic but perhaps less progressive. There clearly is increased survival of people with heart disease and with cancer. Declines in CVD deaths are thought to be due to a combination of primary prevention that reduced the exposure to risk factors, acute disease management (e.g., cardiac catheterization, intensive care units, angioplasty, etc.), and secondary prevention, including medical therapies and treatments. Between 1950 and 1970 most of the decline in

mortality rates from CVD was due to prevention (Goldman & Cook, 1984), whereas acute disease management and medical treatments accounted for about half of the decline between 1980 and 2000 (Ford et al., 2007). Cancer mortality decline also has resulted from a combination of the same factors. For instance, lung cancer is primarily declining because people have reduced smoking, whereas breast, prostate, and colon cancer mortality is reduced because of increased screening, early diagnosis, and new treatments regimens. It is only the decrease in disease onset due to primary prevention that is clearly going to be related to longer disease-free life. Where reduction in mortality occurs because of longer survival with disease, the length of life with disease is increased.

We have chosen to examine changes in high-level functioning rather than severe disability. Recent data indicate increases in this type of functioning problem. These problems may be related to some of the diseases and conditions we have examined. Heart disease, stroke, diabetes, arthritis and musculoskeletal problems, cognitive loss, and obesity are major causes of functioning problems and disability; however, much disability and functioning loss is caused by depression and mental illness, which we have not considered here (Crimmins & Saito, 2000; Ettinger et al., 1994; Jagger et al., 2007; Martin et al., 2009).

The change in mobility functioning loss that we examined should reflect changes within individuals rather than in the environment. Many studies that have reported reductions in the prevalence of disability and rates of disability onset and increases in rates of recovery for the older population may reflect changes in measures with a strong environmental component. For instance, the declines in disability characterized as instrumental activities of daily living disability, which may be more affected by the environment in which people live have been more pervasive and have occurred earlier than disability termed activities of daily living disability, which would be less environmentally affected (Freedman et al., 2004). The fact that we have been able to reduce this kind of disability with either improvements in technology, living environments, or slowing the progression of disease through treatments has obviously been important in improving quality of life and reducing the effects of growing disease prevalence.

Our empirical example showed that in recent years, there has been an expansion of life with disease and mobility functioning loss. Our results are quite different from other analyses of changes in healthy life because our definition of healthy life differs. It is, however, a definition we feel is more in concert with the idea of compression of morbidity. When mortality declines because people survive longer with a disease rather than because people were less likely to get a disease, there will be an expansion of disease morbidity.

The cost of maintaining and providing care for a longer lived–older population is an important part of determining the economic well-being of countries with established social security and government-provided health services. Even if the length of disabled life stays roughly the same but the length of life needing treatment for disease increases, lifetime health costs will increase unless the cost of health care is reduced. Recent increases in Medicare spending in the United States appear to be highly related to this increase in treatment of diseases (Thorpe, Ogden, & Galactionova, 2010).

Can the increase in life expectancy continue? The recent reduction in the rate of progress for U.S. women is sobering. We have always assumed that each generation will be healthier and longer lived than the prior one. The growing problem of lifelong obesity and increases in hypertension and high cholesterol among cohorts reaching old age are a sign that health may not be improving with each generation. The increasing prevalence of disease may to some extent reflect better diagnostics, but there is little indication of less disease.

The compression of morbidity is a compelling idea. People aspire to live out their lives in good health and to die a good death without suffering, disease, and loss of functioning. However, compression of morbidity may be as illusory as immortality. We do not appear to be moving to a world where we die without experiencing disease, functioning loss, and disability.

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