Chronic Disease and Trends in Severe Disability in Working Age Populations

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1.0 Introduction
Over the past two decades, rates of severe disability as measured by limitations in basic activities of daily living (ADLs) such as the ability to bath or dress oneself, have been declining in older populations. A consensus has emerged that the health of the elderly has been improving since the early 1980s, and that this improvement in health is reflected in a declining rate of disability (see Manton et al., 1997; Crimmins, Saito, and Ingegneri, 1997; and Schoeni et al., 2001). Much of this literature has pointed to improvements in medical and assistive technology to treat the disabled, as well as improved prevention of disabling conditions among the elderly, as the leading causes of these declines.

These declines in disability came as a surprise to researchers because they reversed increasing trends in elderly disability in the 1970s. Then, researchers argued that increases in longevity amounted to extensions of the time spent in disability by the elderly (see Crimmins et al., 1989 and Waidman et al., 1995). Thus, they predicted, increases in longevity would inevitably be accompanied by growth in the incidence of disability (see for instance, Gruenberg, 1977). This concern has been replaced with the happy prospect of a compression of morbidity into shorter periods at the end of longer lives.

On the other hand, the news has not been all good over the past twenty years. For both elderly and working age populations, there have been increases in the prevalence of some important chronic conditions such as obesity and asthma. Working age populations in the United States are more likely to claim disability benefits now than they were in 1990 (see Autor and Duggan, 2001; and Bound and Waidmann, 2000). In addition to increases in the size of the work-limited population, severe ADL style disabilities have also risen in

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the working age population since 1980 (see Lakdawalla et al, 2004; and Lakdwalla et al., 2003a and 2003b).

The difference between elderly and working age populations in what has happened to disability rates over the past twenty years is puzzling. If the explanation is medical technology and preventive medicine, then the question is why these have not benefited younger populations in the same way they have benefited the elderly. Of course, this explanation presumes that at root, there have been real changes in the health of populations under consideration that have led to the observed changes in disability prevalence. But is this root assumption correct?

Economists, who have focused on work limitations rather than ADL limitations, have argued that the expansion in disability can be explained by increased incentives to claim disability insurance among working age populations. In particular, there has been a growth in the replacement rate of government disability insurance (Autor and Duggan, 2001; and Bound and Waidmann, 2000). More generous disability benefits could induce more people to report disability, and this incentive would be much stronger for the young.

But is this the whole story? There has been real deterioration in some measures of health over this period in working age populations, such as the dramatic rise in obesity rates. It seems implausible that such changes would have had no effect on disability rates, but how much?

The main aim of this paper is to describe and estimate a new decomposition of disability trends among working age populations into two parts—the part of the trend explained by changes in the prevalence of chronic disease and obesity and the part of the trend explained by changes in the prevalence of disability among people with chronic diseases. If most of the changes in disability in this population are due to change in chronic disease prevalence, then there is little room for statutory incentives as an explanation for ADL disability trends. More importantly, such a result would suggest that recent changes in disability in this population are permanent for the affected age cohorts. If this cohort survives to old age, the use of medical care by this group will place great demands on Medicare financing.

On the other hand, if an increase in disability prevalence among those with chronic disease is the explanation, then there arise two possibilities: that chronic diseases have become more severe over time, or that the incidence of even ADL-style disabilities are dependent on cultural, social, and economic determinants such as the disability insurance payments. Such a result would suggest that the increases in ADL disability seen among working age populations might not be permanent.

2.0 Background

In this section, we make precise exactly what we mean when we say that someone is disabled. Perhaps not surprisingly, this turns out to be quite controversial and is the cause of much confusion when comparing the results of papers that analyze disability—they are quite frequently talking about different things. As we intimate in the
introduction, the definition of disability we adopt in this paper is closely related to ADL limitations. We then review the literature on trends in old age disability, which typically uses ADL limitations as the measure of severe disability. Next, we review the results obtained by some of the authors of this current paper on ADL disability among working age populations. Finally, we summarize the large medical literature on chronic disease trends in working age populations.

2.1 Defining Disability

Though everyone has some intuitive idea about what it means to be disabled, when examined closely, disability turns out to be a hard concept to define—and hence difficult to measure in population based surveys. Disability as perceived by society is a function of the purpose of its definition, and is thus both a plastic and elastic concept that changes both from one social environment to another at a single point in time, and from one period to another over the life cycle (see Berry and Hardman, 1998; and Marshak et al, 1999). Definitions of disability thus vary widely, and tend to be specific to a particular objective or agency (see US DOL, 2002). These unique definitions serve the goals of, for example, removing discrimination through the Americans with Disabilities Act (ADA), determining eligibility for special education services, and qualifying for Social Security disability benefits (see US EEOC, 2002; Knoblauch and Soerenson, 2002; SSA, 2002; U.S.C. 216).

More generally, survey data on disabilities, which inform the policies established and practiced by the above entities, fall into two broad areas--functional limitations and work limitations. The former encompasses the most basic, mechanically-oriented activities of daily living (ADLs) such as dressing, eating, and bathing, as well as instrumental activities of daily living (IADLs) that involve everyday behaviors requiring a higher level of cognitive functioning than ADLs, such as grocery shopping, managing money, and preparing meals (see Crimmins et al. 1997; Manton et al., 1997; Stone, 1984).

Surveys collecting on aging population niches—such as the National Long-Term Care Survey (NLTCS)—tend to gather functional limitation information, while nationally-representative survey instruments, such as the Current Population Survey (CPS) emphasize work disability. Census 2000 data, however, includes elements on long-lasting sensory impairments, ADLs and IADLs, cognitive ability, and work limitations; this recent change attests to an increasing need to understand what disability is, who is affected and to what degree, and possible or likely trends in disability at all ages. There is also a growing movement to improve measures of current functional outcomes, in order to better address ways to improve overall quality of life and employment potential (see Bierman, 2001).

The main data set that we rely on, the National Health Interview Survey (NHIS), includes both work-limitation based measures of disability (which are the measures typically reported by analysts using the NHIS) and ADL limitation based measures (which are the ones we focus on in this paper).
2.2 Elderly Trends in Disability

There is broad literature looking at trends in disability in the American elderly population over the past two decades. Contributors to this literature have relied upon different surveys and different definitions of disability, but have consistently found declines, sometimes sharp and accelerating declines in disability among the elderly.

Manton, Corder, and Stallard (1997) use the 1982, ’84, ’89, and ’94 National Long Term Care Surveys (NLTCS) to investigate trends in the prevalence of disability in the elderly population. Defining disability as an inability to perform an ADL/IADL without aid for at least 90 days, they find that the age-adjusted prevalence of disability for 1994 decreased by 3.6% from 1982 (from 24.9% to 21.3%). The authors compare the size of observed disabled population with that which would have occurred without the apparent declines in disability. There were 0.54 million and 1.2 million fewer disabled in 1989 and 1994, respectively, than there would have been had the 1982 rates stayed fixed (Manton et al., 1993 and 1997). Manton and Gu (2001) update these results using the latest wave of the NLTCS. They confirm a continuing decline in disability among the elderly, especially among the oldest age groups.

Manton et al. also investigate the incidence of disability and the progression to increased forms of disability. They calculate the rates of being institutionalized from having 1-2 ADLs, 3-4 ADLs, 5-6 ADLs, or some number of IADLs exclusively in 1982 and 1984. Decline in disability accelerated from 0.27% per year from 1982 to ’89 to 0.34% from 1989 to 1994, with greater decline in older cohorts (Manton and Gu, 2001). The transition rates from 1982-1984 and from 1984-’89 were also improved (Manton, Corder, Stallard 1993). Manton (2003) and Pardes et al. (1999) attribute these recent improvements in disability prevalence among the elderly to improvements in medical technology that enable seniors to delay both disability and death. They argue strongly that potential future medical breakthroughs (such as the treatment and prevention of senile dementia) hold the promise of further disability reductions for the elderly.

Freedman and Martin (1998) use the 1984 and 1993 Surveys of Income and Program Participation (SIPP) to investigate trends in disability prevalence. Their definition is of disability differs mildly from the one Manton and his colleagues use; they define it as difficulty seeing words in a newspaper, lifting and carrying 10 pounds, climbing stairs, or walking a quarter mile. The authors find that prevalence for difficulty in each category declined over the study period. Prevalence ranged from 15.3% (difficulty seeing words in a newspaper) to 25.8% (walking ¼ milie) in 1984 to 11.6% to 22.3% for the same categories in 1993, a relative improvement of between 0.9% and 2.3% across functions.

Crimmins, Saito, and Reynolds (1997) confirm net decreases in disability among the elderly from 1982 to 1993 despite intermediate fluctuations. They use the Longitudinal Study of Aging (LSOA) (1984, ’86, ’88, ’90) and the National Health Interview Survey (NHIS) (1982 to ’93) to track the prevalence of disability over time. They focus solely on the prevalence of disability in the 70+ population. Overall prevalence of disability in the NHIS (defined as inability to perform personal or routine care) in 1982 was 21.1% and in 1993 was 19.5%. In the LSOA, they find that the percent disabled (defined as an
inability to perform an ADL without aid) in 1984, '86, '87, and '90 was 18.8, 21.6, 21.3, and 20.5% respectively. Although no visually striking trend exists in the plotted data sets, statistical analysis reveals a slight decrease in disability in the pooled population (controlling for age and sex). These decreases are more likely in the activities of IADLs (routine care) as opposed to ADLs (personal care). Hazard models applied to this data reveal that rates of transition to disability and out of disability improved over time: incidence of disability decreased 16% from 1948-‘86 to 1988-‘90.

Using NHIS 1970, ‘80, and ‘90 data and an alternate definition of disability than the one we rely on in this paper (any limitation in usual activity over the past 12 months), Crimmins, Saito, and Ingegneri (1997) find fluctuations in long-term disability prevalence. Institutionalization rates have declined for most ages, but have stayed the same or increased above age 80. Long-term disability increased for the 60+ population from 1970 to 1980, but decreased from 1980 to 1990. For example, males aged 65-69 in 1970, 1980, and 1990 had disability rates of 37.84, 43.68, and 39.39% respectively, and for females the rates were 30, 36.2, and 30.56%. These prevalence figures are subject to assumptions made about the effects of question wording changes after 1982.

Crimmins, Saito, and Ingegneri (1997) also investigated the relative contributions to life expectancy of disability-free and disabled years. They use the NHIS definition of years of active life expectancy: the “years when an individual’s health does not affect ability to perform normal activities of life including both major and secondary activities.” At age 65, total life expectancy increased from 1970 to 1990. (Mortality declines from 1980 to 1990 was 1/3 of that from 1970 to 1980 for females and 3/4 of that for males.) But the proportion of that increase that was due to disability free years was small. From 1970 to 1980, disability-free life expectancy did not increase, but there was a slight increase from 1980 to 1990. McKinlay et al. (1989) also find that disability-free life expectancy has decreased for newborns and middle-aged women from 1964 to 1985. These findings do not entirely support the hypothesis by Fries (1980) that active-life span is increasing faster than total life span.

### 2.3 Disability Trends in Working Age Populations

Using data from the 1984-2000 National Health Interview Surveys (NHIS), Lakdawalla, Bhattacharya, and Goldman (2004) track changes in disability by age. Table 1, taken from their work shows how disability rates have changed between 1984 and 2000 in the NHIS data. They track two different measures of disability: personal care and routine needs disability. These are conceptually different from work limitation disabilities, which are also tracked in the NHIS.1 The numbers in the “Pers. Care” column reflect the

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1 Specifically, NHIS respondents were asked: “Because of any impairment or health problem, does ___ need the help of other persons with personal care needs, such as eating, bathing, dressing, or getting around this home?” If they answered no to this question, they were then asked: “Because of any impairment or health problem, does ___ need the help of other persons in handling routine needs, such as everyday household chores, doing necessary business, shopping, or getting around for other purposes?” These questions allow respondents to be placed in one of three bins: (1) unable to perform personal care needs; (2) limited in performing other routine needs; (3) not limited in personal care or routine needs. The NHIS questionnaire was redesigned in 1997 and the wording of the questions on disability were subtly altered, though it is still possible on the basis of the new questions to place individuals in the three bins. However,
number of people per 10,000 requiring assistance with personal care needs, while the numbers in the “Rout. Needs” column reflect the number per 10,000 requiring assistance with personal care needs or other routine needs.

From 1984 to 1996, Table 1 shows that routine needs disability expanded significantly for individuals between ages 30 and 59. There were significant expansions in the more severe personal care limitation category for all individuals aged 18 to 39. For groups aged 30 to 59, the absolute growth in personal plus routine needs disability was roughly 63 per 10,000. The largest percentage increase occurred for the 30-39 year-olds, whose rate of disability rose by more than fifty percent over this period. According to either definition of disability, the population aged 60-69 actually became less disabled. This is consistent with the findings from previous research that the old are becoming less disabled.

Autor and Duggan (2001) give a detailed analysis of the way in which changes in disability recipiency have affected reported rates of disability among working populations. Disability recipiency, which involves qualification for government aid to the disabled, should be kept conceptually distinct from notions of disability involving requirements for help with personal care or routine needs. Autor and Duggan’s analysis using the NHIS shows that, over the period from 1970 to 1996, overall disability fell much more rapidly among the more educated. This difference in growth rates, however, does not appear when the data are analyzed within employment status groups. That is, among the employed and among those not in the labor force, disability is growing at the same rates across education groups. This suggests that growth in disability is coming from less educated people who are leaving the labor force at higher rates. Since incentives for disability insurance are also likely to be strongest among this group, this piece of evidence is consistent with an explanation that stresses the importance of disability insurance. This could be particularly important for those between ages 40 and 54. The per capita rate of disability awards was constant for this age group from 1984 to 1990, but suddenly shot up between 1990 and 1992, as a result of increases in the replacement rate provided by disability insurance.

Disability payment recipiency alone is unlikely to explain all of the trends in personal care and routine needs disability, because for other age groups the timing of disability award changes does not coincide with the timing of disability growth. The per capita award rate for those under 40 grew by 40% from 1984 to 1990, but only by 14% from 1990 to 1996 (Autor and Duggan, 2001). In contrast, Lakdawalla, Bhattacharya, and Goldman (2004) find that growth in disability among the over 40 group is concentrated entirely in the 1990 to 1996 period. Moreover, the per capita award rate grew by more than 20% for those between 55 and 64, while reported disability actually declined for this age group (Autor and Duggan, 2001).

the NHIS survey designers discourage comparisons of data from before and after the redesign. Table 1 consequently tracks trends separately between 1984 and 1996 and between 1997 and 2000.
2.4 Chronic Disease in Working Age Populations

In this section, we review trends in the prevalence of chronic health conditions in working age populations (less than 65 years old) and the relation between these trends and trends in disability in the same populations. Not surprisingly, prevalence trends of chronic health conditions vary by condition and by cohort; the evidence indicates that more recent cohorts are more likely to suffer from such chronic health conditions as asthma, diabetes (see Mokdad et al., 2000), chronic bronchitis (see ALA, 2002a), and obesity (see Wolf and Colditz, 1998). They are less likely to suffer from heart disease, hypertension (see Reynolds et al., 1999), and arthritis. However, the literature also indicates that the proportion of chronically ill people who have a disability is higher in more recent cohorts, though the latter point has not been systematically investigated. The literature on disability in this population tends to focus mainly on disability that causes work limitations, rather than on other ADL and IADL limitations, which renders much of the literature we report here incomparable with our own results reported below.

Respiratory diseases such as asthma and chronic bronchitis are increasing in prevalence among the non-elderly. In 1982, 2.9 percent of 18-44 year olds, and 3.6 percent of 45-64 year olds, experienced an asthma attack; in 1996, these numbers increased to, respectively, 5.7 percent and 4.9 percent (see ALA, 2002b). Chronic bronchitis sufferers aged 18-44 in 1982 comprised 2.5 percent of the population, while 4.4 percent of the 45-64 year olds had chronic bronchitis. In 1996, these figures rose to 4.5 percent and 5.9 percent, respectively (see ALA, 2002a). The prevalence of childhood disability due to asthma rose 232 percent from 1969 to 1995, while the prevalence of childhood disability due to all other chronic illnesses in childhood rose 113 percent—less than half as much—in the same time span (see Newacheck and Halfon, 2000).

Both the prevalence and incidence of self-reported diabetes increased from 1980-1994 (see CDC, 1997). From 1990 to 1998, the prevalence rate for diabetes among 18-29 year olds increased slightly, from 1.5 percent to 1.6 percent. However, much more striking increases are seen in other working-age groups: among 30-39 year olds, the prevalence increased from 2.1 percent to 3.7 percent during the period (a 69.9 percent rise); for 40-49 year olds, the rate grew from 3.6 percent to 5.1 percent; in the 50-59 year age group, prevalence rose from 7.5 to 9.8 percent; and the 60-69 year olds saw an increase in diabetes prevalence from 10.9 to 12.8 percent over the period (see Mokdad et al., 2000).

The prevalence of congestive heart failure was higher among people aged 40-65 for the period 1988-1991 compared to people in this age group during 1976-1980, with roughly twice as many people at each age experiencing this condition in the later time frame relative to the earlier period (see NHLBI, 2002).

Although the recent rise in obesity has attracted considerable attention, growth in weight is not a recent or short-lived phenomenon. Costa and Steckel (1997) document large secular gains in average height-adjusted weight for men in different birth cohorts over the last century. Height-adjusted weight for people in their 40s, the age group with the highest labor force attachment, has increased by nearly 4 Body Mass Index (BMI) units over this period. To put this into perspective, an increase of this magnitude in the height-
adjusted weight of a 6-foot tall man would require a weight gain of approximately 30 pounds. Similar gains in weight are true for women and for children (see Bhattacharya and Currie, 2001).

Conversely, both the prevalence of arthritis and the prevalence of activity limitations caused by arthritis decreased for working age people between 1989-1991 and 1997. In the earlier period, self-reported arthritis was noted by 6.6 percent of 25-34 year olds, 12.7 percent of 35-44 year olds, 22.6 percent of 45-54 year olds, and 36.5 percent of 55-64 year olds; while the proportions limited in activity were, respectively, 0.6 percent, 1.5 percent, 3.5 percent, and 7.1 percent (see CDC, 1994). In the later period, 5.5 percent of 25-34 year olds had arthritis, while 10.5 percent of 35-44 year olds, 19.4 percent of 45-54 year olds, and 29.7 percent of 55-64 year olds had the condition. Their activity limitation rates due to arthritis were 0.5 percent, 1.3 percent, 2.1 percent, and 5.2 percent, respectively (see CDC, 1997). Boult et. al. (1996) note that a one percent biannual decrease in arthritis can result in four million person-years of increased functional limitation between the years 2001 and 2049.

The overall prevalence of disability (defined as an inability to work) among the working age population aged 25-34 decreased from 4.4 percent in 1988 to 3.6 percent in 1998, but increased during this period from 5.9 percent to 7.0 percent for 35-44 year olds, from 9.1 percent to 10.7 percent for 45-54 year olds, and from 15.6 percent to 16.4 percent for 55-61 year olds (McNeil, 2000). There is no published literature on disability trends in younger populations when disability is defined in terms of inability to perform ADLs or IADLs over this same time period.

Chronic conditions have long been known to be an important cause of disability (see for instance Colvez and Blanchet, 1981). In 1972, the Social Security Administration Survey of Disabled and Nondisabled Adults indicated that 15 percent of the non-institutionalized population aged 20-64 reported being disabled because of a chronic condition, with women affected in larger proportions than men (see Krute and Burdette, 1978). Twenty years later, in 1991-2, Survey of Income and Program Participation (SIPP) data showed that 5.1 percent of 16-67 year olds had a work disability that prevented them from working; in 1997, 5.6 percent of 16-64 year olds had a work disability that prevented them from working—about a 10 percent increase over the six year period (US Census Bureau, 2002a and 2002b).

Chronic conditions that were responsible for a great deal of work limitation in 1992 include heart disease, accounting for 10.9 percent of people aged 18-69 who had a work limitation in that year, arthritis, responsible for 8.3 percent of this niche, respiratory diseases, which underlie 5.6 percent of this group, and diabetes, which caused a work limitation in 3.3 percent of the segment (see Stoddard et al, 1998). There has been an upward trend in the proportion of diabetic working-age adults who report activity limitations. Among 20-44 year olds, in 1964, 31.9 percent of this diabetic group indicated having activity limitations, and this figure increased to 48.3 percent in 1989 for 18-44 year olds. In the 45-64 year age group, 46.4 percent of diabetics had activity
limitations in 1964, yet 54.7 percent of this same age group were similarly afflicted in 1989 (see Songer, 1995).

Overall, there is much reason for concern from the fact that some important chronic disease have become more prevalent in working age populations. While it seems intuitively plausible that these chronic disease trends can explain some of the rise in ADL style disability that we report in section 2.3, it is not clear from the literature how much can be so explained. The purpose of the rest of the paper is to derive this figure.

3.0 Data

The NHIS is a nationally representative set of individual-level data on demographics and health status, designed to represent the non-institutionalized population. It has been collected every year since 1957. The stability of the NHIS survey design makes it particularly attractive for analyzing long-run trends in disability. Although the survey was redesigned in 1982 and 1997, it is possible to construct quantitatively consistent estimates from 1984 to 1996.

Prior to 1982, the NHIS disability data are based on an activity limitation variable. The NHIS asked respondents whether their health limited their ability to perform work or housework. From their answers, they were then grouped into four categories: (1) Unable to perform work or housework; (2) Limited in kind or amount of work or housework; (3) Limited in other activities, besides work or housework; (4) Not limited in any activities.

After 1982, the NHIS asked the same question, but with one subtle difference. Prior to that year, retirees were asked if their health would prevent them from working. Beginning in 1982, they were asked if their health interfered with their major activity, which need not be working. Not surprisingly, therefore, reported rates of activity limitation among older individuals fall substantially in 1982, because elderly retirees are allowed to report a less strenuous major activity.

After 1982, however, the NHIS asks a different question more appropriate for analyzing disability. The survey began asking all respondents over age 60, as well as all those aged 5-59 who reported some activity limitation, if they need help with personal care. This question is preferable to the activity limitation question, in which individuals are allowed to choose their major activity. Since more disabled individuals will tend to report a less strenuous major activity, the activity limitation question will tend to understate the absolute value of changes in disability. Based on a respondent’s answer to the personal care question, she was placed in one of two categories: (1) unable to perform personal care needs or limited in performing other routine needs; (3) not limited in personal care or routine needs. Using this question, we have consistent measures of disability from 1984 to 1996.

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2 More specifically, this question is asked of all people over age 60, and all individuals aged 5-59 who report being limited in their major activity. This procedure yields reliable estimates of disability as long as every person under age 60 who needs help with personal care is also limited in his or her major activity.
The NHIS also asks its respondents to answer a battery of questions regarding their medical history. Among these questions include probes about the presence of chronic disease. Most of these questions are asked in the form “Has a doctor ever told [you] that you have [Disease X]?” There is some legitimate concern that this method of asking about the prevalence of disease conditions might undersample people who are less likely to seek medical attention. If this is indeed the case, then the estimates we present are underestimates of the true influence of chronic disease on disability.

Between 1984 and 1996, the NHIS questionnaire did not ask all the questions about disease prevalence to each of its respondents. Instead, it separated the list disease questions into six different condition lists, and then randomly assigned each respondent to one of the six condition lists. One consequence of this sampling strategy is that we cannot use the NHIS to obtain information about whether, for example, a respondent has both hypertension and arthritis. Since these conditions are on different condition lists, the same respondent is never asked about both of these conditions. However, the condition lists were constructed so that diseases which frequently occur together in the population (such as hypertension and heart disease) were placed in the same condition list. Thus, we can use the NHIS to measure the covariance of commonly co-occurring conditions.

4.0 Methods

In this section, we describe our decomposition of disability trends into two parts—that attributable to changes in the prevalence of chronic disease, and that attributable to changes in the prevalence of disability among those with chronic disease. Because one major theme of this paper is that the cause of disability trends can differ markedly by age, a central challenge we face is that there is no large national database that is repeatedly administered that has large enough samples to say with any confidence how disability and chronic disease have changed within single year age categories. To compensate for this fact, we combine information across age groups, using a well-specified smoothing technology. To learn about 60 year olds, we take into account what happened to 59 and 61 year olds with equal weight, 58 and 62 year olds with less weight, and so on. We note as an aside that all authors in this literature rely on some sort of smoothing—for example many authors report changes disability rates for people in different 5-year age categories. It is inescapable given the constraints of sample size.

4.1 Estimating Changes in Age-Prevalence Curves

To describe the method we use to produce smooth age-specific prevalence functions—the overlap polynomial method\(^3\)—it is helpful to introduce some notation. Let \(N\) represent the number of observations in the data set. Each observation \(i\), taken in year \(y_i\), consists of information about \(i\)’s self-reports regarding disability limitations \(d_i\) and age \((age)\).\(^4\)

Given these data, we will estimate the following logit model of disability prevalence using each year of data available:

\(^3\) MaCurdy, Green, and Paarsch (1990) are the first to use this method in economics. Bhattacharya, Garber, and MaCurdy (1997) use this method to smooth cause-specific mortality profiles for the elderly.

\(^4\) It is possible to adapt this method to use other covariates.
\[ P[d_i | \text{age}_i, \text{year}_i] = \frac{1}{1 - \exp(g_1(\text{age}_i)\beta_1 + g_2(\text{year}_i)\beta_2 + g_1 * g_2 \beta_3)} \] (1)

In effect, we calculate the prevalence of disability at each age and year, in the context of a logistic distribution. The \( g \) functions allow the presence of disability to vary flexibly with the year of observation and the age-cohort of the respondent. Age and year enter the model through the \( g \) functions, which are specified using an overlap polynomial.

The age polynomials are defined as:

\[ g_1(\text{age}_i) = \sum_{j=0}^{K} \left( \Phi \left( \frac{\text{age}_i - k_{j+1}}{\sigma_1} \right) - \Phi \left( \frac{\text{age}_i - k_j}{\sigma_1} \right) \right) p_j(\text{age}_i; \beta_{1j}) \] (2)

where \( p_j(\text{age}_i; \beta_{1j}) \) \( j = 0, ..., K + 1 \) are all \( n \)th-order polynomial in \( \text{age}_i \).5 The terms \( k_0, .., k_{K+1} \) are called “knots,” and \( \sigma_1 \) is a smoothing parameter, all of which are fixed before estimation. With this smoothing technique, the knots define age intervals. When the smoothing parameter approaches zero, the age-profile over each interval simply equals the average disability level within that interval. In this case, the age-profile reduces to a step function, where each interval constitutes a separate step.6 As the smoothing parameter increases, the estimator uses increasingly more information from outside each interval. In the extreme, as the smoothing parameter approaches infinity, there is no meaningful distinction between any two intervals. Allowing nonzero values of the smoothing parameters eliminates the sharp discontinuity of the growth rates at the knots. One advantage of overlapping polynomials over traditional splines is that the function and all its derivatives are automatically continuous at the knots without imposing any parameter restrictions.

The overlap polynomial for year, \( g_2 \), and its interaction with \( g_1 \) allow for flexible changes in the age-prevalence relationship over time. It is defined as:

\[ g_2(\text{year}_i) = \sum_{j=0}^{M} \left( \Phi \left( \frac{\text{year}_i - m_{j+1}}{\sigma_2} \right) - \Phi \left( \frac{\text{year}_i - m_j}{\sigma_2} \right) \right) q_j(\text{year}_i; \beta_{2j}) \] (3)

As before, the \( m \) terms represent the knots, while the \( \sigma \) term represents the smoothing parameter.

The object of the maximum likelihood logit estimation is to obtain consistent estimates for \( \beta_1, \beta_2 \) and \( \beta_3 \) -- \( \hat{\beta}_1, \hat{\beta}_2 \) and \( \hat{\beta}_3 \) respectively. Using these estimates, it is straightforward to generate age-prevalence profiles representative for any particular year. Let \( \rho_{t,a} \) be the disability prevalence among \( a \)-year olds in year \( t \). Then,

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5 We use first-degree polynomials. Though we experimented with higher order polynomials, we find that they add to the costs of computation with no change in the final results.

6 When this is the case, \( \Phi(.) \) reduces to an indicator function equal to zero if \( \text{age} < k_j \) and one if \( \text{age} \geq k_j \).
\[ \rho_{t,a} = \frac{1}{N} \sum_{i} P[d_{it} = 1 | age_i = a, year_i = t; \hat{\beta}_1, \hat{\beta}_2, \hat{\beta}_3] \]  

(4)

### 4.2 Decomposing Causes of Changes in Age-Specific Disability

The aim here is to determine the extent to which age-specific trends in disability can be explained by observed trends in chronic health. Presumably, whatever is left over is explained by trends in other determinants of disability prevalence such as public policy and (mechanically) by disability trends among those with no chronic illness. This exercise is important because if a substantial portion of disability trends among the young can be explained by chronic disease, then these disability trends are likely to signify a permanent increase in population disability prevalence that will persist well into the future. If on the other hand, chronic disease explains little of the trends, and economic incentives are a more important explanation, then when these younger populations retire and no longer face the same economic incentives, the observed increase in disability prevalence might not persist.

For each person \( i \) (suppressed for clarity), let \( D_i \) be a dummy indicating self-reported disability at time \( t \) and let \( C_i = \{C_{1t}, C_{2t}, \ldots, C_{Kt}\} \) be a vector of dummy variables, each of which indicates whether a particular chronic condition is present and observed (by the econometrician) at time \( t \). For illustration, consider just the first chronic condition, \( C_{1t} \).

The probability of disability can be written as follows:

\[
P[D_i] = P[D_i | C_{1t} = 1]P[C_{1t} = 1] + P[D_i | C_{1t} = 0]P[C_{1t} = 0] \]

(5)

The proportion of the disabled population that is attributable to people with \( C_{1t} \), is simply the first of two terms in the previous equation, while the second term is the proportion of disabled population that is attributable to people without \( C_{1t} \) (though these people may have other chronic conditions, or may report being disabled due to public policy, accidents, or other health trends). Using equation (5), we can decompose the change in disability prevalence between \( t-1 \) and \( t \), \( \Delta P[D_i] \), as follows:

\[
\Delta P[D_i] = \Delta P[D_i | C_{1t} = 1]P[C_{1t} = 1] + P[D_i | C_{1t} = 1]\Delta P[C_{1t} = 1] + \Delta P[D_i | C_{1t} = 0]P[C_{1t} = 0] + P[D_i | C_{1t} = 0]\Delta P[C_{1t} = 0] 
\]

(6)

Each term in (5) contributes two terms to (6): a term that reflects the change due to a change in the prevalence of the condition and a term that reflects the change due to a change in the probability of disability among those with the condition.

Now, let \( E_i \) be the portion of disability prevalence that can be explained by the chronic conditions in \( C_i \), when they are observed singly. Define \( E_i \) as a generalization of the first term in (5):
Let $\Delta E_t$ be the portion of the change in disability prevalence between $t-1$ and $t$ that can be explained by the chronic conditions in $C_t$:

$$
\Delta E_t = \Delta P[D_t | C_t = 1]P[C_{t-1} = 1] + \Delta P[D_t | C_{t-1} = 1]P[C_{t-2} = 1] + \cdots + \Delta P[D_t | C_{Kt} = 1]P[C_{Kt-1} = 1]
$$

To show how $E_t$ and $P[D_t]$ are related, consider the case where the presence of only two chronic conditions are observed (that is, $K=2$). In that case, the proportion of disability attributable to each of the conditions can be decomposed as follows:

$$
P[D_t | C_{t-1} = 1]P[C_{t-1} = 1] + P[D_t | C_{t-2} = 1]P[C_{t-2} = 1] + \cdots + P[D_t | C_{Kt} = 1]P[C_{Kt} = 1] = E_t
$$

Notice that the first terms of both decompositions in (9) are identical and represent the contribution of people who have both chronic conditions to the prevalence of disability. For this $K=2$ case, note that $E_t = P[D_t | C_{t-1} = 1]P[C_{t-1} = 1] + P[D_t | C_{t-2} = 1]P[C_{t-2} = 1]$. Thus,

$$
E_t = P[D_t | C_{t-1} = 1, C_{t-2} = 0]P[C_{t-1} = 1, C_{t-2} = 0] + P[D_t | C_{t-1} = 0, C_{t-2} = 1]P[C_{t-1} = 0, C_{t-2} = 1] + 2P[D_t | C_{t-1} = 1, C_{t-2} = 1]P[C_{t-1} = 1, C_{t-2} = 1]
$$

On the other hand, the true probability of disability attributable to the two conditions, $P[D_t | C_{t-1} + C_{t-2} \geq 1]$, can be decomposed as follows:

$$
P[D_t | C_{t-1} + C_{t-2} \geq 1] = P[D_t | C_{t-1} = 1, C_{t-2} = 0]P[C_{t-1} = 1, C_{t-2} = 0] + P[D_t | C_{t-1} = 0, C_{t-2} = 1]P[C_{t-1} = 0, C_{t-2} = 1] + P[D_t | C_{t-1} = 1, C_{t-2} = 1]P[C_{t-1} = 1, C_{t-2} = 1]
$$

Comparing (10) and (11), it is evident that $E_t$ overestimates the portion of disability attributable to chronic conditions by the joint prevalence term, $P[D_t | C_{t-1} = 1, C_{t-2} = 1]P[C_{t-1} = 1, C_{t-2} = 1]$. That is, by taking each of the observed chronic
conditions singly, $E_t$ produces an upper bound on how much disability prevalence can be explained by chronic health conditions. It is easy to generalize this argument to more than two conditions, though the proof requires the introduction of some cumbersome notation, so I omit it here. The principle is the same though: $E_t$ overcounts relative to

$$P \left[ D_t \left( \sum_{i=1}^{K} C_{it} \geq 1 \right) \right]$$

because it includes too many joint prevalence terms. Thus, in equation (8), $\Delta E_t$ measures how an upper bound (to the contribution of observed trends in chronic conditions to disability) changes over time.

While it would be attractive to use equation (11) to evaluate exactly how the trends in chronic health explain trends in disability, for practical reasons it is not possible to do so. In particular, to implement our strategy using equation (11) would require large amounts of data on people with every conceivable set of multiple conditions. In practice, this is impossible since there are many combinations of conditions that are rare in the population. Also, as we note above, the NHIS does not ask about all chronic conditions to all people—it randomly assigns each respondent one condition list out of six that it asks about.

On the other hand, we can implement the main insight of equation (11) by expanding the condition set we consider to include all common combinations of conditions. For example, since the prevalence of diabetes combined with heart disease is common, we include three conditions in our calculations from this set: diabetes with heart disease, diabetes alone, and heart disease alone. By doing this we limit the error due to over counting for all the common disease combinations.

The set of chronic diseases we consider include all of the most common causes of severe ADL disability: arthritis, asthma, cancer, COPD, diabetes, hypertension, heart disease, stroke, and obesity. The set of jointly occurring conditions we consider include: heart disease & hypertension; diabetes & hypertension; hypertension and stroke; heart disease & stroke; and all conditions interacted with obesity. The last set of interactions is possible because the NHIS does not ask about body height and weight within one of the six randomly assigned condition lists, but rather asks about these variables in a part of the questionnaire that is asked of all respondents.

### 5.0 Results

In this section, we present our decomposition of the trends between 1984 and 1996 in disability prevalence as measured by the inability to perform personal care tasks. Recall Table 1, which shows increasing disability prevalence among under-60 populations over that time period. We focus on trends between 1984 and 1996 because Table 1 shows either small or mixed changes in disability prevalence between 1997 and 2000. We do not analyze routine needs disability trends here because the results are similar to the personal care disability trends that we do present here.

---

7 We calculated obesity by using NHIS respondents’ self-reported body height and weight, and constructing a body mass index (BMI) which equals height (in meters) divided by weight (in kilograms) squared. A person is defined as obese if their BMI is over 30.
Though the results we present may seem to tell a complicated story, they can be simply summarized. With the exception of increasing obesity prevalence, changes in chronic disease prevalence cannot account for the increasing prevalence of disability in the under-60 population. Within chronically ill populations, however, people were more likely to be disabled in 1996 than they were in 1984. Thus, the two main sources of increasing disability among those under age 60 are rising obese populations and an increasingly disabled chronically ill population.

Tables 2, 3, and 4 summarize the results of our decomposition for 30 year olds, 45 year olds, and 60 year olds respectively. These tables are estimated using smoothed versions of the probabilities listed in equation (8) for each chronic condition, evaluated at the age indicated. Recall that $\Delta E_i$ is the total change in disability attributable to changes in chronic disease.

The first two data columns in each table show how much of the total change in disability prevalence is due to the change in the prevalence of chronic disease $j$ between 1984 and 1996 — $P[D_i \mid C_{j^*} = 1] \Delta P[C_{j^*} = 1]$ — as well as this number as a percentage of the total change in disability attributable to changes in chronic disease —

$$\frac{P[D_i \mid C_{j^*} = 1] \Delta P[C_{j^*} = 1]}{\Delta E_i}.$$

The second two data columns show how much of the total change in disability prevalence is due to the change in disability rates among those who have condition $j$ in absolute terms, and as a percentage of $\Delta E_i$ — $\Delta P[D_i \mid C_{j^*} = 1] P[C_{j^*} = 1]$ and

$$\frac{\Delta P[D_i \mid C_{j^*} = 1] P[C_{j^*} = 1]}{\Delta E_i}$$

respectively.

The last two data columns show the sum of those smoothed probabilities, again in absolute terms and as a percentage of $\Delta E_i$ —

$$P[D_i \mid C_{j^*} = 1] \Delta P[C_{j^*} = 1] + \Delta P[D_i \mid C_{j^*} = 1] P[C_{j^*} = 1]$$

and

$$\frac{P[D_i \mid C_{j^*} = 1] \Delta P[C_{j^*} = 1] + \Delta P[D_i \mid C_{j^*} = 1] P[C_{j^*} = 1]}{\Delta E_i}$$

respectively. These last columns represent the total contribution of changes in condition $j$ on changes in disability prevalence.

Finally, since disability rates also changed in the non-chronically ill population, we report (at the bottom of each table) the remainder in the total disability change attributable to
people without chronic conditions, \( \Delta P[D_t = 1] - \Delta E_t \), as well as this number normed by \( \Delta E_t \), \( \frac{\Delta P[D_t = 1] - \Delta E_t}{\Delta E_t} \).

Table 2 shows the decomposition for 30 year olds. For this group, smoothed disability rates rose by 0.002 percentage points between 1984 and 1996 (or about 20 cases per 10,000 population). Among those with chronic disease, disability rates rose by 0.006 percentage points over the same period; disability rates actually fell by 0.004 percentage points among the non-chronically ill. Among the chronically ill, 40% of the change in disability prevalence is due to changes in the prevalence of chronic disease, while 60% of the change is due to increases in the probability of disability among the chronically ill.

The single largest source of increased chronic disease prevalence resulting in disability among 30 year olds is an increase in obesity. If all the prevalence of all other chronic diseases had stayed the same while obesity rates increased as they actually did, our decomposition suggests that disability rates in this age group would have risen by 0.002 percentage points, and this calculation ignores the increase in prevalence of obese individuals with other chronic diseases. Thus, increasing obesity prevalence by itself explains a third of the rise in disability in this group.

Table 2 also shows that increases in the probability of disability among the chronically ill are an important source of the overall rise in disability. Increases in disability rates among heart disease patients explain 20% of the overall rise attributable to chronic disease, while increases in disability among obese heart disease patients explain a further 35% of the overall rise. Heart attack survival rates increased substantially over this period. Our evidence suggests that improvements in therapy kept people alive, but increasingly in a disabled state, at least for 30 year olds. Increases in disability rates among asthma and hypertension patients also explain 10% and 13% of the rise, respectively. Stroke patients were likely to be disabled in 1996 than they were in 1999, providing evidence of improvements in the care of stroke patients.

Table 3 shows the results of our decomposition for 45 year olds. In this group, smoothed disability rates rose by 0.0047 percentage points between 1984 and 1996. In this period, disability prevalence rose by 0.01 percentage point among the chronically ill (100 per 10,000 population), and fell by 0.0053 percentage points among the non-chronically ill. About 43% of the change in disability prevalence among the chronically ill is due to increases in chronic disease prevalence among 45 year olds, while about 57% is due to increasing disability among the chronically ill.

As was the case for 30 year olds, Table 3 shows that obesity is a major source of the increase in disability in this group, explaining 30% of the overall increase in disability. The increase in prevalence of obese individuals with arthritis, diabetes, or hypertension together explains a further 20% of the overall rise. Increasing prevalence of individuals with stroke and hypertension explains 12% of the overall rise.
Table 3 also shows that (holding fixed disease prevalence) increasing disability among individuals with COPD (21% of the overall increase), hypertension (24%), and asthma (9%) are also important sources of rising disability in this group. Obese individuals with diabetes in this age group are also increasingly likely to be disabled. Increasing disability in this latter group explains a further 14% of the overall increase attributable to the chronically ill. As was the case for 30 year olds, there is evidence of improvements in disability rates among some subsets of the chronically ill population. For example, 45 year old stroke patients and patients with both asthma and COPD were less likely to be disabled in 1996 than they were in 1984. In contrast with 30 year olds, 45 year old non-obese heart disease patients with no history of hypertension were also less likely to be disabled in 1996 than they were in 1984.

Finally, Table 4 shows our decomposition for 60 year olds. In this population, there were substantial declines in disability prevalence among both the chronically ill (by about 28 cases per 10,000) and the non-chronically ill (by about 62 cases per 10,000). The entire decline in disability prevalence among the chronically ill is due to declining prevalence of disability among those with chronic disease. If the prevalence of disability among the chronically ill had remained constant between 1984 and 1996, while the prevalence of chronic disease had evolved as it actually did, there would have been a 0.0038 percentage point (38 cases per 10,000) increase in disability for 60 year olds over that period. Conversely, if the prevalence of chronic disease had stayed fixed, while disability prevalence among the chronically ill evolved as it actually did, disability rates among the chronically ill would have fallen by 0.0066 percentage points (66 cases per 10,000).

Table 4 shows that for 60 year olds, obesity is again the largest single source of increasing chronic disease prevalence resulting in increasing disability, though asthma and stroke are also important sources. Declining prevalence of hypertension and heart disease, on the other hand, play important roles in the decline in disability prevalence.

Finally, Table 4 shows with few exceptions, disability rates among the chronically ill declined substantially. In particular, disability among patients with asthma, diabetes, heart disease, hypertension, stroke, and obesity declined by 8, 32, 18, 25, 14, and 21 cases per 10,000 population respectively. However, disability among patients with both heart disease and hypertension rose by 14 cases per 10,000; among obese individuals with hypertension, disability rose by 62 cases per 10,000. Similarly, disability rose among patients with arthritis (3 cases per 10,000) and with COPD (22 cases per 10,000).

6.0 Discussion and Conclusions

While previous literature has established rising disability rates in younger populations and falling disability rates in older populations (results that we confirm), the decomposition estimated in this paper is a starting point in understanding why disability prevalence has moved as it has. Our main results are:

- Between 1984 and 1996, the rising prevalence of obesity has been an important source of the rise in disability prevalence for all the age groups we examine.
Among age groups under 60, changes in the prevalence in other chronic diseases (including heart disease, hypertension, diabetes, and cancer) have had a mixed or small impact on overall disability rates.

Among age groups under 60, chronically ill populations were substantially more likely to be disabled in 1996 than they were in 1984, while non-chronically ill populations were substantially less likely to be disabled in 1996 than in 1984.

Among age groups 60 and over, both chronically ill and non-chronically ill populations were less likely to be disabled in 1996 than they were in 1984.

Even if an increase in disability prevalence meant nothing more than an increase in the set of people unable to perform basic activities like dressing oneself, such increases would be a source of considerable concern, at least to the newly disabled and their caretakers. The well-established link between disability prevalence and medical care expenditures by the elderly heightens the importance of this phenomenon—disability is closely linked to the public expenditures on health insurance. In the remainder of this section, we consider some of the consequences of our findings for future Medicare expenditures.

The well-documented decline in disability among older populations over the past 25 years has led some authors to forecast substantially more optimistic projections of future Medicare expenditures than would be predicted if disability trends were ignored (see, for example, Pardes et al, 1999 and Manton and Gu, 2001). Such optimistic forecasts have been criticized because disability rates have been increasing among younger populations (Lakdawalla et al. 2004; Lakdawalla et al. 2003a). As these younger populations age into Medicare eligibility, and if they remain increasingly disabled, then future cohorts of elderly may not enjoy further declines in disability. Accounting for both the rising disability among younger populations and falling disability rates among older populations results in considerably less optimistic forecasts of future spending on Medicare. A key issue related to the accuracy of these alternate forecasts relates to the permanence of disability. If the development of disability at younger ages augurs disability at older ages, then the less optimistic forecasts are correct. On the other hand, if disability developed at younger ages is transitory, then the original optimistic forecasts are more likely true.

The decomposition of disability trends reported in this paper are directly germane to the permanence of disability in younger populations. We emphasize two different sources of the changes in disability: (1) changes in the prevalence of chronic disease; and (2) changes in the probability of disability among chronically ill populations. If chronic disease prevalence is a major source of the rise in disability prevalence, then the rise in disability is more likely to be permanent. Since most chronic illness are permanent, unless these diseases cause younger populations to die at substantial rates before age 65—given rising life expectancies and improved medical technologies, this is not likely to be the case—rising disability rates caused by increasing chronic disease prevalence implies permanent increases in disability. With the exception of rising obesity prevalence, we find that rising chronic disease prevalence does not, on net, explain the rise in disability among populations between 18 and 59 years old; hence we do not find
empirical support for this particular argument that the changes in disability are permanent.

We do however find that the increasing prevalence of obesity is an important source of the rise in disability among younger populations. Of course, an individual who becomes obese does not necessarily remain so forever—weight loss is possible if difficult. However, a case can be made that once an obese individual is disabled, it can be hard to recover, so this result buttresses the argument that the changes in disability are permanent. In the case of obesity, though, this argument is further complicated by the fact that the health effects of increased body weight are different for the younger and older populations. In older populations, increased body weight can sometimes be protective against conditions that commonly lead to disability (for example, increased bone density with increased weight leads to fewer hip fractures).

Alternatively, if rising disability among chronically ill populations (as opposed to rising chronic disease prevalence) is a major source of the rise in disability prevalence, then the overall rise in disability may or may not be permanent, depending upon why the chronically ill are more likely to be disabled. Rising disability due to this source suggests strongly that a chronically ill population is sicker now than it was before, but this fact does not establish the cause and may be due to a number of counterintuitive reasons. For example, rising disability among the chronically ill may be due to improved medical care—chronically ill people who otherwise would have died when treated with the old technology are kept alive with the new technology, but in a disabled state. Or perhaps the chronically ill population is sicker for reasons having little to do with technological change. For example, an increasingly obese populace might produce both more diabetics and a more severely ill diabetic population. Whether these changes in the chronically ill population result in permanent increases in disability prevalence, and what effect these changes will have on the disability rates of future elderly cohorts is an empirical issue that requires further research. In any case, it should be clear that accurate forecasts of future Medicare expenditures cannot be constructed by ignoring the increasing disability prevalence among younger populations.
References


Bhattacharya J, Currie J. “Youths and Nutritional Risk: Malnourished or Misnourished?” in Risky Behavior Among Youths, J Gruber (ed.), (2001)


Table 1: Age-Specific trends in the proportion of people with personal care or routine needs limitations per 10,000 population, 1984-2000.

<table>
<thead>
<tr>
<th>Age Groups</th>
<th>18-29</th>
<th>30-39</th>
<th>40-49</th>
<th>50-59</th>
<th>60-69</th>
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<tr>
<td>1984</td>
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<td>82</td>
<td>30</td>
<td>118</td>
<td>63</td>
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<tr>
<td>85-86</td>
<td>25</td>
<td>75</td>
<td>37</td>
<td>125</td>
<td>53</td>
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<td>27</td>
<td>79</td>
<td>33</td>
<td>126</td>
<td>51</td>
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<tr>
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<td>27</td>
<td>86</td>
<td>28</td>
<td>127</td>
<td>58</td>
</tr>
<tr>
<td>91-92</td>
<td>30 *</td>
<td>101 *</td>
<td>55 *</td>
<td>173 *</td>
<td>76</td>
</tr>
<tr>
<td>93-94</td>
<td>26 *</td>
<td>104 *</td>
<td>48 *</td>
<td>185 *</td>
<td>71</td>
</tr>
<tr>
<td>95-96</td>
<td>31 *</td>
<td>98</td>
<td>54 *</td>
<td>181 *</td>
<td>78</td>
</tr>
<tr>
<td>change 84-96</td>
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<td>16</td>
<td>24</td>
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</tr>
<tr>
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<td>63</td>
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<td>7</td>
<td>5</td>
<td>-3</td>
<td>20</td>
</tr>
</tbody>
</table>

*Significantly different from base year (1984 or 1997-8) according to 2 tailed t-test at 95% level.
Table 2: Decomposition of Chronic Disease to Change in Disability Prevalence 1984-1996 (Age 30)

| Age 30         | Change in Disability Due to Change in Prevalence 1984-1996 | % Contribution for Prevalence | Change in Disability due to Change in Pr(Disab|Cond) 1984-1996 | % Contribution for Pr(Disab|cond) | Total Contribution to Change in Disab Rate from 1984-1996 | % of contribution to change in disab rate from 1984-1996 |
|---------------|-----------------------------------------------------------|--------------------------------|----------------------------------------------------|-------------------------------|----------------------------------------------------------|----------------------------------------------------------|
| Arthritis     | -1.04E-04                                                 | -2%                            | 7.11E-05                                           | 1%                            | -3.25E-05                                                | -1%                                                      |
| Asthma        | 1.71E-04                                                 | 3%                             | 6.10E-04                                           | 10%                           | 7.81E-04                                                 | 13%                                                      |
| COPD          | 9.76E-05                                                 | 2%                             | 2.56E-04                                           | 4%                            | 3.53E-04                                                 | 6%                                                       |
| Diabetes      | -1.71E-05                                                | 0%                             | 3.19E-04                                           | 5%                            | 3.02E-04                                                 | 5%                                                       |
| Heart Disease | -6.49E-05                                                | -1%                            | 1.20E-03                                           | 20%                           | 1.13E-03                                                 | 19%                                                      |
| Hypertension  | -2.68E-04                                                | -4%                            | 7.65E-04                                           | 13%                           | 4.98E-04                                                 | 8%                                                       |
| Cancer        | 0                                                        | 0%                             | 0.00E+00                                           | 0%                            | 0.00E+00                                                 | 0%                                                       |
| Obesity       | 2.03E-03                                                 | 33%                            | -3.39E-04                                          | -6%                           | 1.69E-03                                                 | 28%                                                      |
| Stroke        | -1.58E-03                                                | 33%                            | -5.23E-04                                          | -9%                           | -6.81E-04                                                | -11%                                                     |
| Asthma & COPD | 4.44E-04                                                 | 7%                             | -2.94E-04                                          | -5%                           | 1.50E-04                                                 | 2%                                                       |
| Heart Disease & Hypertension & Stroke | 2.47E-07 | 0% | 6.30E-07 | 0% | 8.77E-07 | 0% |
| Heart Disease & Hypertension | -1.41E-05 | 0% | 2.23E-04 | 4% | 2.08E-04 | 3% |
| Heart Disease & Stroke | -2.28E-06 | 0% | 8.41E-06 | 0% | 6.13E-06 | 0% |
| Obesity & Arthritis | 3.12E-04 | 5% | -2.50E-04 | -4% | 6.16E-05 | 1% |
| Obesity & Diabetes | 6.99E-05 | 1% | -7.29E-05 | -1% | -2.97E-06 | 0% |
| Obesity & Heart Disease | -2.59E-06 | 0% | 2.11E-03 | 35% | 2.11E-03 | 35% |
| Obesity & Hypertension | -7.67E-05 | -1% | -6.95E-04 | -11% | -7.72E-04 | -13% |
| Stroke & Hypertension | -1.91E-07 | 0% | 2.91E-04 | 5% | 2.91E-04 | 5% |
| Total         | 2.42E-03                                                | 40%                            | 3.68E-03                                           | 60%                           | 6.10E-03                                                 | 100%                                                     |

*total change in disability 1984 to 1996:*

*remainder attributable to change among people with out chronic conditions:*

-4.10E-03 -67%
Table 3: Decomposition of Chronic Disease to Change in Disability Prevalence 1984-1996 (Age 45)

| Age 45          | Change in Disability Due to Change in Prevalence 1984-1996 | % Contribution for Prevalence | Change in Disability due to Change in Pr(Disab|Cond) 1984-1996 | % Contribution for Pr(Disab|Cond) 1984-1996 | Total Contribution to Change in Disab Rate from 1984-1996 | % of contribution to change in disab rate from 1984-1996 |
|-----------------|----------------------------------------------------------|-------------------------------|----------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------------|
| Arthritis       | -3.61E-04                                               | -4%                           | 3.55E-04                                                | 4%                                                       | -6.51E-06                                               | 0%                                                       |
| Asthma          | 4.44E-04                                                | 4%                            | 8.51E-04                                                | 9%                                                       | 1.29E-03                                                | 13%                                                      |
| COPD            | 3.05E-04                                                | 3%                            | 2.13E-03                                                | 21%                                                      | 2.44E-03                                                | 24%                                                      |
| Diabetes        | 1.63E-05                                                | 0%                            | 5.88E-04                                                | 6%                                                       | 6.04E-04                                                | 6%                                                       |
| Heart Disease   | -8.14E-05                                               | -1%                           | -6.92E-04                                               | -7%                                                      | -7.73E-04                                               | -8%                                                      |
| Hypertension    | -9.40E-04                                               | -9%                           | 2.42E-03                                                | 24%                                                      | 1.48E-03                                                | 15%                                                      |
| Cancer          | 0                                                       | 0%                            | 0.00E0                                                  | 0%                                                       | 0.00E0                                                  | 0%                                                       |
| Obesity         | 3.00E-03                                                | 30%                           | -1.45E-04                                               | -1%                                                      | 2.86E-03                                                | 29%                                                      |
| Stroke          | -3.89E-04                                               | 30%                           | -8.90E-04                                               | -9%                                                      | -1.28E-03                                               | -13%                                                     |
| Asthma & COPD   | -3.66E-04                                               | -4%                           | -1.04E-03                                               | -10%                                                     | -1.40E-03                                               | -14%                                                     |
| Heart Disease & Hypertension & Stroke | 4.51E-06 | 0% | 1.40E-05 | 0% | 1.86E-05 | 0% |
| Heart Disease & Hypertension | -2.45E-04 | -2% | 5.02E-04 | 5% | 2.57E-04 | 3% |
| Heart Disease & Stroke | -1.67E-04 | -2% | -5.72E-05 | -1% | -2.24E-04 | -2% |
| Obesity & Arthritis | 1.46E-03 | 15% | 7.26E-04 | 7% | 2.19E-03 | 22% |
| Obesity & Diabetes | 1.72E-04 | 2% | 1.40E-03 | 14% | 1.57E-03 | 16% |
| Obesity & Heart Disease | 1.77E-05 | 0% | 4.08E-04 | 4% | 4.26E-04 | 4% |
| Obesity & Hypertension | 2.85E-04 | 3% | -2.91E-04 | -3% | -5.75E-06 | 0% |
| Stroke & Hypertension | 1.18E-03 | 12% | -6.15E-04 | -6% | 5.61E-04 | 6% |
| Total           | 4.34E-03                                               | 43%                           | 5.66E-03                                                | 57%                                                      | 1.00E-02                                                | 100%                                                     |

Total change in disability 1984 to 1996: 0.00467200 47%

remainder attributable to change among people with out chronic conditions: -5.33E-03 -53%
| Age 60          | Change in Disability Due to Change in Prevalence 1984-1996 | % Contribution for Prevalence | Change in Disability due to Change in Pr(Disab|Cond) 1984-1996 | % Contribution for Pr(Disab|cond) | Total Contribution to Change in Disabil Rate from 1984-1996 | % of contribution to change in disabil rate from 1984-1996 |
|----------------|----------------------------------------------------------|-------------------------------|----------------------------------------------------------|----------------------------------|----------------------------------------------------------|----------------------------------------------------------|
| Arthritis      | -9.13E-04                                               | -33%                          | 2.75E-04                                                 | 10%                              | -6.38E-04                                               | -23%                                                     |
| Asthma         | 1.21E-03                                                | 44%                           | -7.80E-04                                                | -28%                             | 4.34E-04                                                | 16%                                                      |
| COPD           | -4.36E-04                                               | -16%                          | 2.16E-03                                                 | 78%                              | 1.72E-03                                                | 62%                                                      |
| Diabetes       | 5.85E-05                                                | 2%                            | -3.21E-03                                                | -116%                            | -3.15E-03                                               | -114%                                                    |
| Heart Disease  | -1.49E-03                                               | -54%                          | -1.75E-03                                                | -63%                             | -3.23E-03                                               | -117%                                                    |
| Hypertension   | -2.15E-03                                               | -78%                          | -2.47E-03                                                | -89%                             | -4.61E-03                                               | -167%                                                    |
| Cancer         | -6.21E-04                                               | -22%                          | 0.00E+00                                                 | 0%                               | -6.21E-04                                               | -22%                                                     |
| Obesity        | 5.53E-03                                                | 200%                          | -1.21E-03                                                | -77%                             | 3.41E-03                                                | 123%                                                     |
| Stroke         | 1.35E-03                                                | 49%                           | -1.36E-03                                                | -49%                             | -1.27E-05                                               | 0%                                                       |
| Asthma & COPD  | 1.69E-03                                                | 61%                           | 2.36E-04                                                 | 9%                               | 1.93E-03                                                | 70%                                                      |
| Heart Disease & Hypertension & Stroke | -2.95E-04 | -11% | 1.41E-04 | 5% | -1.54E-04 | -6% |
| Heart Disease & Hypertension | -1.87E-03 | -67% | 1.40E-03 | 50% | -4.71E-04 | -17% |
| Heart Disease & Stroke | -2.36E-03 | -85% | -1.91E-03 | -69% | -4.28E-03 | -155% |
| Obesity & Arthritis | 4.06E-03 | 147% | -3.79E-05 | -1% | 4.02E-03 | 145% |
| Obesity & Diabetes | -8.42E-04 | -30% | -2.29E-03 | -83% | -3.13E-03 | -113% |
| Obesity & Heart Disease | 3.80E-04 | 14% | -6.15E-04 | -22% | -2.35E-04 | -8% |
| Obesity & Hypertension | 2.35E-04 | 8% | 6.19E-03 | 224% | 6.43E-03 | 232% |
| Stroke & Hypertension | 2.89E-04 | 10% | -4.70E-04 | -17% | -1.81E-04 | -7% |
| Total          | 3.84E-03                                                | 139%                          | -6.61E-03                                                | -239%                            | -2.77E-03                                               | -100%                                                    |

**Total change in disability 1984 to 1996:**

-8.99E-03 -325%

**remainder attributable to change among people with out chronic conditions:**

-6.23E-03 -225%