RESEARCH REPORT

Costs of Illness Among Older Adults: An Analysis of Six Major Health Conditions with Significant Environmental Risk Factors

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Costs of Illness Among Older Adults: An Analysis of Six Major Health Conditions with Significant Environmental Risk Factors

George Van Houtven, Amanda A. Honeycutt, Boyd Gilman, Nancy T. McCall, Wanda W. Throneburg, and Kathy E. Sykes

Abstract

This study estimates the cost burden associated with six major illnesses among Americans age 65 or older: chronic lung disease, ischemic heart disease, stroke, lung cancer, pneumonia, and gastrointestinal illness. These illnesses were selected because of their relatively high impact among older populations and because they include environmental exposures as a significant risk factor. A prevalence-based cost-of-illness approach was applied. Medical costs were estimated from Medicare claims data in 2000. Productivity losses were estimated through regression analyses of National Health Interview Survey data and using age-specific earnings and household production estimates. Estimated costs range from $0.5 billion (gastrointestinal illness) to almost $60 billion (ischemic heart disease). The combined costs of these conditions among the 65-or-older population in 2000 were almost $135 billion. A simple extrapolation of these cost estimates based on population growth and increases in average medical care prices since 2000 implies that the comparable costs in 2007 were more than $196 billion. With the expectation that these costs will continue to increase significantly as the population ages, priority should be given to prevention strategies such as environmental quality improvements.

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Introduction

The US population is expected to age rapidly over the next decades; the percentage of Americans age 65 or older is projected to grow from less than 13 percent of the population currently to more than 20 percent by 2040. This demographic shift is certain to increase pressure on already rising aggregate health costs, and it increases the expected benefits of measures that help to prevent illness among older Americans. Environmental programs are a case in point. Because older individuals are often more susceptible to harm from pollutant exposures, improving environmental conditions may be a particularly effective way to reduce the burden of illness in an aging population. To promote a better understanding of these potentially avoidable health costs among older Americans, this analysis estimates the total annual cost burden associated with six major illnesses among Americans age 65 or older.

The six categories of illness selected for this analysis are chronic lung disease (CLD), ischemic heart disease (IHD), stroke, lung cancer, pneumonia, and gastrointestinal (GI) illness. These conditions were selected for several reasons. First, each has a relatively high rate of prevalence among older populations (compared with younger populations) and (except GI illness) is a major cause of death among persons age 65 or older. Therefore, they are major contributors to the total costs of illness in this age group. Second, the costs of these illnesses have rarely, if ever, been specifically estimated for individuals age 65 or older.

Applying a consistent data set and methods across the six illness categories not only fills a gap in the literature, it also provides estimates that are directly comparable across the illness categories. Finally, these conditions were selected because many cases of these illnesses are potentially preventable through improvements in environmental conditions. All of the illnesses are known or strongly suspected to include environmental exposures as a significant risk factor. In some cases, such as lung cancer and GI illness, environmental exposures are considered to be direct causes of illness, whereas in others, such as asthma, exposure exacerbates existing conditions.

Because these illnesses are often associated with exposure to poor environmental conditions, a specific objective of this analysis is to inform such efforts as the US Environmental Protection Agency's Aging Initiative, which was established in 2002 to study environmental health impacts among older persons and to help prioritize policies for mitigating these impacts (US EPA, 2003). Despite the growing size and importance of this subpopulation, few economic studies to date have focused on the health benefits of environmental policies for older Americans. The burden of disease estimates developed in this analysis are not exclusively associated with environmental exposures; however, they do provide starting points for evaluating the potential benefits for older Americans of policies to improve air, water, and general environmental quality in the United States.

Overview of Selected Health Conditions

This section provides a brief discussion of the six health conditions with regard to (1) their impact on older populations in the United States, (2) their links to environmental exposures, and (3) the available evidence on costs of illness.

Although several studies have estimated costs for these conditions, few have specifically focused on the 65-or-older population, and the variety of data sources (including Medicare claims data and several national health surveys) and measurement approaches used makes it difficult to compare results across studies. An important feature of this study is that it applies a consistent set of data sources and estimation methods across the six conditions. As a result, it provides directly comparable cost estimates across the six conditions for the 65 and older population.

The first condition, CLD, which includes asthma, emphysema, and other conditions classified as chronic obstructive pulmonary disease (COPD), affects millions of older adults (Lucas, Schiller, & Benson, 2004). Chronic lower respiratory diseases, in particular, are the fourth leading cause of death for persons age 65 or older (NCHS, 2002). Exposures to common air pollutants, such as tobacco smoke, particulate matter, and ozone, have been found in several studies to cause and/or exacerbate these conditions. For a summary of the epidemiological

evidence linking common air pollutants and respiratory and cardiovascular illness, see *The Benefits and Costs of the Clean Air Act, 1990 to 2010* (US EPA, 1999).

A number of studies have estimated costs for a range of different outcomes associated with CLD, including hospitalization costs, expenditures for all health care services, work-loss costs, employer costs for absenteeism and employees' health care services, and informal caregiving costs. Consequently, cost estimates also varied widely. Estimated annual costs per person for all health care services associated with CLD ranged from approximately $1,000 to $7,800 (Ray et al., 2000; Wilson, Devine, & So, 2000). (All dollar figures in this section have been converted to 2000 dollars using the Annual Medical Care Consumer Price Index.) Aggregate annual health care expenditures associated with CLD were estimated to range from $2.8 billion in direct costs for adults (18 or older) with asthma to $23.3 billion in direct costs for COPD (NHLBI, 1996; Wiess, Gergen, & Hodgson, 1992).

The second condition, IHD, which includes heart attacks and angina pectoris, is among the most common conditions suffered by individuals age 65 or older in the United States (Lucas et al., 2004). Diseases of the heart are also the leading cause of death among persons 65 or older, accounting for roughly 33 percent of deaths in this age group (NCHS, 2002). Several studies have also shown that exposures to common pollutants (e.g., particulate matter) can increase risks associated with heart disease, and exposures to less common toxic pollutants (e.g., lead) have also been found to increase these risks (ATSDR, 1999; US EPA, 1997 [Appendix G], 1999).

Estimated costs for heart disease also vary widely. Estimated direct medical costs associated with heart disease ranged from $5,900 to $7,400 per person (Druss et al., 2001; Ray et al., 2000). Total estimated medical costs associated with heart disease ranged from $67 billion for females age 45 or older to more than $100 billion for all circulatory diseases in persons 65 or older (Hodgson & Cohen, 1999; Hoerger et al., 1999). Large differences in estimated costs arise primarily because of differences in the cost categories analyzed and in the age groups considered.

The third condition, stroke, affects 2 to 3 million individuals aged 65 or older each year in the United States (Lucas et al., 2004). Cerebrovascular diseases, which include stroke, are the third leading cause of death in the United States among persons aged 65 or older (NCHS, 2002). Several studies have shown that exposure to pollutants, such as particulate matter, ozone, and lead, increases risks of stroke-related deaths (ATSDR, 1999).

A few studies estimated the average costs related to hospitalization due to stroke in older populations. One study estimated average hospitalization costs for stroke for persons over the age of 65 that ranged from $13,400 to almost $63,000, depending on the type of stroke (Holloway, Witter, Lawton, Lipscomb, & Samsa, 1996). Another study estimated hospital charges of approximately $13,000 per person (age 40 or older) for stroke alone (Mushinski, 1997). Other studies estimated total direct and indirect costs of stroke for persons of all ages to be approximately $46 to $47 billion per year (AHA, 2004; NCHS and NHLBI, 2000).

The fourth condition, lung cancer, is the least prevalent of the six health conditions analyzed in this paper; nevertheless, lung cancer has the second highest prevalence of cancers among persons 65 or older (Lucas et al., 2004). Moreover, lung cancer is known to impose significant costs on a per-case basis. Links between environmental exposures and lung cancer are well established, with known or suspected environmental causes including exposures to particulate matter (Pope et al., 2002), asbestos (ATSDR, 2001), and radon (ATSDR, 1990).

The estimated costs of lung cancer in the literature range from $8.2 billion to $32.5 billion per year using the broader definition of respiratory cancer (Brown & Fintor, 1995; Sullivan, Ramsey, & Lee, 2000). One study estimated average Medicare payments per year for several cancers, including lung cancer, to be about $28,000 per affected beneficiary (Riley, Potosky, Lubitz, & Kessler, 1995).

The fifth condition, pneumonia, is a relatively high-prevalence condition among older individuals, but more importantly, when older individuals are afflicted with this condition, they generally require more costly medical care than younger individuals. Pneumonia

and influenza combined are the fifth leading cause of death among persons age 65 or older (NCHS, 2002). As with CLD, exposures to common air pollutants, such as particulate matter and ozone, have been found in several studies to cause and/or exacerbate pneumonia (US EPA, 1999).

Pneumonia cost studies have primarily focused on hospitalization costs. Mean or median costs per hospitalization associated with pneumonia range from about $5,900 to $10,400 per person (Fine et al., 2000; Warren et al., 2003). Variations in these estimates reflect differences in the definitions used for pneumonia and the methods used (i.e., primary diagnosis costs versus attributable costs). Total direct medical cost estimates associated with pneumonia range from $5.7 billion (for persons age 65 or older) to $19.4 billion per year (Niederman, McCombs, Unger, Kumar, & Popovian, 1998; Thom, n.d.).

The final condition, GI illness, is common in all age groups in the United States; however, persons age 65 or older face particularly high risks of hospitalization and death. For example, from 1979 to 1995, GI illness hospitalization rates for persons older than age 65 were more than twice as high as for younger persons. Exposure to waterborne pathogens is suspected to be a significant contributor to overall rates of GI illness (Bennett, Holmberg, Rogers, & Solomon 1987; Morris & Levin, 1995; Payment et al., 1991), although the attributable fraction is uncertain.

One study of GI illness-related costs used a disease classification approach similar to the one used in this analysis, which was specified to capture GI illness conditions most closely (although not exclusively) associated with environmental exposures. Sandler et al. (2002) estimated direct medical costs associated with GI illness to be $1.7 billion per year for all age groups, with additional indirect costs of $540 million per year. Just over half of these costs were estimated to result from foodborne illnesses.

Methods

To assess the economic burden of the selected illnesses among older adults, we applied a cost-of-illness (COI) approach that measures both the direct and indirect costs of illness. The breakdown of these costs components is summarized in Table 1.

Direct costs represent the dollar value of goods and services consumed as a result of illness and for which payment is made. These costs include payments for treatment, diagnosis, continuing care, rehabilitation, and terminal care. They are typically measured as costs related to hospital stays, physician services, nursing homes, prescription drugs, and in-home health care services.

Indirect costs represent costs for which no payment changes hands but for which an economic effect is nonetheless observed. These costs include primarily productivity losses associated with illness and premature death, and they are typically measured as the value of lost productivity (labor and household) due to illness.

We applied a prevalence-based approach to estimate direct and indirect costs. Prevalence-based cost estimates include costs related to a condition for the prevalent population over a given period (usually a year). These estimates include costs for newly diagnosed cases as well as costs for persons in the later stages of disease. Therefore, to the extent that these costs are the result of environmentally caused illness, they represent the benefit that could be obtained in a given year by avoiding causative

Table 1. Categorization of costs of illness

Direct Costs
Medical costs (Medicare-reimbursed)
Inpatient services
Physician visits
Outpatient services
Home health care
Durable medical equipment
Self-administered drug costs
Nursing home care costs
Indirect Costs
Morbidity costs
Labor productivity losses
Household productivity losses
Mortality costs
Labor productivity losses
Household productivity losses

exposures in that and previous years. We provide estimated costs associated with each of the six selected health conditions among individuals 65 or older in the year 2000.

Below we describe the data sources and methods used to estimate the different components of direct and indirect costs. For each component, we applied a consistent set of data and methods across the six health conditions. We defined each health condition in a consistent manner across data sources by using the same set of ICD-9 (International Classification of Disease, Ninth Revision) codes to identify service use and other costs for each condition: chronic lung disease (491–494, 496), ischemic heart disease (410–414), stroke (430–434, 426), lung cancer (162.2–162.9, 197, 231), pneumonia (480–487), and gastrointestinal illness (001–009 [except 008.45], 558.9).

Direct Cost Estimation

To make best use of the available national data, we separated direct costs into two mutually exclusive components: medical costs and costs associated with self-administered prescription drugs. A third component of direct costs that is not fully captured by this analysis is the cost associated with nursing home care. We explored this issue by analyzing nursing home charges using the 1999 National Nursing Home Survey. However, findings from that survey indicated that none of the individual conditions had a meaningful or statistically significant impact on annual nursing home costs. Because of these findings, we did not include nursing home costs in the aggregate COI estimates.

Medical Costs

For individuals age 65 or older, Medicare claims provide the most comprehensive source of data on costs for medical services. To access a nationally representative sample of these claims for 2000, we used data from the Consumer Assessment of Health Plans Surveys (CAHPS) for Medicare Fee-for-Service (MFFS) beneficiaries. The CAHPS-MFFS sample included 145,875 noninstitutionalized Medicare beneficiaries age 65 or older. From this sample, we analyzed Medicare claims for five main categories of services: inpatient services, physician visits, outpatient services, home health care, and durable medical equipment. For each of the six health conditions and five medical service categories, claims were selected based on their reported diagnosis codes. For inpatient services, we only selected claims recorded with a *primary* diagnosis matching one of the ICD-9 codes for the condition. For outpatient and home health services, for which Medicare claims do not report a primary diagnosis, we selected claims recorded with any diagnosis code matching the ICD-9 codes. For professional fees and durable medical equipment, there is a unique code for each claim.

Using these selected claims data, we estimated both the prevalence rate (number of cases per thousand individuals) and average cost ($/case) of medical services for each condition. To estimate the total number of cases among the entire noninstitutionalized population of individuals 65 or older in 2000, we assumed that the estimated prevalence rates from CAHPS-MFFS were applicable to the entire population of approximately 33.5 million persons. To estimate the aggregate medical costs associated with these cases in 2000, we multiplied their number by the corresponding average medical cost estimates for each condition.

Costs for Self-Administered Drugs

Self-administered prescription drugs are not reimbursable by Medicare and are therefore not included in the claims-based cost estimates. To estimate these prescription drug costs for each of the six health conditions, we used data from the 2000 Medical Expenditures Panel Survey (MEPS), a nationally representative subsample of the National Health Interview Survey (NHIS). The 2000 MEPS requested information about the number of prescription medication purchases (including refills) and total expenditures for prescription drugs by sources of payment and by condition.

We first calculated total prescription drug expenditures by condition for each individual age 65 or older in the sample. We then calculated average prescription drug expenditures across all individuals with a given condition. Combining these average costs with the prevalence estimates from the Medicare claims analysis, we estimated aggregate drug costs for each condition.

Indirect Cost Estimation

To estimate indirect costs for each condition, we applied a human-capital approach. This approach, commonly used in COI studies, measures the monetary value of time lost from work or household production activities because of excess morbidity or premature mortality. These productivity losses are estimated based on market earnings and an imputed value for household production.

Although the human-capital approach measures key components of the economic burden of illness on society, it has inherent limitations. For several reasons, indirect cost estimates based on this approach are best interpreted as lower-bound estimates for the full indirect costs of each condition. First, they do not include the value of time lost from consumption, leisure, or volunteer activities, all of which may be higher among older individuals. Second, they do not include the productivity or other losses incurred by informal caregivers. Third, they do not capture the costs of pain and suffering associated with an illness.

Furthermore, although the human-capital approach measures productivity losses due to premature mortality, these estimates should not be interpreted as measures of the full value of lost life. Rather, they estimate one component of the economic burden resulting from premature mortality. Primarily because of lower remaining life expectancy and labor force participation rates among older adults, these estimates tend to be lower for older adults. These results should not be interpreted to mean that the lives of older individuals are valued less by society.

Morbidity

Using data from the 2001 NHIS, we estimated the impact of specific health conditions on labor and household productivity among persons age 65 or older. For labor productivity losses, we estimated the losses associated with being completely unable to work (out of the labor force) due to the health condition. These estimates were based on respondents who reported that they were not currently working but did work previously. We estimated a probit model of not working for those who reported working previously and included controls for age and for three of the health conditions for which adequate data were reported: CLD, IHD, and stroke. The resulting probit model coefficients were used to calculate the marginal effect of having each of the three health conditions on the probability of not currently working for persons who reported working previously. The marginal effects are the estimates of the impact of each health condition on the probability of being unable to work because of the condition.

To estimate household productivity losses, we used a regression approach to analyze the determinants of the number of reported bed days by NHIS respondents age 65 or older. By controlling for several other factors, including education, poverty status, self-reported health status, labor force participation status, and smoking status, the regression analysis allowed us to estimate the incremental effect of specific conditions on number of bed days. Based on these results, we predicted the average number of bed days attributable to each condition.

To estimate the dollar values associated with the changes in labor force participation and bed days attributable to each condition, we applied existing estimates of age-specific annual earnings and household productivity values for 2000. Using values reported in Grosse (2003), we calculated average annual labor force earnings of $31,052 for individuals age 65 or older who are in the labor force with positive earnings. The average annual value of household services produced by persons 65 or older was estimated to be $12,936, an average of $35 per day.

Mortality

To assess mortality-related productivity losses, we used data from the 1998 National Vital Statistics Report (NVSR), which provides statistics on death rates in 1996 by age group and cause of death. The 1998 NVSR was the most recent NVSR that used ICD-9 codes to categorize causes of death and could therefore be most closely matched with the illness classification approach used in our analysis. We applied these rates to determine the number of annual deaths (by age group) that are primarily associated with each of the six health conditions.

To estimate the dollar value of productivity losses associated with premature mortality, we multiplied the cause-specific and age-group-specific number of deaths for each health condition by estimates of age-group-specific present value of earnings (earnings and household production), which were also estimated by Grosse (2003). Because labor and household production estimates for the group age 85 or older were not available for this analysis, we were not able to estimate mortality-related productivity losses for this group. Average productivity losses for persons 85 or older are expected to be relatively low compared with younger age groups; however, by not including values for this age group, we have underestimated total mortality-related losses for each condition.

Results

Using the data and methods described above, we estimated the costs of illness associated with each of the six selected health conditions in 2000 among individuals age 65 or older. These results are summarized below for each condition (in 2000 dollars). We first summarize the estimates of (1) rates of illness and mortality and (2) average direct and indirect costs of illness for each condition. We then combine these values and report the estimates of aggregate costs.

Prevalence and Average Direct Costs

Table 2 summarizes the estimates of the prevalence and the direct medical costs associated with the six health conditions based on the CAHPS-MFFS beneficiary data. The percentage of beneficiaries 65 or older with each condition ranged from 1 percent for lung cancer to almost 18 percent for IHD. CLD and stroke had the second and third highest prevalence rates affecting, respectively, 11 and 7 percent of this population.

Although the prevalence of lung cancer was low among the Medicare population age 65 or older, per capita medical costs were the highest of the six health conditions, at more than $7,500 per case per year. This annual cost was more than twice the estimated amount for the next highest cost illnesses—pneumonia, IHD, and stroke—which imposed direct medical costs of roughly $3,000 per case per year. GI illness was associated with the lowest average costs, at less than $600 per case per year.

Although not reported in Table 2, the analysis of CAHPS-MFFS data also found the following for all six health conditions:

- Inpatient services accounted for the largest share of average medical costs (compared with physician, outpatient, home health, and durable medical equipment costs), ranging from 37 percent for CLD to 83 percent for pneumonia.

Table 2. Prevalence and average direct medical costs for six health conditions: annual medical payments in 2000 for Medicare beneficiaries age 65 or older

	Beneficiaries with Diagnosis			Direct Medical Costs ($/Case/Year)	
Health Condition	Number	Percent	CI[a](±)	Mean	CI[a](±)
Chronic lung disease	2,871,630	11	(10.8, 11.1)	$1,830	(1,748, 1,913)
Ischemic heart disease	4,696,071	18	(17.7, 18.1)	$3,003	(2,880, 3,125)
Stroke	1,924,797	7	(7.2, 7.5)	$2,812	(2,653, 2,971)
Lung cancer	276,900	1	(1.0, 1.1)	$7,751	(6,697, 8,534)
Pneumonia	1,288,106	5	(4.8, 5.0)	$3,052	(2,886, 3,218)
Gastrointestinal illness	588,371	2	(2.2, 2.3)	$579	(522, 634)

[a] 95 percent confidence interval for percent and mean estimate

Note: Geographic weights were used to obtain unbiased nationally representative estimates for the Medicare population age 65 or older.

- Rates of illness were higher among persons age 75 or older compared with persons age 65 to 74. This difference was most notable for stroke and pneumonia, but was not statistically significant (at a 0.05 level) for lung cancer.
- Rates of illness were higher for males 65 or older than for females 65 or older (with the exception of GI illness, which had similar rates for males and females in this age group).

Using MEPS data as described above, we also estimated the average cost of self-administered prescription drugs for each condition. The number of MEPS respondents 65 or older who reported prescription medication purchases for lung cancer was too small to reliably include in this analysis; however, the numbers for the other conditions ranged from 114 respondents for stroke to 174 respondents for CLD. Based on these observations, we estimated average self-administered prescription drug costs ranging from $35 per case per year for pneumonia and GI illness to $363 per case per year for CLD.

Average Productivity Losses Due to Morbidity

Using data from the 2001 NHIS and from Grosse (2003), we estimated average morbidity-related labor productivity losses for three of the six health conditions. These results are presented in Table 3. Pneumonia and GI illness were not included in this part of the analysis because NHIS did not contain information about these illnesses. Of the 6,139 respondents age 65 or older in the NHIS sample, approximately 8 percent indicated that they were unable to work but did work previously. Estimates of the impact of having each health condition on the probability of being unable to work, controlling for age and the other conditions, were 2 percent for IHD, 4 percent for CLD, and 6 percent for stroke. These estimated probabilities are presented in Table 3.

As shown in Table 3, the average earnings for individuals 65 or older—conditional on being in the labor force—is approximately $31,000 per year (Grosse, 2003). Multiplying the illness-specific incremental probability of being unable to work by the average conditional earnings provides an estimate of the average productivity loss due to inability to work for individuals 65 or older who have the illness listed. These average annual labor productivity losses were estimated to range from $621 per person with IHD to almost $1,900 per person with stroke.

Table 3. Average labor productivity losses due to inability to work, by health condition

Health Condition	Estimated Probability of Being Unable to Work	Average Annual Earnings for Persons Age 65 or Older in Labor Force[a]	Average Labor Productivity Loss ($/Case/Year)
Chronic lung disease	4%	$31,052	$1,273
Ischemic heart disease	2%	$31,052	$621
Stroke	6%	$31,052	$1,894

[a] Source: Grosse (2003)

Note: Estimates are in 2000 dollars and for persons age 65 or older.

Using NHIS data, we also estimated household productivity losses for three of the six health conditions. We restricted the sample to all persons age 65 or older, regardless of employment status, which resulted in a sample of 3,950 older adults. Because of the discrete nature of the variable of interest for this analysis (i.e., number of days spent in bed during the year), we used a negative binomial regression with a log link to estimate the determinants of bed days.

The regression results are presented in Table 4. Controlling for sociodemographic characteristics—age, gender, education, income, work status, and race—and smoking status, the results indicate that CLD, heart disease, and stroke all have positive effects on the number of bed days experienced during the year. The effects of stroke and heart disease were found to be significant at a level < 0.01, whereas CLD was significant at a 0.06 level.

Based on the regression results, we estimated the average number of bed days attributable to each health condition for individuals age 65 or older. For each individual in the analysis sample with one of the conditions (525 with stroke, 749 with CLD, and 1,891 with IHD), we first used the regression results to estimate the difference in predicted bed days with and without the condition (i.e., calculating predicted bed days for condition=0 as compared with condition=1). We then estimated the average of these differences for each health condition subsample. The average

Table 4. Determinants of bed days: negative binomial regression results

Independent Variable: Number of Bed Days in 2002 (N=3,950)

Explanatory Variable	Coefficient
High school graduate	-0.16
Female	0.27[a]
Low income (< 200% of poverty line)	0.03
Middle income (< 500% of poverty line)	0.08
High income (≥ 500% of poverty line)	-0.52
Former smoker	0.29
Never smoked	0.01
Smoking status unknown	-25.08[b]
Non-Hispanic white	-0.25
Non-Hispanic black	0.21
Non-Hispanic other	0.41
Retired	0.79[b]
Not working but previously worked	2.21[b]
Never worked	1.30[b]
No functional limitation reported	-1.29[b]
Age (in years)	0.02
Self-report of chronic lung disease	*0.408[a]*
Self-report of heart disease	*0.73[b]*
Self-report of stroke	*0.81[b]*
Constant term	-0.65

[a] Denotes P-value based on robust standard errors < 0.10 and > 0.05.

[b] Denotes P-value based on robust standard errors < 0.05.

Notes: All explanatory variables except constant term and age are indicator/dummy variables.

Reference case is Hispanic male, high school dropout, current smoker, with income below 100% of the poverty line, who currently works and has a self-reported functional limitation, but does not have chronic lung disease, ischemic heart disease, or stroke history.

number of bed days per year associated with each illness varied from 5 days per case of CLD to 8 days per case of IHD to 14 days per case of stroke.

To estimate the indirect costs associated with each bed day, we assumed that they each resulted in 1 day of lost household productivity. Based on estimates from Grosse (2003), the average value of household productivity for individuals age 65 or older was equivalent to approximately $35 per day in 2000. This estimate is based on the average time spent in household production (e.g., housework, yard maintenance), care providing, and personal care activities, each valued at the average market wage rate. Multiplying the average number of attributable bed days for each illness by this value produced estimates of average annual household productivity losses equal to $185 per case of CLD, $278 per case of IHD, and $512 per case of stroke.

Average Productivity Losses Due to Mortality

To estimate the number of deaths in 2000 associated with each category of illness among individuals 65 or older, we applied age- and illness-specific mortality rates for 1996. In the 1998 NVSR, these rates were reported for three age groups of interest: 65 to 74, 75 to 84, and 85 or older. Assuming that the percentage of the population in each age group who died due to each illness did not change significantly from 1996 and 2000, we applied these percentages to the 2000 US population in each age group to estimate the total number of deaths associated with each illness.

These estimates are presented in Table 5. Of the six health conditions, IHD is responsible for the highest number of deaths in all three age categories, with an estimated total of almost 450,000 deaths among persons 65 or older. Deaths related to GI illness account for by far the fewest number of estimated deaths (fewer than 1,000). Total deaths associated with each of the other four health conditions were estimated to fall between 80,000 and 160,000 in 2000.

To estimate productivity losses associated with these deaths, we again used results from Grosse (2003); however, in this case we used the average present value of future earnings and household production (assuming a 5 percent discount rate) for each age group. The present value of labor and household productivity that is lost due to premature death in

Table 5. Deaths in 2000, by health condition

	Estimated Number of Deaths by Age Group		
Health Condition	65 to 74	75 to 84	85 or older
Chronic lung disease	29,869	44,651	23,806
Ischemic heart disease	97,226	169,993	176,275
Stroke	25,053	59,972	70,975
Lung cancer	56,402	47,156	12,802
Pneumonia	10,408	28,789	44,067
Gastrointestinal illness	98	212	263

2000 is approximately $190,000 for individuals age 65 to 74 and $94,000 for individuals age 75 to 84. Unfortunately, present value estimates were not available for individuals age 85 or older; therefore, total mortality-related productivity losses in this age group could not be calculated.

Aggregate Direct and Indirect Costs of Illness

Combining the estimated rates of morbidity and mortality with the average direct and indirect costs reported above, we estimated aggregate costs of illness for each of the six health conditions (see Table 6). First, to estimate the total number of cases of each illness, we applied the estimated prevalence rate from the Medicare beneficiary population age 65 or older (see Table 2) to the entire population age 65 or older in 2000 (33.5 million). The total number of deaths attributable to each illness was calculated by summing across the three age categories reported in Table 5. IHD accounts for both highest number of illnesses (more than 6 million) and deaths. Lung cancer accounts for the fewest number of illnesses (355,000), but more deaths than CLD, pneumonia, or GI illness.

Aggregate direct costs for IHD were found to be significantly higher than for the other conditions. Cases of IHD among persons age 65 or older were estimated to impose medical and drug costs of almost $20 billion per year in 2000. By comparison, CLD, stroke, and pneumonia had direct cost estimates of between $5 billion and $10 billion. Due primarily to the low rate of prevalence of lung cancer, aggregate direct costs associated with lung cancer were estimated to be less than $3 billion (although this estimate does not include drug costs), and for GI illness they were less than $0.5 billion.

Aggregate indirect costs resulting from morbidity, which were estimated for three of the six health conditions (CHD, IHD, and stroke), were found in each case to be between $5 and $6 billion per year. Due to data limitations, productivity losses could not be estimated for the other three conditions, which are less prevalent in the population age 65 or older.

Aggregate indirect costs associated with premature mortality were found to be highest for IHD (almost $35 billion), followed by lung cancer (approximately $15 billion), and CLD and stroke (both close to $10 billion). Due to data limitations, none of these estimates includes mortality-related productivity losses among persons 85 or older. The resulting underestimation of productivity losses is largest in absolute terms for IHD because more than 170,000 deaths are attributed to IHD among the population 85 or older (see Table 5) and largest in relative terms for pneumonia because more than 50 percent of pneumonia-caused deaths are from this age group.

Summing the direct and indirect cost estimates for each condition, the total estimated aggregate costs range from less than $1 billion for GI illness to almost $60 billion for IHD. The combined cost of these conditions among the 65-or-older population in 2000 was estimated to be almost $135 billion. To put these numbers in context, this is roughly one-tenth of total health expenditures in the United States in 2000.

By extrapolating these numbers using somewhat simplified assumptions, it is also possible to approximate total costs for these conditions in 2007. If we assume that (1) the prevalence and mortality

Table 6. Estimated cases and aggregate costs of illness for six health conditions among individuals age 65 or older in 2000

	Cases (in thousands)		Direct Costs ($ millions)			Indirect Costs ($ millions)			Total Cost
Health Condition	Illnesses	Deaths	Medical	Rx Drug	Subtotal	Morbidity	Mortality	Subtotal	($ millions)
Chronic lung disease	3,685.8	98.3	6,745.0	1,337.0	8,082.0	5,374.6	9,895.8	15,270.5	23,352.5
Ischemic heart disease	6,027.5	443.5	18,100.7	1,648.8	19,749.5	5,416.2	34,535.8	39,951.9	59,701.4
Stroke	2,470.5	156.0	6,947.1	371.8	7,318.9	5,945.4	10,423.7	16,369.1	23,688.0
Lung cancer	355.4	116.4	2,754.8	n.e.	2,754.8	n.e.	15,182.4	15,182.4	17,937.2
Pneumonia	1,653.3	83.3	5,045.9	57.3	5,103.2	n.e.	4,695.7	4,695.7	9,798.9
Gastrointestinal illness	755.2	0.6	437.3	26.6	463.9	n.e.	38.7	38.7	502.5

n.e. = not estimated

rates from these illnesses among the 65-and-older population were constant from 2000 to 2007 (i.e., number of illness cases and related deaths grew at the same rate as the population) and (2) that per capita medical costs grew at the same rate as average medical care prices (based on the Annual Medical Care Consumer Price Index), then total costs for these illnesses would have increased by 45.4 percent. This implies that the combined cost of these conditions among Americans age 65 or older in 2007 was roughly $196 billion.

Discussion

The population of older adults in the United States is expected to increase rapidly over the next 50 years. With this trend will come rising burdens of illness and increasing demands on the public health system. In this analysis, we examined recent evidence regarding the aggregate cost burden imposed by six major health conditions among older adults, and we estimated total direct and indirect costs of $135 billion for 2000 (in 2000 dollars). Projecting forward, this implies combined costs of roughly $196 billion in 2007 (in 2007 dollars).

Given the magnitude of the current cost burden associated with these illnesses and the expectation that these costs will increase significantly as the US population ages, it is particularly important to consider strategies for preventing these illnesses. Key among these strategies are policies to improve environmental health (one of the top 10 high-priority public health issues identified in Healthy People 2010). All of the six health conditions are known to be associated, at least in part, with exposure to environmental pollutants, and older adults are often more susceptible than younger adults to environmental exposures. Therefore, improving air and water quality can play an important role in preventing and limiting the cost burden associated with these conditions in the population age 65 or older.

The cost estimates in this paper cannot be interpreted as those specifically attributable to environmental exposures. Unfortunately, the science and empirical evidence regarding the epidemiological links between environmental exposures and these health outcomes are not sufficiently advanced to estimate the environmentally attributable fraction (EAF) with much certainty for most of these conditions. For example, in an often-cited study, Doll and Peto (1981) estimate that 1 to 5 percent of all cancers in the United States are caused by environmental pollution. If we apply this fraction to our estimates for lung cancer, it would seem that environmentally related costs for lung cancer in older adults would be at most $1 billion; however, there is considerable uncertainty regarding the applicability of the Doll and Peto EAF to lung cancer in older adults.

Similarly, studies by Payment et al. (1991, 1997) suggest that roughly one-third of GI illnesses in Canada are related to drinking water. Assuming similar rates for older adults in the United States would imply that the costs of GI illness from waterborne exposures were between $100 and $200 million in 2000. These estimates are best interpreted as rough approximations of environmentally attributable costs of illness until more reliable EAF estimates can be developed for these conditions.

For several reasons, the aggregate COI values reported in this paper are also best interpreted as lower-bound estimates of the total annual societal losses associated with the illnesses studied. First, a well-recognized limitation of the COI approach is that it cannot capture all of the relevant losses associated with illness, and for illnesses affecting older adults, this limitation is particularly important. The COI approach does not measure the (negative) value of pain and suffering for those directly or indirectly affected by the condition, nor does it capture the value of lost leisure time. Moreover, in cases where the conditions lead to premature mortality, the COI approach cannot measure the full value to society of avoiding those deaths.

What the COI method does is measure the portion of economic losses that are most directly observable from available data on medical expenditures, labor market participation and earnings, and household production activities. These measurable losses represent a true burden on society, but they do not tell the entire story. For older adults who, on average, spend relatively less time in paid-labor activities and more time in leisure-related activities, unmeasured losses are likely to be particularly large.

Second, due to data limitations, this analysis does not include certain direct and indirect costs, such as nursing home costs, reductions in work days (as opposed to leaving the workforce), and mortality-related productivity losses for individuals age 85 or older. These omitted costs are expected to be relatively small compared with the measured costs, but unfortunately they could not be reliably measured.

Third, estimating condition-specific medical costs based on Medicare claims data is complicated by the fact that inpatient services are often reported with more than one diagnosis. To estimate inpatient costs, we used a conservative approach that is likely to underestimate these costs. We only included costs for the condition of interest listed as the primary diagnosis. This approach includes some costs that may be associated with comorbid conditions, but it omits a portion of the costs attributable to a secondary condition.

Finally, the estimates of productivity losses due to morbidity are based on self-reported diagnoses in the NHIS. These self-reports are less precise than the ICD-9 diagnosis codes used to estimate direct medical costs; therefore, the indirect cost estimates contain this additional source of uncertainty.

One caveat to this lower bound interpretation of our COI estimates relates to how the estimates were extended to the entire population of older Americans. Because Medicare fee-for-service (FFS) covered roughly 75 percent of the population age 65 and older in 2000, the estimates based on Medicare claims data were extrapolated to the remaining 25 percent of the population. This extrapolation is likely to overestimate prevalence in the noninstitutionalized non-FFS population because they are on average somewhat younger and in somewhat better health than those in Medicare FFS.

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