Economic Costs of Diabetes in the U.S. in 2007

AMERICAN DIABETES ASSOCIATION

OBJECTIVE — The prevalence of diabetes continues to grow, with the number of people in the U.S. with diagnosed diabetes now reaching 17.5 million. The objectives of this study are to quantify the economic burden of diabetes caused by increased health resource use and lost productivity, and to provide a detailed breakdown of the costs attributed to diabetes.

RESEARCH DESIGN AND METHODS — This study uses a prevalence-based approach that combines the demographics of the population in 2007 with diabetes prevalence rates and other epidemiological data, health care costs, and economic data into a Cost of Diabetes Model. Health resource use and associated medical costs are analyzed by age, sex, type of medical condition, and health resource category. Data sources include national surveys and claims databases, as well as a proprietary database that contains annual medical claims for 16.3 million people in 2006.

RESULTS — The total estimated cost of diabetes in 2007 is $174 billion, including $116 billion in excess medical expenditures and $58 billion in reduced national productivity. Medical costs attributed to diabetes include $27 billion for care to directly treat diabetes, $58 billion to treat the portion of diabetes-related chronic complications that are attributed to diabetes, and $31 billon in excess general medical costs. The largest components of medical expenditures attributed to diabetes are hospital inpatient care (50% of total cost), diabetes medication and supplies (12%), retail prescriptions to treat complications of diabetes (11%), and physician office visits (9%). People with diagnosed diabetes incur average expenditures of $11,744 per year, of which $6,649 is attributed to diabetes. People with diagnosed diabetes, on average, have medical expenditures that are ~2.3 times higher than what expenditures would be in the absence of diabetes. For the cost categories analyzed, ~$1 in $5 health care dollars in the U.S. is spent caring for someone with diagnosed diabetes, while ~$1 in $10 health care dollars is attributed to diabetes. Indirect costs include increased absenteeism ($2.6 billion) and reduced productivity while at work ($20.0 billion) for the employed population, reduced productivity for those not in the labor force ($0.8 billion), unemployment from disease-related disability ($7.9 billion), and lost productive capacity due to early mortality ($26.9 billion).

CONCLUSIONS — The actual national burden of diabetes is likely to exceed the $174 billion estimate because it omits the social cost of intangibles such as pain and suffering, care provided by nonpaid caregivers, excess medical costs associated with undiagnosed diabetes, and diabetes-attributed costs for health care expenditures categories omitted from this study. Omitted from this analysis are expenditure categories such as health care system administrative costs, over-the-counter medications, clinician training programs, and research and infrastructure development. The burden of diabetes is imposed on all sectors of society—higher insurance premiums paid by employees and employers, reduced earnings through productivity loss, and reduced overall quality of life for people with diabetes and their families and friends.

Diabetes Care 31:596–615, 2008

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Abbreviations: ADA, American Diabetes Association; BLS, Bureau of Labor Statistics; CDC, Centers for Disease Control and Prevention; CMS, Centers for Medicare and Medicaid Services; MEPS, Medical Expenditure Panel Survey; NAMCS, National Ambulatory Medical Care Survey; NHAMCS, National Hospital Ambulatory Medical Care Survey; NHANES, National Health and Nutrition Examination Survey; NHHCS, National Home and Hospice Care Survey; NHIS, National Health Interview Survey; NIS, Nationwide Inpatient Sample; NNHS, National Nursing Home Survey; PVFP, present value of future productivity; SSI, Social Security Insurance.

DOI: 10.2337/dc08-9017

See accompanying editorial, p. 624.

Previous research highlighting the high cost of diabetes in terms of its economic burden and cost to society has been helpful in health policy debates and decision-making (1–4). Knowledge of the costs of diabetes improves understanding of the importance of addressing health care and prevention issues associated with diabetes. This 2008 update of the 2003 American Diabetes Association (ADA) study (3) encompasses the continued growth in diabetes prevalence; changing practices, technology, and cost to treat people with diabetes; and improvements in the data sources and methods to estimate the economic and social burden of diabetes.

RESEARCH DESIGN AND METHODS

— This study combines research findings from the medical, public health, and economics literature with new empirical analysis to provide detailed information on the cost of diabetes by demographic group, health care delivery setting, medical conditions treated, and cost component. Major data sources analyzed and referenced in this article include the National Health Interview Survey (NHIS), National Health and Nutrition Examination Survey (NHANES), Medical Expenditure Panel Survey (MEPS), Ingenix MCURE database, Nationwide Inpatient Sample (NIS), National Ambulatory Medical Care Survey (NAMCS), National Hospital Ambulatory Medical Care Survey (NHAMCS), National Nursing Home Survey (NNHS), and National Home and Hospice Care Survey (NHHCS). A brief description of how these data sources are used and their respective strengths and limitations for estimating the cost of diabetes is provided in an APPENDIX.

The approach used to estimate medical costs largely follows the prevalence-based approach used in ADA's two most recent cost of diabetes studies (1,3). All estimates are extrapolated to the U.S. population in 2007 and reported in year 2007 dollars. Cost data from earlier years were inflated to year 2007 dollars using the appropriate components of the medical consumer price index (the nursing facility index, the hospital inpatient index, the pharmaceutical index, etc.).

Estimating the size of the population with diabetes

We estimate that approximately 17.5 million people in the U.S. have been diagnosed with diabetes. The estimated prevalence of diagnosed diabetes is substantially higher than the 2002 estimate of 12.1 million from ADA's previous cost study, reflecting the growth and aging of the population, the rising prevalence of overweight and obesity, improvements in detection, decreasing mortality, and growth in minority populations with higher rates of diabetes (5,6). Comparison of the 2007 estimate to the 2002 estimate suggests that the net number of people with diagnosed diabetes is growing by ~1 million people per year. These estimates are similar to those produced by CDC and other published estimates (7).

Analysis of the 2004 through 2006 NHIS suggests that 5.6% of the noninstitutionalized population in the U.S. has diagnosed diabetes. This estimate is based on respondents answering "yes" to the question of whether they have ever been told by a physician they have diabetes (excluding gestational diabetes and "borderline" diabetes). Previous research has found that self-report of physician's diagnosis of diabetes is accurate (8). We combined NHIS files for years 2004 through 2006 to increase sample size (n = 121,215 people) so that separate prevalence rates could be estimated by eight age-groups (<18, 18–34, 35–44, 45–54, 55–59, 60–64, 65–69, 70+), sex, and race/ethnicity (non-Hispanic white, non-Hispanic black, non-Hispanic other, and Hispanic). Analysis of the 2004 NNHS (n = 13,502 people) finds that ~24% of the estimated 1.5 million long-term residents of nursing facilities have been diagnosed with diabetes. We assume that the institutionalized population other than nursing homes (e.g., prisons) and the noncivilian population have diabetes prevalence rates similar to the noninstitutionalized population controlling for demographics.

Analysis using NHANES suggests that 2.2% of the noninstitutionalized U.S. population has undiagnosed diabetes. We combined three NHANES files (1999–2000, 2001–2002, and 2003–2004) to increase sample size (n = 29,608 people) to calculate prevalence by demographic. All cost estimates presented in this article are based on the population with diagnosed diabetes. Additional research is needed to determine the extent to which people with undiagnosed diabetes incur excess medical costs and lost productivity associated with their diabetes, but if this population incurs even modest disease-related costs, the overall economic burden of diabetes could be substantially higher than our estimates.

Combining prevalence rates for the noninstitutionalized population with estimates for the long-term resident population in nursing facilities, and applying rates to U.S. Census Bureau population estimates for 2007 by age-group, sex, and race/ethnicity, suggests that over 24 million people in the U.S. have diabetes (Table 1). Diabetes prevalence increases with age (type 2 diabetes). Blacks and Hispanics have higher diabetes prevalence within each age-group, but because the age distribution of the groups is toward a younger population than the age distribution of the nation as a whole, the higher overall prevalence of these groups is masked somewhat. Approximately 2 million people with diabetes have no medical insurance—with one in three of these uninsured people undiagnosed. Approximately half of all people with diabetes have medical insurance through the government—primarily through Medicare, as an estimated 8.5 million people with diabetes are age 65 or older.

Health resource use attributed to diabetes

People with diabetes have higher use of hospital inpatient care, outpatient and physician office visits, emergency visits, nursing facility stays, home health visits, visits with other health professionals, and prescription drug and medical supply use than their peers without diabetes. In addition to health care services to directly treat diabetes, people with diabetes are at increased risk for neurological symptoms, peripheral vascular disease, cardiovascular disease, renal complications, endocrine/metabolic complications, ophthalmic complications, and other complications (see APPENDIX for a comprehensive list of comorbidities) (3,9–15). A portion of health care expenditures for these chronic conditions, therefore, should be attributed to diabetes. We use the term "attributed" to mean the difference in health care use for people with diabetes compared to what their health care use would be in the absence of diabetes—estimating the excess health care use that is theoretically due to (or caused by) diabetes and its complications. We use primary diagnosis code (ICD-9) to classify medical claims data by medical condition.

The approach used to quantify the increase in health resource use associated with diabetes was influenced by four data limitations: *1*) absence of a single data source for all estimates, *2*) small sample size in some data sources, *3*) correlation of both diabetes and its comorbidities with other factors such as age and obesity, and *4*) underreporting of diabetes as a comorbidity. We address these limitations and their implications below.

No single data source. There is no readily available data source that is ideal for estimating the increased use of health care services associated with diabetes. The MEPS is the most complete source in that it contains medical claims data, diabetes status, patient demographic, and other patient information such as health-seeking behavior. The MEPS, unfortunately, has insufficient sample size to analyze health resource use and expenditures for many chronic complications of diabetes by demographic group and health care delivery setting. Also, the MEPS sampling frame excludes the institutionalized population, including long-term residents of nursing facilities who have high prevalence of diabetes and are high users of health care resources. For each of the major health care delivery settings, we use a nationally representative data file: NAMCS for physician office visits, NHAMCS for hospital outpatient and emergency visits, NHHCS for hospice care; NIS for hospital inpatient care, and NNHS for nursing facility care. We use MEPS to estimate health resource use and unit costs for a variety of health resources.

Small sample size. For some data sources we combined several years of data to increase sample size. Large samples were needed to produce reliable estimates of health resource use and cost by age-group and sex. (While race and ethnicity were used to estimate the number of people with diabetes, sample sizes were generally insufficient to calculate separate health resource use and unit cost patterns by race and ethnicity).

Correlation of both diabetes and its comorbidities with other factors. The prevalence of type 2 diabetes increases with age and factors related to behavior (e.g., diet and obesity), as does the risk for hypertension and other medical conditions. Not controlling for factors that increase risk of both diabetes and other medical conditions will overestimate the health resource use attributed to diabetes.

Table 1—*U.S. population (in thousands) and percent of U.S. population with diabetes, 2007*

	Total U.S. population	With diagnosed diabetes		With undiagnosed diabetes		Total with diabetes*	
Total population*	301,736	17,486	5.8%	6,640	2.2%	24,126	8.0%
Race/ethnicity							
Non-Hispanic white	199,091	11,403	5.7%	4,520	2.3%	15,923	8.0%
Non-Hispanic black	37,002	2,775	7.5%	699	1.9%	3,474	9.4%
Non-Hispanic other	20,101	1,076	5.4%	317	1.6%	1,393	6.9%
Hispanic	45,541	2,231	4.9%	1,104	2.4%	3,335	7.3%
Sex							
Male	148,744	8,543	5.7%	3,113	2.1%	11,656	7.8%
Female	152,992	8,943	5.8%	3,528	2.3%	12,471	8.2%
Age (years)							
<18	73,878	157	0.2%	35	0.1%	192	0.3%
18–34	70,373	964	1.4%	669	1.0%	1,633	2.3%
35–44	43,356	1,686	3.9%	1,174	2.7%	2,860	6.6%
45–54	43,838	3,443	7.9%	1,327	3.0%	4,770	10.9%
55–59	18,235	2,307	12.7%	756	4.1%	3,063	16.8%
60–64	14,323	2,261	15.8%	775	5.4%	3,036	21.2%
65–69	10,690	1,879	17.6%	850	8.0%	2,729	25.5%
≥70	27,042	4,788	17.7%	1,055	3.9%	5,843	21.6%
Insurance							
Private	169,886	7,057	4.2%	3,018	1.8%	10,075	5.9%
Government	91,794	8,997	9.8%	2,891	3.1%	11,888	13.0%
Uninsured	40,055	1,432	3.6%	731	1.8%	2,163	5.4%

Source: Combined information from the 2004–2006 NHIS, 2004 NNHS, 1999–2004 NHANES, and the U.S. Census Bureau population estimates for 2007. *Numbers do not necessarily sum to totals because of rounding.

Underreporting of diabetes as a comorbidity. National data files for individual health delivery settings are based on administrative records and use admissions or visits as the unit of analysis. Although diabetes is sometimes listed as a primary or secondary condition in the diagnosis codes, there is no way to link records across visits, admissions, and settings to create a profile that identifies all patients with diabetes.

Because of the above limitations we estimate health resource use attributed to diabetes using one of two approaches for each cost component. For some cost components we employ an attributed risk methodology using population etiological fractions similar to the approach used in previous ADA studies and in the cost of illness literature (16). For other cost components (home health, pharmaceuticals, medical supplies, and podiatric services) we use a simple comparison of annual per capita health resource use for people with and without diabetes controlling for age and sex. Both approaches are equivalent under a reasonable set of assumptions, but the second approach cannot be used with some of the data sources analyzed because of underreporting of diabetes as a comorbidity.

Health resource use associated with diabetes for three major health service delivery settings (H)—hospital inpatient, emergency departments, and other ambulatory visits—is estimated by combining etiological fractions (ε) with total projected U.S. health service use (U) in 2007 as follows:

$$\text{Attributed health resource use}_{H} = \sum_{\text{age}}\sum_{\text{sex}}\sum_{\substack{\text{medical}\\\text{condition}}} \varepsilon_{H,a,s,c} \times U_{H,a,s,c}$$

The etiological fraction for each age-group (a), sex (s), and medical condition (c) is calculated using the diagnosed diabetes prevalence rate (P) and the rate ratio (R):

$$\varepsilon_{H,a,s,c} = \frac{P_{a,s} \times (R_{H,a,s,c} - 1)}{P_{a,s} \times (R_{H,a,s,c} - 1) + 1}$$

The rate ratio for hospital inpatient days, emergency visits, and other ambulatory visits (physician office visits combined with hospital outpatient visits) represents how annual per capita health service use for the population with diabetes compares with the population without diabetes:

$$R_{H,a,s,c} = \frac{\text{annual per capita use for people with diabetes}_{a,s,c}}{\text{annual per capita use for people without diabetes}_{a,s,c}}$$

To help mitigate bias caused by correlation between diabetes, the chronic medical conditions associated with diabetes, and other factors, we use age-sex-setting–specific etiological fractions for each medical condition. The primary data source for calculating etiological fractions is the Ingenix MCURE database. This database contains a complete set of medical claims for over 16.3 million people in 2006. These claims primarily come from large employers, but the database also contains some Medicare claims. Despite the overrepresentation of the privately insured population, the MCURE database proves to be an extremely powerful tool because it allows us to link patient records during the year and across health delivery settings. Also, due to its sheer size, it allows us to generate age-sex-setting–specific relative rate ratios for each medical condition that are more stable than rates estimated using the MEPS.

Unlike the MEPS, the MCURE database does not contain information on underlying health status and unhealthy

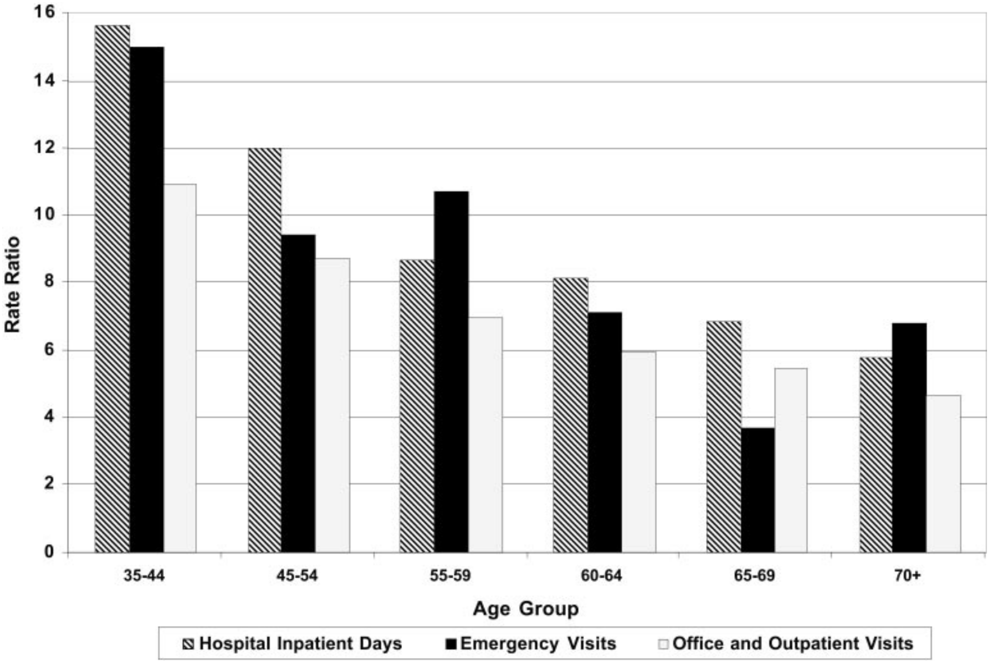

Figure 1—*Rate of health resource use by men with diabetes relative to men without diabetes for visits/days where heart failure is the primary diagnosis.*

lifestyle that could contribute to both diabetes and other health problems. For the 10 medical conditions that are the largest contributors to the overall cost of diabetes, we estimated a series of multivariate Poisson regressions, using data from the MEPS, to determine the extent to which controlling only for age and sex might bias the rate ratios. We estimated two regressions: a naïve and a full model. The dependent variable for each regression is annual health resource use. Separate regressions were run using hospital inpatient days, emergency visits, and ambulatory visits (physician office and hospital outpatient visits combined) as the dependent variable. The naïve model contains only a flag variable (1 = yes, 0 = no) for diabetes and variables to control for age and sex. The full model contains the variables in the naïve model, and also controls for education level, income, marital status, medical insurance status, and race and ethnicity. The rate ratio coefficients for the diabetes flag variable in the naïve and full models are then compared. We found statistically significant overestimates in the rate ratio when using the naïve model for three condition categories: general medical conditions that are not identified as chronic conditions associated with diabetes, hypertension, and renal failure (a major complication of both diabetes and hypertension). Diabetes and hypertension often coexist, with obesity being a contributing factor to both health problems. To remedy the attributed rate overestimation for these three categories, we scale the MCURE rate ratios using the regression results from the MEPS analysis by applying the following scalar:

$$\text{Scalar}_{\text{MEPS}} = \frac{\log(\text{RR}_{\text{Full}})}{\log(\text{RR}_{\text{Naive}})} \tag{4}$$

$$\text{RR}_{\text{Final}} = (\text{RR}_{\text{MCURE}})^{\text{Scalar}_{\text{MEPS}}}$$

For general medical conditions, health care utilization is scaled down by 7% for emergency visits, hospital outpatient visits, and physician office visits. Inpatient days are scaled down by 48%. Visits where hypertension is the primary diagnosis were scaled down by 33, 35, and 34% for emergency visits, hospital outpatient visits, and physician office visits, respectively. Visits where renal failure is the primary diagnosis were scaled down by 8, 52, and 47% for emergency visits, hospital outpatient visits, and physician office visits.

We did not use the rate ratios from the MEPS analysis directly because the MCURE data have a much larger sample size and the estimates are more stable than estimates generated from the MEPS. Analysis of the MEPS found no consistent evidence that rate ratios from the naïve model (which are used to calculate etiological fractions) are biased for the other medical conditions modeled.

The prevalence of diabetes and comorbidities, and the rate at which people with diabetes use more comorbidity-related health care services, varies by demographic and by health care delivery setting. The rate ratios decline with age for most medical conditions and are generally higher for hospital inpatient days as compared to ambulatory visits. For illustration, we use male patients with heart failure as their primary diagnosis for the visit or admission (Fig. 1). Men with diabetes use significantly more health resources than men of similar age who do not have diabetes. For example, among men age 60–64, those with diabetes have eight times the number of hospital inpatient days, seven times the number of emergency visits, and six times the number of physician office and outpatient visits for heart failure compared to their peers without diabetes.

We use an attributable risk approach to estimate the portion of nursing facility use attributed to diabetes. Two analyses were conducted using the 2004 NNHS. First, we compared the prevalence of diabetes among nursing facility residents with the prevalence of diabetes among the overall population in the same age-sex group. Second, we analyzed the primary diagnosis codes associated with the nursing facility admission, attributing to dia-

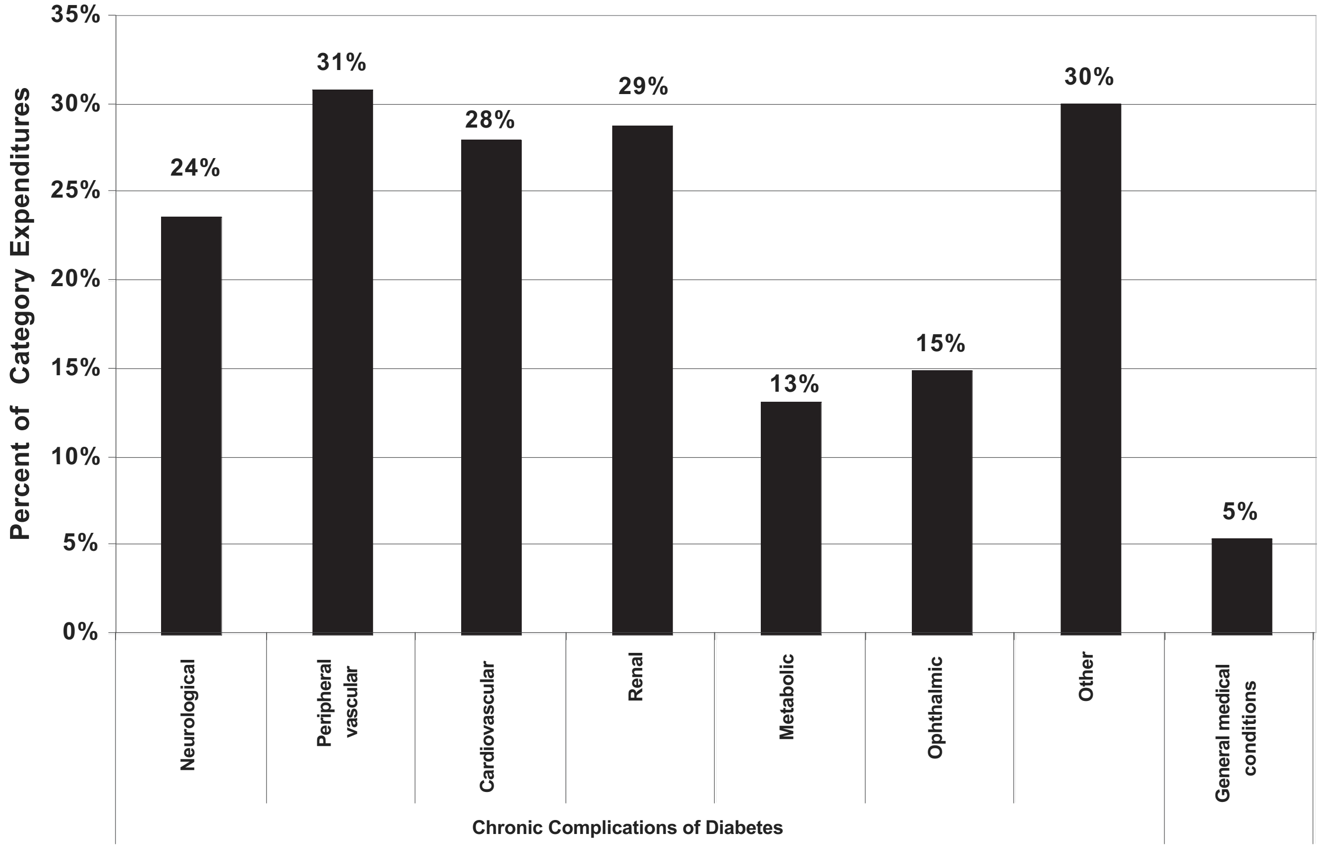

Figure 2—*Percent of category expenditures associated with diabetes. See* APPENDIX *for diagnosis codes for each category of complications.*

betes 100% of the admissions where diabetes is the primary diagnosis. Both approaches give similar results, so we use the first approach as it is more consistent with the approach used for other settings.

Estimates of disease-related health resource use for home health services, ambulance services, podiatric services, pharmaceuticals, diabetes supplies, and other medical supplies were based on the MEPS. For these categories we calculated the average age-sex–specific annual expenditures for people with diabetes compared to people without diabetes. Multiplying estimates of per capita health resource use attributed to diabetes by the number of people with diabetes produced national estimates of health resource use attributed to diabetes. Although we use the NIS to estimate inpatient care attributed to diabetes, the NIS contains only hospital costs (and not the cost for professional services by physicians who bill separate from the hospital). Therefore, we use the MEPS to calculate use of physician services per inpatient day by medical condition.

Summarizing the attributed health resource use across age, sex, health delivery setting, and detailed comorbidities, and comparing this number to total health resource use, Fig. 2 summarizes the proportion of medical expenditures for each condition attributed to diabetes. The etiological fractions, however, vary substantially by demographic and setting.

Differences between these overall etiological fractions and those used in the 2003 study are due primarily to three factors:

One, the etiological fractions used in the 2003 study were estimated using odd ratios from logistic regression rather than relative rate ratios. While odds ratios are good proxies for the relative rate ratios for comorbidities with low prevalence, for comorbidities with high prevalence (e.g., general medical conditions) the etiological fractions will be overestimated.

Two, etiological fractions used in this study are based on a data source with much larger sample sizes, so we were able to compute age-sex-setting–specific relative rate ratios for each comorbidity. For hospital inpatient, emergency, and other (office and hospital outpatient) ambulatory care settings, we calculate etiological fractions for each of the eight age-groups modeled (whereas the 2003 study calculated fractions for three larger age-groups). Setting-specific etiological fractions provide more precise estimates for attributing health resource use because people with diabetes might have both increased incidence of use (e.g., more hospital admissions) and increased intensity of use (e.g., longer average length of hospital stay). Compared to the 2003 study, use of setting-specific etiological fractions increases the estimate of hospital inpatient costs attributed to diabetes and lowers the estimate of ambulatory costs attributed to diabetes.

Three, for hypertension, renal failure, and general medical conditions, we adjust the relative rate ratios to take into account that controlling only for age and sex will overestimate the impact of diabetes on prevalence of these three categories of medical conditions. Both hypertension and diabetes are correlated with obesity, with obesity directly increasing the risk of hypertension independently of the increased risk via diabetes. Likewise, the clinical relationship between diabetes and renal failure, a comorbidity of both hypertension and diabetes, might be overestimated if only controlling for age and sex.

For general medical conditions, the hypothesis is that diabetes increases use

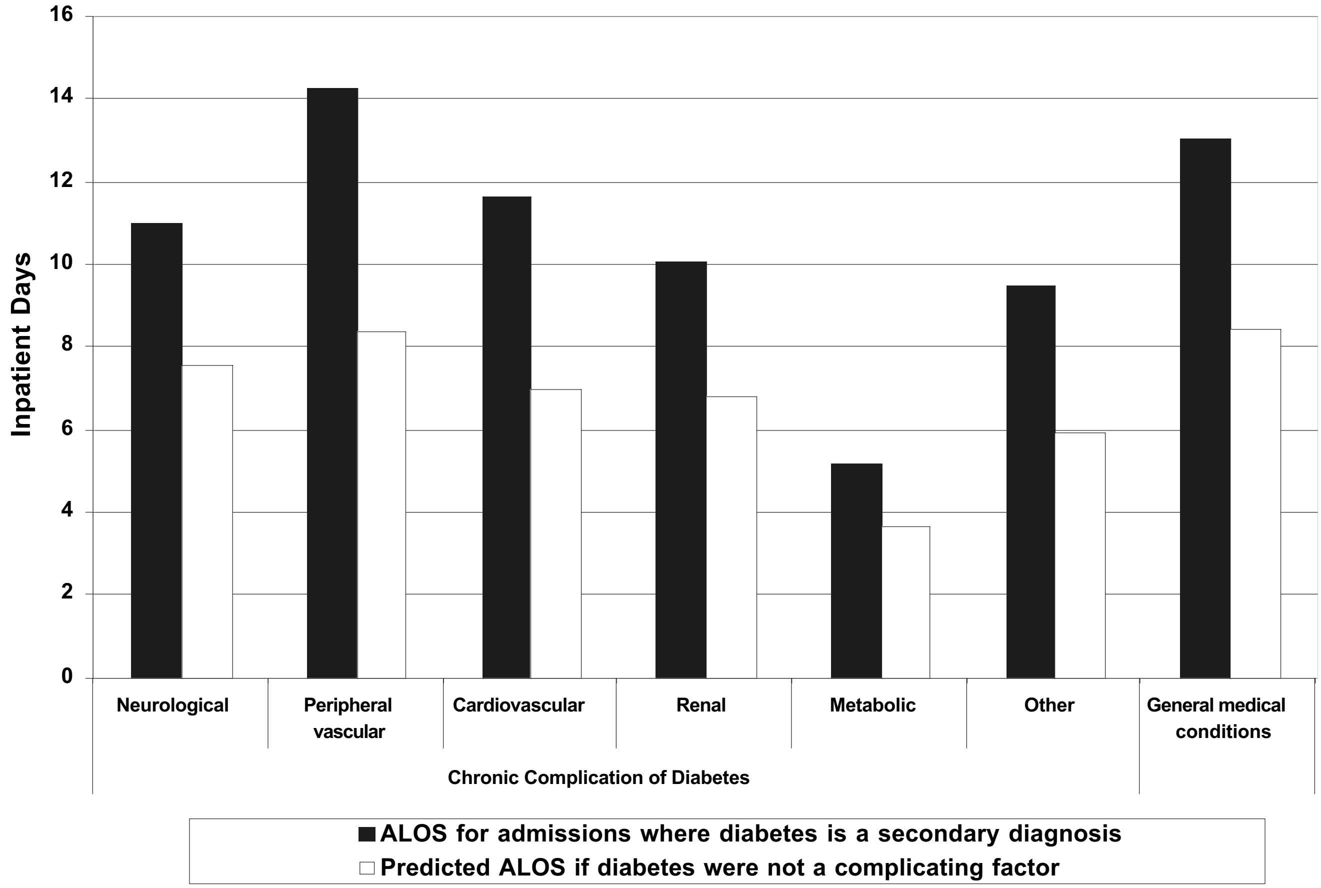

Figure 3—*Average hospital length of stay (ALOS) when diabetes is a secondary diagnosis.*

of health care services because diabetes has a compounding influence. Analysis of the MCURE database finds that people with diabetes are slightly more likely to be admitted to the hospital for general medical conditions, controlling for age and sex, but they are also more likely to have a longer length of stay. Analysis of the 2005 NIS finds that hospital admissions where diabetes is listed as a secondary diagnosis have longer average length of stay than would occur if diabetes were not a complicating factor. Using multivariate ordinary least-squares regression (results not shown) with discharge-level data, we estimate the relationship between length of stay and having diabetes listed as a secondary diagnosis code, controlling for the average length of stay associated with the primary diagnosis, patient age and sex, and insurance status. We use the regression findings to predict length of stay for the admissions where diabetes is a secondary diagnosis, both with and in the absence of diabetes as a complicating factor (Fig. 3). The results, while not used to calculate the cost estimates presented, illustrate that diabetes contributes to longer length of stay (in addition to the impact of diabetes on increased risk of admission). For example, patients admitted for general medical conditions that are not identified comorbidities of diabetes had an average length of stay of 13 days when diabetes was listed as a secondary complication. The multivariate regression results suggest that if diabetes were not a complication, the length of stay would have been 4 days shorter, indicating that diabetes increased the length of stay by nearly 50%.

Estimates of health resource use attributed to diabetes are combined with estimates of the average medical cost per event to compute total medical costs attributed to diabetes. Cost data come primarily from the MEPS and the NIS, with some cost estimates obtained from published sources. For many cost components, we use medical cost-per-event estimates specific to the medical condition modeled.

Using the 2003–2005 combined MEPS files, we calculate the average cost per visit for each category of medical conditions for hospital emergency and outpatient visits, as well as for visits to physician offices (Table 2). In addition, we use the MEPS to calculate the average cost per prescription filled (Table 3). We analyzed the NHIS to determine the percent of people with diabetes (by age and sex) who use insulin and oral medications. We combined this information with MEPS data on the annual cost for insulin and oral medications for each person who uses these items. Other cost components calculated on an annual per capita basis include home health services, ambulance services, podiatric services, diabetes supplies, and all other medical supplies. For these categories we calculated the average age-sex–specific annual cost per person with and without diabetes. The excess in cost for people with diabetes is considered to be attributed to diabetes.

We use the NIS, rather than the MEPS, to estimate hospital costs associated with inpatient services received. Hospital-specific cost-to-charge ratios are available for the 2004 NIS and were used to calculate average cost per hospital day. The NIS is a much larger sample than the MEPS, which is particularly important for

Table 2—*Average cost ($) per medical event, by complication, 2007*

Medical event	Diabetes	Chronic complications							General medical
		Neurological	Peripheral vascular	Cardiovascular	Renal	Metabolic	Ophthalmic	Other	
Hospital inpatient day*†	1,853	2,363	2,226	3,225	1,872	2,156	2,408	1,718	2,188
Outpatient visit†	331	487	714	577	592	295	753	403	745
Emergency visit†	696	798	811	680	576	594	1,613	636	701
Physician office visit†	132	160	199	151	169	118	182	162	162

Source: *2004 NIS; †2003–2005 MEPS. Estimates adjusted to 2007 dollars.

estimating the average cost for medical conditions that can have large variance in hospital cost per day. In addition, the NIS contains five-digit diagnosis codes necessary for identifying many comorbidities of diabetes, whereas the public use files for the MEPS contain only three-digit diagnosis codes. However, costs captured by the NIS do not include physician costs so we use the MEPS to calculate the physician services cost per inpatient day by medical condition. Combining physician costs from the MEPS and facility costs from the NIS yields the cost-per-inpatient-day estimates in Table 2. Over-the-counter medications are excluded from the analysis as there is no information to determine whether people with diabetes have higher rates of use than people without diabetes.

Productivity foregone

The indirect costs associated with many diseases are substantial, and for populations such as working-age adults, the lost productivity costs to society can exceed disease-related medical costs (17–20). The indirect costs associated with diabetes include health-related days absent from work, reduced job performance due to health problems, reduced labor force participation and reduced earnings capacity from permanent disabilities, and lost productivity from premature mortality.

Lost productivity among adults with diabetes in the labor force or who are prevented from working by disability directly affects the nation's economic output as measured by the gross domestic product. Productivity loss also occurs among the population not in the labor force and includes the impact of health problems on the ability to provide services in the home and volunteer work.

To estimate the value of lost productivity, we calculate the number of full-time equivalent workdays lost due to increased absenteeism and reduced performance at work (presenteeism), and the years of lost work due to chronic disability and premature mortality. The productivity loss for people employed in the workforce is calculated by combining age-sex–specific estimates of workforce participation rates (estimated from the 2006 NHIS), average earnings (from the Bureau of Labor Statistics), and the size of the population with diabetes.

The cost of lost productivity is difficult to quantify, especially for those not in the labor force. Some studies have valued the time of those not in the labor force using minimum wage (i.e., to reflect the cost to hire help in the home), but this likely underestimates the value of productivity for nonretired individuals who choose not to be in the workforce. On the other hand, using the average earnings of those in the labor force will likely overestimate the value of productivity for those not in the labor force as individuals in the labor force tend to have higher education levels (and by assumption greater productivity, on average). We use 75% of the average earnings for people in the labor force as a proxy for the value of productivity for people under age 65 not in the labor force. We conduct sensitivity analysis to determine how this 75% assumption affects the overall cost estimates.

Absenteeism and presenteeism

People with diabetes have higher rates of health-related absenteeism than their peers without diabetes (21–23). A synthesis of the published literature found that people with diabetes have health-related absenteeism rate that was, on average, 0.8% higher than people without diabetes (equivalent to 1.9 workdays per worker with diabetes per year). Estimates vary

Table 3—*Average cost per medical event, 2007*

Medical event	Unit cost ($)
Prescription (excluding insulin and oral agents)*	72
Oral agents (per user per year)*	697
Insulin (per insulin user per year)*	751
Diabetic supplies (per person with diabetes per year)*, [a]	102
Home health visits (cost per person per day of use)*, [a]	204
Hospice care day†	147
Nursing facility day‡ (excluding food and rent) [b]	131 (120)
Other medical supplies (excess cost per person with diabetes per year)*, [a]	
Glasses/contacts	5.57
Ambulance services	5.92
Orthopedic items	5.52
Hearing devices	9.02
Prosthesis	4.09
Bathroom aids	1.52
Medical equipment	7.09
Disposable supplies	10.85
Alterations/modifications	7.10
Other	0.14

Source: *2003–2005 MEPS; †Hospice Association of America 2006. ‡Average of cost for semi-private room and private room per the Genworth Financial 2007 Cost of Care Survey (http://longtermcare.genworth.com/comweb/consumer/pdfs/long_term_care/Cost_Of_Care_Survey.pdf). Note: [a]Cost estimate varies by age and sex. [b]An estimated 38% of the cost per day in a nursing home is for food and rent. For long-term residents, we exclude from the cost estimates expenses for room and board that would still have been incurred if the person were living at home. Estimates are adjusted to 2007 dollars.

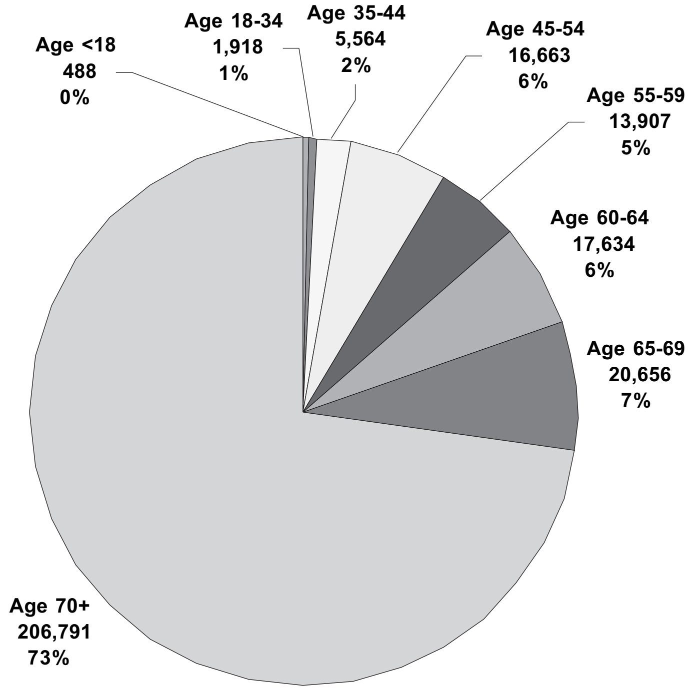

Figure 4—*Age distribution of deaths associated with diabetes.*

across the four studies reviewed—ranging from 0.5% to 1.2% (23). Analysis of the 2006 NHIS finds that self-reported workdays absent is higher for people with diabetes, with part of this increase associated with higher rates of hypertension among people with diabetes. After adjusting for the effect of hypertension not attributed to diabetes, we calculate that the average lost number of workdays per employed person per year is 1.8, ranging from a low of 0.9 days for the population aged 18–34 years to a high of 2.5 days for the population ages 45–54 years.

Reduced productivity at work generally is measured using surveys, asking workers, for example, if during the past week they have experienced a loss of concentration, had to repeat a job, worked more slowly than usual, been fatigued at work, or were unable to do their work. These surveys often ask for a self-assessment of the degree to which work productivity suffered on these days. Findings from multiple studies suggest that people with diabetes have higher rates of reduced work productivity than do their peers without diabetes, although such studies lack the rigor of a clinically controlled trial (23–26).

A synthesis of the literature found that annual health-related at work productivity loss associated with diabetes is 9.2%, although the rate from the four studies reviewed ranged from 1.9% to 21.8% (23). These estimates do not simultaneously control for other factors that might be correlated with diabetes, and these same studies find that hypertension is associated with an average 6.9% decline in productivity. After adjusting the diabetes presenteeism estimate for the portion of hypertension not attributed to diabetes, we calculate a productivity loss associated with diabetes of 6.6% (or 14 days per worker with diabetes per year). The effect of lost productivity on the job due to chronic illness, such as diabetes, could be reflected in the wage of the afflicted worker rather than a cost to the employer. Our calculation of lost productivity reflects the cost to society without differentiating between the cost to the afflicted worker and the cost to the employer.

Disability

Diabetes increases the likelihood that chronic disability prevents working, or in some cases limits employment opportunities reducing earnings (27–30). Between 60 and 70% of people with diabetes have a form of neuropathy, such as sensory impairment or pain in the foot or hands, and about 82,000 lower-limb amputations are performed each year on people with diabetes (31). The cost estimates for diabetes-related disability are based on estimated disability cases that are sufficient to result in social security supplemental insurance (SSI) payments—a conservative assumption. We identify these cases using the 2004–2006 NHIS, and use multivariate logistic regression (results not shown) to compare rates of disability by diagnosed diabetes status controlling for other factors hypothesized to be correlated with the likelihood of receiving disability payments. The rate of people unable to work because of diabetes-related disability increases with age.

The cost per person not working per day is calculated using average daily earnings for those working. SSI payments are not included in the cost estimate, as this is considered a transfer payment (i.e., a cost to one person is a benefit to another person).

Mortality

Diabetes has become one of the leading causes of death in the U.S. Death certificates underreport deaths attributed to diabetes because diabetes is often a secondary cause of death. We combine CDC data for 2004 on cause of death, etiological fractions derived from several sources, and estimates of total diabetes cases in 2004 by age and sex to estimate mortality rates for diabetes-attributed deaths from renal disease, cerebrovascular disease, and cardiovascular disease (as well as directly from diabetes). We extrapolate these rates to the 2007 population using the growth in number of diabetes cases between 2004 and 2007. People with diabetes are at increased risk for many other diseases, and heart disease and stroke account for an estimated 65% of deaths in people with diabetes (32). Using relative risk information from a meta analysis of the cardiovascular disease literature, we estimate that diabetes is responsible for ∼16% of deaths where cardiovascular diseases (excluding cerebrovascular diseases) is the primary cause of death (32). Using the etiological fractions for emergency department use as a proxy for the mortality etiological fractions, we estimate that 38%of deaths listing cerebrovascular disease as the primary cause and 57% of deaths listing renal failure as the primary cause can be attributed to diabetes. The majority of diabetes attributed deaths occur among the elderly, with 73% of deaths occurring among people age 70 and older, and 7% of deaths occurring among people age 65–69 (Fig. 4).

To estimate the national productivity loss of early mortality we compute the net present value of future productivity (PVFP) for men and women by age. The

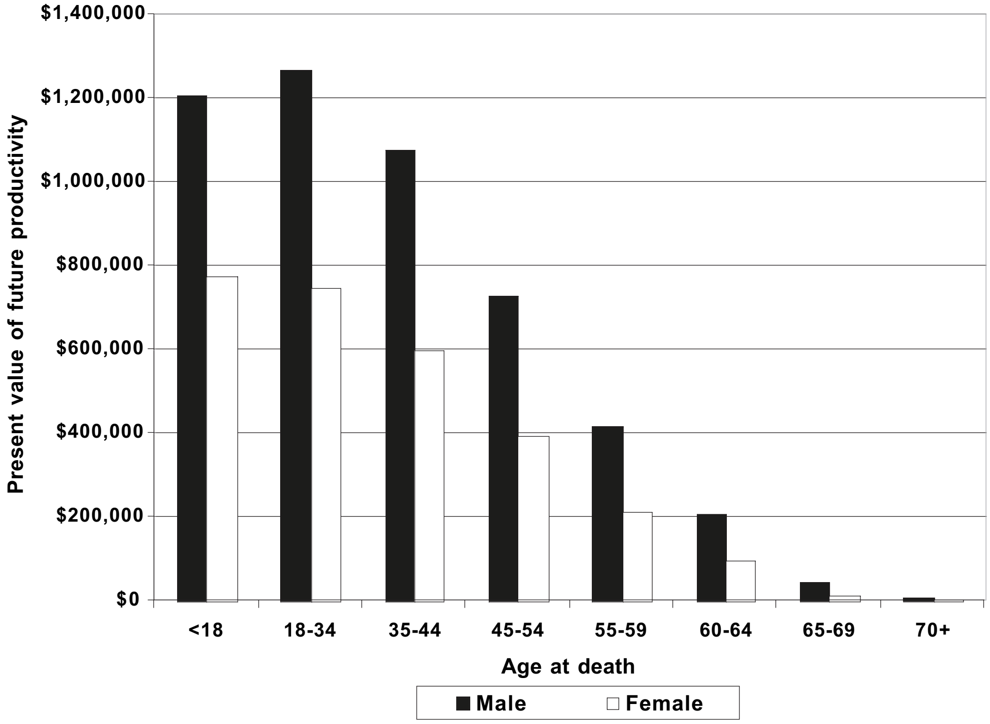

Figure 5—*Net present value of future lost earnings from premature death.*

approach combines Bureau of Labor Statistics (BLS) information on average annual earnings (E) and labor force participation rates (L) by age (A) and sex (S), and CDC information on expected mortality rates (M) for men and women in the U.S (33). We use a real discount rate (d) of 3%, a rate often used in public health studies and assume that productivity growth (p) will increase real earnings by 1% per year (34–36). Also, we assume that the value of productivity generated for the population age 18–65 who are not employed is 75% of the value of employed people of the same age and sex. Labor force participation rates and average annual earnings are low for the population age 75 and older, so we make the simplifying assumption that PVFP for this population is zero. NPV is calculated using the following formula, with estimates by age and sex provided in Fig. 5:

$$PVFP_{A,S} = \sum_{a=A}^{64}\left(\frac{E_{a,S} \times (0.75 + 0.25 \times L_{a,S}) \times (1+p)^{(a-A)} \times \prod_{A}^{a}(1 - M_{a,S})}{(1+d)^{(a-A)}}\right) + \sum_{a=65}^{74}\left(\frac{E_{a,S} \times L_{a,S} \times (1+p)^{(a-A)} \times \prod_{A}^{a}(1 - M_{a,S})}{(1+d)^{(a-A)}}\right)$$

The PVFP declines with age and is higher for men than for women, reflecting differences in annual earnings, labor force participation rates, and expected remaining years of life. The PVFP is sensitive to the chosen discount rate, with each percentage point increase in the discount rate causing the U.S. total PVFP productivity loss from diabetes-attributed mortality to drop by $1.5–$2 billion (or 6–7% of total mortality costs).

RESULTS

Summary

The total national cost of diabetes in the U. S. is estimated at $174 billion in 2007. Diabetes is responsible for an estimated $116 billion in medical costs, as well as $58 billion in reduced productivity from work-related absenteeism, reduced productivity at work and at home, unemployment from chronic disability, and premature mortality. In addition to these quantified costs, diabetes imposes high intangible costs on society in terms of reduced quality of life, and the pain and suffering of people with diabetes, their families, and their friends.

ADA's previous estimate of the cost of diabetes ($132 billion in 2002, consisting of $92 billion in medical costs and $40 billion in lost productivity), if adjusted for inflation would be equivalent to $153 billion in 2007 dollars. The $21 billion increase between the 2002 estimate (in 2007 dollars) and new 2007 estimate of $174 billion reflects three factors: *1*) growth in diabetes prevalence, *2*) medical costs rising faster than general inflation, and *3*) improvements made in the methods and data sources to estimate the cost of diabetes. Coincidentally, the $116 billion in excess medical expenditures is almost the same number obtained by inflating the 2002 estimate ($92 billion) by growth in diagnosed diabetes prevalence and general medical inflation as measured by BLS.

The indirect costs of diabetes are higher than the 2002 estimates, even after adjusting for growth in diabetes prevalence and general inflation, in large part because of the change in data and methods to model lost productivity due to absenteeism and presenteeism. The cost of unemployment from permanent dis-

Table 4—*Health resource use (in millions of units) in the U.S., by diabetes attribution and cost component, 2007*

	Population with diabetes					
	Attributed to diabetes		Incurred by people with diabetes			
Health resource	Units	% of U.S. total	Units	% of U.S. total	Incurred by population without diabetes	U.S. total*
Institutional care						
Hospital inpatient days	24.3	13	40.7	22	145.7	186.4
Nursing/residential facility days	56.1	10	140.6	25	433.3	573.9
Outpatient care						
Physician's office visits	64.7	7	137.6	14	822.1	959.7
Emergency visits	5.6	5	11.5	10	104.4	115.9
Hospital outpatient and freestanding ambulatory surgical center visits	5.7	6	10.9	12	81.7	92.7
Home health visits	27.4	13.8	46.0	23.2	152.7	198.8
Hospice care days	0.2	<1	9.6	11	81.5	91.1
Retail prescriptions	175.3	8	359.6	17	1,762.0	2,121.6

*Numbers do not necessarily sum to totals because of rounding.

ability and premature mortality are consistent with the 2002 estimates, adjusting for growth in diabetes prevalence and inflation.

Health resource use attributed to diabetes

Combining estimates of per capita use of health care services, diabetes prevalence rates, etiological fractions, and the 2007 population in the U.S. produces national estimates of total health resource use, health resource use by people with diabetes, and health resource use attributed to diabetes (Table 4). For example, of the projected 186 million hospital inpatient days in the U.S. in 2007, an estimated 40.7 million days (22%) are incurred by people with diabetes and 24.3 million (13%) are attributed to diabetes. While 1 in 4 nursing facility days is incurred by a person with diabetes, 1 in 10 days is attributed to diabetes. About half of all physician office visits, emergency visits, hospital outpatient visits, and outpatient prescriptions (excluding oral agents and insulin) incurred by people with diabetes are attributed to their diabetes.

Differences between these estimates and estimates from the ADA 2003 study reflect, in part, the use of setting-specific etiological fractions and a new data source to estimate the relative rate ratios used to calculate the etiological fractions. Attributed hospital inpatient days, and physician office and emergency visits all increased from the earlier study, with hospital outpatient visits remaining relatively unchanged. Attributed nursing facility days are substantially lower than our earlier estimate, reflecting a change in method for calculating attributed days (i.e., use of a population etiological fraction that is specific to nursing homes rather than separate etiological fractions for each medical condition that were derived from the MEPS).

Table 5 shows estimated health resource use attributed to diabetes, by type of service and aggregated into three broad age categories. The population age 65 and older uses a large portion of services, reflecting the burden diabetes places on the Medicare program.

Tables 6–8 provide a breakdown of health resource use attributed to diabetes by medical condition. Table 6 shows total use attributed to diabetes; Table 7 shows the share of attributed use associated with each medical condition; and Table 8 shows the proportion of U.S. health resource use attributed to diabetes. Nursing facility days, home health visits, and hospice care days are not calculated by complication. These tables reveal several trends:

- A large portion of health resource use attributed to diabetes is for general medical conditions that are not chronic complications of diabetes. As discussed earlier, we find that diabetes contributes to longer hospital length of stay regardless of the reason for admission (and controlling for other factors that affect hospital length of stay). Compared to their peers without diabetes, people with diabetes have much higher rates of physician office visits and emer-

Table 5—*Health resource use attributed to diabetes in the U.S., by age and type of service, 2007 (in thousands)*

	Age (years)			
Health resource	< 45	45–64	≥ 65	Total*
Institutional care				
Hospital inpatient days	2,115	7,586	14,562	24,262
Nursing/residential facility days	1,269	11,103	43,687	56,059
Outpatient care				
Office-based physician visits	7,353	26,552	30,808	64,713
Emergency visits	1,499	1,984	2,084	5,567
Hospital outpatient and freestanding ambulatory surgical center visits	1,307	2,535	1,888	5,730
Home health visits	0	8,939	18,449	27,388
Hospice care days	4	22	165	192
Retail prescriptions	15,181	71,295	88,841	175,317

*Numbers do not necessarily sum to totals because of rounding.

Table 6—*Health resource use attributed to diabetes in the U.S., by medical condition (in thousands)*

		Chronic complications								
Health resource	Diabetes	Neuro-logical	Peripheral vascular	Cardio-vascular	Renal	Metabolic	Ophthalmic	Other	General medical conditions	Total*
Hospital inpatient days	828	1,318	1,221	6,446	1,755	82	15	1,871	10,726	24,262
Office-based physician visits	21,931	2,386	1,405	6,635	1,905	403	4,934	1,443	23,672	64,713
Emergency visits	336	173	53	592	229	22	7	280	3,874	5,567
Hospital outpatient and freestanding ambulatory surgical center visits	2,544	154	189	549	147	27	173	173	1,773	5,730

*Numbers do not necessarily sum to totals because of rounding.

gency visits for general medical conditions.
- A substantial amount of attributed health resource use is for chronic complications of diabetes. In particular, cardiovascular disease, neurological symptoms, and renal complications are associated with high resource use attributed to diabetes.
- Diabetes is listed as the primary diagnosis code for a large portion of physician office visits and hospital outpatient visits attributed to diabetes. Diabetes is listed as the primary diagnosis code for a small proportion of inpatient days and emergency visits attributed to diabetes. Because inpatient days for general medical conditions constitutes a sizable (44%) portion of total inpatient days attributed to diabetes, additional attention was paid to this cost component. In Fig. 3 we presented findings from an analysis of the 2005 NIS that shows that hospital stays for general medical conditions are longer when diabetes is listed as a complication (controlling for other factors that affect length of stay). Analysis of the MCURE database shows that people with diabetes have higher rates of hospital admissions and more inpatient days associated with admissions where the primary diagnosis code is not an identified chronic complaint associated with diabetes. For men age 18–44 years, those with diabetes have admission rates that are about twice that of men without diabetes (Fig. 6). This ratio declines with age, such that men age 70 and older with diabetes have only 5% more admissions than men in this age-group without diabetes. For the 70 and older age-group, men with diabetes still have 70% more inpatient days than men without diabetes for admissions with a primary diagnosis code listed as a general medical condition. The rate ratios are similar for women, with diabetes associated with an increase in admissions of between 8 and 54% and total inpatient days associated with an increase of between 63 and 111% across different age-groups.

Health care expenditures attributed to diabetes

Health care expenditures attributed to diabetes reflect the additional expenditures the nation incurs because of diabetes. This equates to the total health care expenditures for people with diabetes minus the projected level of expenditures that would have occurred in the absence of diabetes.

Table 9 summarizes national expenditures for the cost components analyzed, accounting for over one trillion dollars in projected expenditures for 2007. Approximately $205 billion in expenditures is incurred by people with diabetes, reflecting $1 of every $5 health care dollars. Costs attributed to diabetes total $116 billion, or 57% of total medical costs incurred by people with diabetes. For the cost components analyzed, over $1 of every $10 health care dollars is attributed to diabetes.

National health-related expenditures are projected to exceed $2 trillion in 2007, but only half of these expenditures are included in our analysis (37,38). These cost estimates omit national expenditures (and any portion of such expenditures that might be attributable to diabetes) for administering government health and private insurance programs, investment in research and infrastructure, over-the-counter medications, disease management and other programs targeted to people with diabetes, and office visits to nonphysician providers other than podiatrists (e.g., dentists, optometrists, etc.). Expenditures for health re-

Table 7—*Share of total attributed health resource use, by medical condition*

		Chronic complications								
Health resource	Diabetes	Neuro-logical	Peripheral vascular	Cardio-vascular	Renal	Metabolic	Ophthalmic	Other	General medical conditions	Total*
Hospital inpatient days	3	5	5	27	7	0	0	8	44	100
Office-based physician visits	34	4	2	10	3	1	8	2	37	100
Emergency visits	6	3	1	11	4	0	0	5	70	100
Hospital outpatient and freestanding ambulatory surgical center visits	44	3	3	10	3	0	3	3	31	100

*Numbers do not necessarily sum to totals because of rounding.

Table 8—*Proportion of total health resource use attributed to diabetes in the U.S. by medical condition*

Health resource	Diabetes	Chronic complications: Neurological	Peripheral vascular	Cardio-vascular	Renal	Metabolic	Ophthalmic	Other	General medical conditions	Total
Hospital inpatient days	100	26	36	34	35	51	27	44	7	13
Office-based physician visits	100	26	18	11	15	4	19	13	3	7
Emergency visits	100	22	12	19	9	41	9	7	4	5
Hospital outpatient and freestanding ambulatory surgical center visits	100	27	24	10	11	4	18	14	2	6

sources unrelated to diabetes (e.g., care in residential mental retardation facilities) are likewise excluded from the analysis.

Almost half of all health care expenditures attributed to diabetes come from higher rates of hospital admission and longer average lengths of stay per admission. Of the projected $430 billion in national expenditures for hospital inpatient care (including both facility and professional services costs), approximately $97 billion (or 23%) is incurred by people who have diabetes and $58.3 billion (14%) is directly attributed to their diabetes. Retail prescriptions (excluding insulin and oral agents) are another major expense category, with 17% of prescription costs incurred by people with diabetes and 8% of costs ($12.7 billion) attributed to their diabetes.

Over half (56%) of all health care expenditures attributed to diabetes are for health resources used by the population age 65 years and older, much of which is borne by the Medicare program (Table 10). The population age 45–64 incurs 35% of diabetes-attributed costs, with the remaining 9% incurred by the population under age 45. The annual attributed health care cost per person with diabetes increases with age, primarily as a result of increased use of hospital inpatient and nursing facility resources, physician office visits, medications (other than insulin and oral agents), and home care (Table 11). Dividing total attributed health care expenditures by the number of people with diabetes, we estimate the average annual excess expenditures for the population under age 45, age 45–64, and age 65 and above at $3,808, $5,094, and $9,713, respectively.

Table 12 summarizes diabetes-attributed health care expenditures for those cost components modeled by medical condition, with inpatient days being the largest component of attributed costs. General medical conditions comprise 76% of the projected $430 billion in national expenditures for hospital inpatient care. With 7% of inpatient days for this condition group attributed to diabetes, this category constitutes the single largest contributor to the attributed medical cost of diabetes. The second largest category of diabetes costs is inpatient days associated with cardiovascular disease. Cardiovascular disease, as the primary diagnosis for admissions, generates $66 billion per year in inpatient expenditures in the U.S. (or

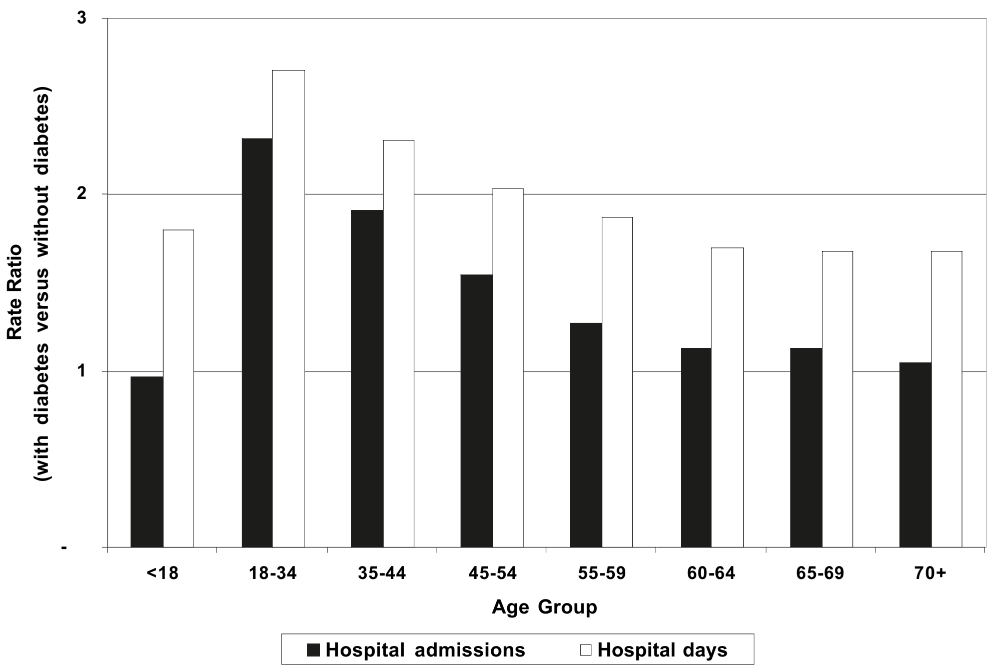

Figure 6—*Rate ratios for inpatient care where the primary diagnosis code is a general medical condition: males. A ratio of 1.0 means that per capita hospital admissions (or days) for people with diagnosed diabetes is the same as the per capita admissions (or days) for people without diabetes.*

Table 9—*Health care expenditures in the U.S., by diabetes status and type of service, 2007 (in millions of dollars and % of U.S. total)*

	Population with diabetes					
	Attributed to diabetes		Total incurred by people with diabetes			
Cost component	Dollars	% of U.S. total	Dollars	% of U.S. total	Population without diabetes	U.S. total*
Institutional care						
Hospital inpatient	58,344	14	96,974	23	332,902	429,875
Nursing/residential facility	7,486	10	18,525	25	56,692	75,217
Outpatient care			21,739			
Physician's office	9,897	6	8,065	14	132,984	154,723
Emergency department	3,870	5	7,879	10	73,381	81,446
Ambulance services	103	5	370	18	1,726	2,096
Hospital outpatient	2,985	4	6,770	10	60,054	66,824
Home health	5,586	14	9,391	23	31,149	40,546
Hospice	28	<1	1,411	11	10,622	12,033
Podiatry	273	19	408	28	1,028	1,437
Outpatient medications and supplies						
Insulin	3,733	100	3,733	100	NA	3,733
Diabetic supplies	1,783	100	1,783	100	NA	1,783
Oral agents	8,586	100	8,586	100	NA	8,586
Retail prescriptions	12,692	8	26,035	17	127,562	153,597
Other equipment and supplies	890	5	2,714	14	16,901	19,615
Total*	116,257	11	205,092	20	834,379	1,051,505

*Numbers do not necessarily sum to totals because of rounding.

15% of total U.S. medical expenditures for inpatient care). Together, the general medical conditions and cardiovascular disease categories are responsible for 91% of U.S. expenditures for inpatient care and 76% of hospital inpatient costs attributed to diabetes.

The population with diabetes is older and sicker than the population without diabetes. Table 13 shows that annual medical expenditures for the cost components analyzed are over four times higher ($11,744 vs. $2,935). A more important comparison is the health care expenditures for people with diabetes compared to what expenditures for this same population (i.e., age-sex adjusted) would be in the absence of diabetes. People with diabetes have health care expenditures that are 2.3 times higher ($11,744 vs. $5,095) than expenditures for this same population would be in the absence of diabetes, suggesting that diabetes is responsible for $6,649 in excess expenditures per year per person with diabetes.

The 2.3 multiple is similar to the 2.4 multiple in the 2003 study. The ratio of costs with to without diabetes, adjusting for demographic mix, ranges from a low of 1.4 for ambulance services to a high of 3.0 for podiatry services.

Indirect costs attributed to diabetes

The national cost of lost productivity associated with diabetes in 2007 is estimated at $58.2 billion. This includes diabetes-attributed absenteeism from work, reduced productivity while at work, reduced productivity for those not in the labor force, inability to work because of disability, and premature mortality.

The number of workdays absent because of diabetes in 2007 is estimated at 15 million, at a national cost of $2.6 billion (Table 14). These statistics are calculated by combining age-sex–specific estimates of the number of people with diabetes, labor force participation rates, annual workdays lost from absenteeism per worker, and average daily earnings. The population with the highest per capita productivity loss from absenteeism is males age 45–54. With 1.7 million people with diabetes, a labor force participation rate of 84%, average days absent of 2.5 days per worker per year, and average daily earnings of $240, the absenteeism cost per person with diabetes per year is $493 (Table 15). Per capita cost is significantly lower for the youngest and oldest age-groups—populations with lower rates of employment, lower days absent per worker per year, and lower average daily earnings.

More substantial are the estimated costs associated with presenteeism. Because of high labor force participation rates and high daily earnings, the male population age 35–44 has the highest annual per capita cost of presenteeism ($2,883 per person with diabetes). At the national level presenteeism loss is equivalent to 120 million workdays lost, with an estimated national cost of $20 billion in 2007.

Reduced productivity for those not in the labor force is calculated by extrapolating the age-sex work absenteeism rates to the population not in the labor force and valuing each lost productivity day using 75% of daily earnings of their peers in the labor force. The estimated productivity loss is equivalent to six million days, with a national cost of $800 million.

At any given time during 2007, ~16 million people were unemployed and receiving SSI payments due to disability. Over one million of these people had diabetes, with over 445,000 cases of unemployment attributed to diabetes, equating to 107 million lost workdays at a national cost of $7.9 billion.

An estimated 284,000 deaths in 2007

Table 10—*Health care expenditures attributed to diabetes in the U.S., by age group and type of service, 2007 (in millions of dollars)*

Cost component	Age (years) <45	45–64	≥65	Total*
Institutional care				
Hospital inpatient	4,551	18,447	35,346	58,344
Nursing/residential facility	166	1,527	5,793	7,486
Outpatient care				
Physician's office	1,113	3,982	4,802	9,897
Emergency department	1,047	1,384	1,438	3,870
Ambulance services	4	79	21	103
Hospital outpatient	645	1,312	1,028	2,985
Home health	0	1,823	3,763	5,586
Hospice	1	3	24	28
Podiatry	14	58	202	273
Outpatient medications and supplies				
Insulin	788	1,564	1,381	3,733
Diabetic supplies	217	859	707	1,783
Oral agents	967	4,163	3,456	8,586
Retail prescriptions	1,099	5,161	6,432	12,692
Other equipment and supplies	77	448	365	890
Total*	10,689	40,810	64,758	116,257

*Numbers do not necessarily sum to totals because of rounding.

are attributed to diabetes (Table 16). This includes 77,000 deaths where diabetes is listed as the primary cause of death, 123,000 deaths where cardiovascular disease is listed as the primary cause of death (with 16.5% of national deaths from cardiovascular disease attributed to diabetes), 59,000 deaths where cerebrovascular disease is the listed primary cause of death, and 25,000 deaths where renal disease is listed as the primary cause of deaths. Taking into account the age and sex distribution of these deaths, we estimate that the value of lost productivity from premature mortality is $26.9 billion. Using net present value of future productivity as a proxy for productivity loss is a departure from the method used to calculate the value of productivity loss associated with the other components of indirect costs. Absenteeism, presenteeism, and unemployment from disability are all calculated to have occurred during 2007. The productivity loss in 2007 associated with premature mortality should be calculated based on the expected productivity of people who would have been alive in 2007 but who died prematurely in earlier years (2006, 2005, etc.) because of diabetes. However, such an approach would be difficult to implement. The approach used does provide practical consistency and there is no "double counting" with the discounted future productivity loss for people who die prematurely in 2007 counted in 2007.

Estimates of diabetes deaths attributed to renal disease and cerebrovascular disease are substantially higher than estimates in the 2003 study, reflecting the larger etiological fraction used in this study. The 2003 study used the overall comorbidity etiological fraction as a proxy for the mortality etiological fraction. For this study we use the emergency room etiological fraction as a proxy for the mortality etiological fraction. For cardiovascular disease we calculated the etiological fraction using mortality risk data from the literature (32).

CONCLUSIONS— Diabetes cost the nation an estimated $174 billion in 2007. This burden is spread across society, although the burden falls disproportionately on the people with diabetes and their families. On the surface it appears that the burden falls primarily on insurers who pay a significant portion of medical costs, employers who experience productivity loss, and the people with diabetes and their families who incur higher out-of-pocket medical costs and reduced earnings potential or employment opportunities. Ultimately, though, the burden is passed along to all of society in the form of higher insurance premiums and taxes, reduced earnings, and reduced standard of living. Furthermore, with just under 1 in 10 people having diabetes, this disease directly or indirectly touches almost everyone in society.

Because the risk of developing

Table 11—*Annual per capita health care expenditures attributed to diabetes by age group 2007*

Cost component	Age (years) <45	45–64	≥65	Total*
Institutional care				
Hospital inpatient	1,621	2,303	5,302	3,337
Nursing/residential facility	59	191	869	428
Outpatient care				
Physician's office	397	497	720	566
Emergency department	373	173	216	221
Ambulance services	1	10	3	6
Hospital outpatient	230	164	154	171
Home health	0	228	564	319
Hospice	0	0	4	2
Podiatry	5	7	30	16
Outpatient medications and supplies				
Insulin	281	195	207	214
Diabetic supplies	77	107	106	102
Oral agents	344	520	518	491
Retail prescriptions	392	644	965	726
Other equipment and supplies	27	56	55	51
Total*	3,808	5,094	9,713	6,649

*Numbers do not necessarily sum to totals because of rounding.

Table 12—*Health care expenditures attributed to diabetes in the U.S., by medical condition for select settings, 2007 (in millions of dollars)*

		Chronic complications								
Setting	Diabetes	Neuro-logical	Peripheral vascular	Cardio-vascular	Renal	Metabolic	Ophthalmic	Other	General medical conditions	Total*
Hospital inpatient	1,535	3,115	2,719	20,790	3,285	176	36	3,215	23,473	58,344
Physician's office	2,899	382	279	1,004	323	48	899	233	3,830	9,897
Emergency department	234	138	43	403	132	13	11	178	2,717	3,870
Hospital outpatient	842	75	135	317	87	8	130	70	1,321	2,985

*Numbers do not necessarily sum to totals because of rounding.

chronic diseases increases with age, the aging population is expected to drive a substantial increase in the number of people with diabetes even if other risk factors remain unchanged. The U.S. Census Bureau projects a rise in the percent of the population age ≥65 years, from 12.4% in 2003 to 19.7% by 2030 (39). A recent study estimates that prevalence of diagnosed diabetes will more than double between 2005 and 2050, from 5.6 to 12% (40). A recent nationally representative, longitudinal study found that elderly people newly diagnosed as having diabetes experience much higher rates of complications in the years after diagnosis than do their peers without diabetes, implying a substantial burden on the individual and on the health care system (41).

The cost estimates presented might be conservative for several reasons:

- Omitted from this analysis due to data limitations is whether diabetes is associated with increased use of over-the-counter medications and higher rates of visits to optometrist and dentist offices. Diabetes increases the risk of periodontal disease, so one would expect dental costs to be higher for people with diabetes. Also omitted from the cost estimates are expenditures for prevention programs targeted to people with diabetes (e.g., disease management programs), research activities (e.g., to develop new drugs), and administration costs (e.g., to administer the Medicare and Medicaid programs, to process insurance claims). Administration costs for government health programs and private insurers are ~$150 billion per year. Expenditures for investment in medical research and health infrastructure total over $130 billion per year. If a portion of these costs were attributed to diabetes, the national cost of diabetes would be billions of dollars higher than our estimate suggests.
- The cost estimates presented are based on the assumption that people with undiagnosed diabetes incur no excess medical and indirect costs attributed to diabetes. Additional research is needed to quantify whether people with undi-

Table 13—*Annual per capita health care expenditures by diabetes status, 2007*

		Unadjusted		Age-sex adjusted		
Cost component	With diabetes	Without diabetes	Ratio with to without diabetes	Without diabetes	Ratio with to without diabetes	Attributed to diabetes
Institutional care						
Hospital inpatient	5,546	1,171	4.7	2,209	2.5	3,337
Nursing/residential facility	1,059	199	5.3	631	1.7	428
Outpatient care						
Physician's office	1,243	468	2.7	677	1.8	566
Emergency department	461	258	1.8	240	1.9	221
Ambulance services	21	6	3.5	15	1.4	6
Hospital outpatient and freestanding ambulatory surgical center	387	211	1.8	216	1.8	171
Home care	551	110	5.0	232	2.4	319
Hospice care	NA	NA	NA	NA	NA	2
Podiatry	23	4	6.5	8	3.0	16
Outpatient medications and supplies						
Insulin	214	NA	NA	NA	NA	214
Diabetic supplies	102	NA	NA	NA	NA	102
Oral agents	491	NA	NA	NA	NA	491
Retail prescriptions	1,489	449	3.3	763	2.0	726
Other equipment and supplies	155	59	2.6	104	1.5	51
Total*	$11,744	$2,935	4.0	$5,095	2.3	$6,649

*Numbers do not precisely sum to totals because of rounding.

Table 14—*Indirect costs attributed to diabetes, 2007*

Cost component	Productivity loss	Total cost attributable to diabetes ($ billions)	Proportion of indirect costs (%)
Work days absent	15 million days	2.6	4
Reduced performance at work	120 million days	20.0	34
Reduced productivity days for those not in labor force	6 million days	0.8	1
Permanent disability	445,000 people, 107 million days	7.9	14
Mortality	284,000 deaths	26.9	46
Total		58.2	100

agnosed diabetes incur disease-related costs in excess of their peers without diabetes. That people with diabetes already have complications at the time of diagnosis suggests that diabetes-related costs are present among the undiagnosed. The population with undiagnosed diabetes might represent a population less inclined to seek medical attention, contributing to a delay in diagnosis. If people with undiagnosed diabetes have disease-related medical costs that are 10, 20, or 30% as high as people with diagnosed diabetes, then the national cost of diabetes could be $7, $13 or $20 billion higher, respectively, than our estimates suggest.

- The lost productivity estimates are for those individuals with diagnosed diabetes and exclude lost productivity associated with diabetes of family members. For example, the productivity loss associated with adults who take time off from work to care for an elderly parent is not included in the cost estimates. The value of informal care giving is excluded from our cost estimate.
- Our estimate of lost productivity attributed to chronic disability from diabetes is likely conservative due to three factors: One, using SSI payments to identify cases of disability likely underestimates disability cases because the criteria for SSI eligibility includes requirements for documentation of disability from a health professional and apply income limits. Two, our estimates omit the value of productivity loss that results in reduced earnings potential but does not prevent working. Three, we do not include productivity loss associated with early retirement, and a longitudinal study using the Health and Retirement Survey found that people with diabetes tend to retire ~1.2 years earlier than their peers without diabetes (27).

One challenge for this study was to control for correlation between diabetes and use of health resources for reasons not directly attributed to diabetes. Health behavior that affects both the presence of diabetes and the presence of other comorbidities, unless controlled for, could result in an overestimate of the link between diabetes and use of health resources. Controlling for age and sex helps to control for this correlation. In addition, for the top-10 cost drivers we conducted additional analysis with the MEPS, and based on the results, we reduced the etiological fractions for hypertension, renal complications, and general medical conditions. This potential limitation also applies to the estimates of indirect costs attributed to diabetes.

Other study limitations discussed previously include small sample size for some data sources used, the use of a data source (MCURE) that overrepresents the commercially insured population, and the need to use different approaches to

Table 15—*Annual productivity loss per person with diabetes by cause, 2007*

Sex	Age	Absenteeism	Presenteeism	Reduced productivity for those not in labor force	Unemployment from disability	Premature mortality
Male	<18	—	—	—	—	4,306
	18–34	22	1,458	17	936	3,366
	35–44	99	2,883	10	728	4,476
	45–54	493	2,688	72	652	4,468
	55–59	360	2,196	109	315	3,081
	60–64	181	1,517	131	806	1,822
	65–69	86	721	—	274	569
	70+	45	378	—	146	284
Female	<18	—	—	—	—	2,070
	18–34	50	844	21	743	1,095
	35–44	47	1,378	14	1,216	1,456
	45–54	240	1,310	70	449	1,388
	55–59	179	1,093	90	491	994
	60–64	72	604	80	492	642
	65–69	27	228	—	448	140
	70+	17	140	—	74	116

Table 16—*Mortality costs attributed to diabetes, 2007*

Primary cause of death	Total U.S. deaths (thousands)	Deaths attributed to diabetes: Deaths (thousands)	% of total U.S. deaths	Value of lost productivity (millions of dollars)
Diabetes	77	77	100.0	9,520
Renal disease	43	25	57.4	2,116
Cerebrovascular disease	155	59	37.6	3,849
Cardiovascular disease	739	123	16.5	11,417
Grand total	NA*	284	NA*	26,902

*Grand total comprises mortality for reasons other than diabetes, renal disease, cerebrovascular disease, and cardiovascular disease.

model different cost components because of data limitations. One sensitivity analysis conducted was to compare relative rate ratios for the population age 65–69 and age 70 and older calculated from two sources—MCURE and the Medicare 5% Sample. The relative rate ratios for each health care delivery setting (hospital inpatient, emergency, and ambulatory) and comorbidity group were similar for the two data sources, and if we had used the rate ratios calculated from the Medicare 5% Sample, our estimate of total national medical costs attributed to diabetes would be ∼1% higher.

The medical cost analysis is largely based on claims data, and claims data tend to be less accurate than clinical reports in identifying patients with specific conditions. The direction of bias for the cost of diabetes is unknown, as use of claims data might overdiagnose for some conditions and underdiagnose for other conditions.

All models are simplifications of reality and their conclusions are affected by both structural boundaries and the uncertainties of the data with which they are calibrated. Despite limitations, the estimates presented here show a consistent picture that diabetes places an enormous burden on society—in both economic terms and reduced quality of life. Although this study improves on the methods and uses new data sources compared to the 2003 study, the overall cost of diabetes estimates are consistent with earlier estimates after adjusting for increasing prevalence of diabetes and price increases. Some of the estimates by cost component, medical condition, and age differ from the 2003 study.

The present findings demonstrate that the burden of diabetes and its complications on the individual and on the health care system is significant. Much of this cost is preventable through improved diet and exercise, prevention initiatives to reduce the prevalence of diabetes and its comorbidities, and improved care for people with diabetes to reduce the need for costly complications. Improved understanding of the economic cost of diabetes and the major determinants of costs helps to inform and motivate decisions that can reduce the national burden of this disease.

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Table A1—*Summary of data sources*

Data source and description	Used to estimate/analysis	Strengths and limitations
National Health Interview Survey (NHIS): combined 2004–2006 surveys to increase sample size.	Diabetes diagnosed prevalence by age, sex, and race/ethnicity Prevalence of insulin and oral agents use Impact of diabetes on employment/hours worked Activity limitation and restriction	+Large sample size +Contains employment-related information −Diabetes status self-reported of whether ever been told by physician you have diabetes −Excludes institutionalized population where diabetes is overrepresented
National Health and Nutrition Examination Survey (NHANES): combined the three biannual surveys (1999–2000, 2001–2002, and 2003–2004) to increase sample size.	Verify diagnosed prevalence Estimate undiagnosed prevalence	+Contain both self-reported and lab test–identified diabetic persons −Excludes institutionalized population where diabetes is overrepresented
Medical Expenditure Panel Survey (MEPS): combined 2003–2005 surveys to increase sample size.	Average cost per physician office, outpatient, and emergency visit and outpatient prescription Average annual expenditures for podiatry, home health, insulin, oral agents, diabetes-related supplies use and cost, other medical equipment and supplies	+Rich source of health resource use and cost information −Relatively small sample size per year −Contains only three-digit diagnosis codes; many chronic conditions of diabetes require four-digit codes to identify −Excludes institutionalized population where diabetes is overrepresented
National Ambulatory Medical Care Survey (NAMCS): combined 2003–2005 surveys to increase sample size.	National number of physician office visits by medical condition(using primary diagnosis code) Average number of scripts written per visit	+Larger sample size than MEPS +Contains five-digit diagnosis codes to identify chronic conditions of diabetes −Visits are the unit of observations, with incomplete information on patients (including whether they have diabetes)
National Hospital Ambulatory Medical Care Survey (NHAMCS): combined 2003–2005 surveys to increase sample size.	National number of hospital outpatient and emergency visits by medical condition (using primary diagnosis code) Average number of scripts written per visit	+Same as for NAMCS −Same as for NAMCS
Nationwide Inpatient Sample (NIS): used 2004–2005 surveys.	National number of hospital inpatient days for diabetes and comorbidities of diabetes (using primary diagnosis) Cost per inpatient day calculated using hospital-specific cost-to-charge ratios	+Same as for NAMCS −Same as for NAMCS
National Home and Hospice Care Survey (NHHCS): used 2000 data.	Hospice care use (also validate home health)	+Same as for NAMCS −Same as for NAMCS
National Nursing Home Survey (NNHS): used 2004 data.	Nursing facility use	+Same as for NAMCS −Same as for NAMCS
Ingenix MCURE database	Calculate age-sex specific relative rate ratios for each medical condition for hospital inpatient days, emergency visits, and ambulatory visits (physician office and hospital outpatient combined)	+Large sample size −All medical records can be linked for the year to identify people with diabetes based on whether they have any diabetes diagnosis code during the year −Lacks detailed data on health behavior found in MEPS

Table A2 —*Chronic complications of diabetes*

Chronic complications of diabetes	ICD-9 codes
Neurological symptoms	
Myasthetic syndromes in diseases classified elsewhere (amyotrophy)	358.1
Other specified idiopathic peripheral neuropathy	356.8
Mononeuritis of upper and lower limbs	354, 355
Arthropathy associated w/neurological disorders (Charcot's arthropathy)	713.5
Peripheral autonomic neuropathy	337.1
Polyneuropathy in diabetes	357.2
Neuralgia, neuritis, and radiculitis, unspecified	729.2
Diabetes with neurological complications	250.6
Occlusion of cerebral arteries	434
Hemorrhagic stroke	430–432
Late effects of cerebrovascular disease	438
Occlusion of stenosis of pre-cerebral arteries	433
Other and ill-defined cerebrovascular disease	437
Acute, but ill-defined, cerebrovascular disease	436
TIAs	435
Peripheral vascular disease	
Atherosclerosis	440
Embolism and thrombosis, structure of artery	444, 447.1
Other peripheral vascular disease	443
Other disorders of circulatory system	459
Phlebitis and thrombophlebitis, portal vein throbosis and thrombolism and venous thrombolism	451,452
Other venous embolism and thrombolism	453
Varicose veins of lower extremities	454
Gangrene and amputations	785.4, 885–887, 895–897
Chronic ulcer of skin	707
Cardiovascular disease	
Aortic and other aneurysms	441, 442
Hypotension	458
Angina	413
Conduction disorders and cardiac dysrhythmias	426–427
ASCVD	429.2
Cardiomegaly	429.3
Cardiomyopathy	425
Other acute and subacute forms of ischemic heart disease	411
Heart failure	428
Diabetes w/peripheral circulatory disorders	250.7
Myocardial degeneration	429.1
Myocardial infarction	410, 412
Other chronic ischemic heart disease	414
Hypertension	401–405
Renal Complications	
Infections of kidney	590
Other disorders of bladder	596
Cystitis	595
Renal sclerosis, unspecified	587
Glomerulonephritis, nephrotic syndrome, nephritis, and nephropathy	580–583
Proteinuria	791.0
Renal failure and its sequelae	584, 586, 588
Other disorders of kidney and ureter	593
Urinary tract infection	599.0

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Table A2 —*Continued*

Chronic complications of diabetes	ICD-9 codes
Diabetes and renal complications	250.4
Chronic renal failure (ESRD)	585
Endocrine/metabolic complications	
Dwarfism-obesity syndrome	259.4
Glycogenosis and galactosemia	271.0, 271.1
Disorders of iron metabolism	275.0
Hypercholesterolemia	272.0
Hyperchylomicronemia	272.3
Hyperkalemia	276.7
Hypertriglyceridemia	272.1
Macroglobulinemia	273.3
Lancereaux's disease	261
Lipidoses	272.7
Other specified endocrine disorders	259.8
Other and unspecified hyperlipidemia	272.4
Mixed hyperlipidemia	272.2
Renal glycosuria	271.4
Ophthalmic complications	
Other retinal disorders	362
Vascular disorders of the iris and ciliary body	364.0, 364.4
Disorders of the optic nerve and visual pathways	377
Diabetes with ophthalmic complications	250.5
Cataract	366
Glaucoma	365
Visual disturbance, low vision, blindness	368–369
Other complications	
Bacteremia, bacterial infection, Coxsackie virus	079.2, 790.7
Candidiasis of skin and nails	112.3
Chronic osteomyelitis of the foot	730.17
Other and unspecified noninfectious gastroenteritis and colitis	558.9
Impotence of organic origin	607.84
Infective otitis externa	380.1
Degenerative skin disorders	709.3
Candidiasis of vulva and vagina	112.1
Cellulitis	681, 682
Diabetes with other specified manifestations	250.8
Diabetes with unspecified complication	250.9
Other bone involvement in disease classified elsewhere	731.8

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