The Lifetime Cost of Diabetes and Its Implications for Diabetes Prevention

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EPIDEMIOLOGY/HEALTH SERVICES RESEARCH

OBJECTIVE

To assess the cost implications of diabetes prevention, it is important to know the lifetime medical cost of people with diabetes relative to those without. We derived such estimates using data representative of the U.S. national population.

RESEARCH DESIGN AND METHODS

We aggregated annual medical expenditures from the age of diabetes diagnosis to death to determine lifetime medical expenditure. Annual medical expenditures were estimated by sex, age at diagnosis, and diabetes duration using data from 2006–2009 Medical Expenditure Panel Surveys, which were linked to data from 2005–2008 National Health Interview Surveys. We combined survival data from published studies with the estimated annual expenditures to calculate lifetime spending. We then compared lifetime spending for people with diabetes with that for those without diabetes. Future spending was discounted at 3% annually.

RESULTS

The discounted excess lifetime medical spending for people with diabetes was $124,600 ($211,400 if not discounted), $91,200 ($135,600), $53,800 ($70,200), and $35,900 ($43,900) when diagnosed with diabetes at ages 40, 50, 60, and 65 years, respectively. Younger age at diagnosis and female sex were associated with higher levels of lifetime excess medical spending attributed to diabetes.

CONCLUSIONS

Having diabetes is associated with substantially higher lifetime medical expenditures despite being associated with reduced life expectancy. If prevention costs can be kept sufficiently low, diabetes prevention may lead to a reduction in long-term medical costs.

With its increasing prevalence and high cost of treatment, diabetes places an enormous demand on the economic resources of the U.S. Approximately 20% of the nation's health care dollars go to treating people with diabetes (1). Annual per capita medical spending for people with diabetes is more than two times that for those without diabetes (1). Type 2 diabetes, which accounts for 90% to 95% of diabetes cases, has been found to be preventable through lifestyle or pharmacological interventions (2–5). The high cost associated with diabetes suggests that reducing incidence through prevention might lower lifetime medical spending and alleviate some of the future economic burden of treating diabetes.

In many cases, chronic disease prevention has been found to be cost effective but not cost saving (6). While prevention averts costs from treating the disease, it may

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also extend life expectancy and thus could result in more years of health care spending and possibly in greater lifetime medical spending. Considering the shortened life expectancy seen with diabetes, it is unknown whether lifetime medical costs for people with diabetes exceed those of otherwise similar people without diabetes. Previous studies of the economic consequences of diabetes prevention (7,8) have yielded mixed findings. Some studies have suggested that preventing diabetes, like preventing some other chronic diseases, would increase medical costs in part because of increased life spans. Other studies (9–12) have found that diabetes prevention would lead to substantial long-term cost savings, despite the extended life expectancy. To assess the cost implications of diabetes prevention, it is crucial to know lifetime medical costs for people with diabetes relative to those of people without diabetes. Knowing this would provide a benchmark against which to measure potential medical costs, if any, that might be avoided by preventing incident cases.

Previous studies of the cost of diabetes (1,13) have used cross-sectional data and documented substantial economic costs associated with diabetes within a single year. Several studies (14,15) also have used claims-based longitudinal data or retrospective data to examine the annual medical costs of diabetes over a limited period of time after diagnosis. However, few national-level estimates of the lifetime medical costs of diabetes are available. The objective of this study is to provide nationally representative estimates of excess lifetime medical expenses attributable to diabetes.

RESEARCH DESIGN AND METHODS

We calculated excess lifetime medical spending attributable to diabetes in three steps. First, we estimated annual medical spending by diabetes status using data from nationally representative surveys. Second, based on published data, we derived sex- and age-specific annual survival rates by diabetes status and used those to adjust the estimated annual spending from step 1 to obtain survival-adjusted annual spending. Third, we aggregated survival-adjusted annual spending over the predicted remaining life span. The resulting lifetime medical spending estimate was compared by diabetes status to calculate the lifetime spending attributable to diabetes.

Data Sources

We used data from the 2006–2009 Medical Expenditure Panel Survey (MEPS), which were linked to 2005–2008 data from the National Health Interview Survey (NHIS) to estimate annual medical spending by diabetes status (16). MEPS is a survey of a nationally representative U.S. civilian noninstitutionalized population and is administered by the Agency for Healthcare Research and Quality. The MEPS sample is drawn from households that participated in the NHIS, which is conducted by the National Center for Health Statistics. Each year, a subsample of NHIS participants is randomly selected for inclusion in the following year's MEPS; the sample is retained in MEPS for 2 years. MEPS obtains information on participants' use of medical care and their medical spending, as well as information on demographics, socioeconomics, and health conditions. Medical expenditures are defined as the payments that health care providers receive from all payers (including insurance providers, survey respondents, and other sources). Insurance premiums are not included. Diagnosed diabetes was self-reported.

Because the NHIS includes information on age at diagnosis of diabetes, linking the surveys allowed us to estimate diabetic patients' medical spending by their age at diagnosis and duration of diagnosed diabetes at the time of the survey response. We excluded respondents who either reported having diabetes in the MEPS but not in the NHIS (n = 366) or reported having diabetes and starting insulin therapy before the age of 30 years (n = 284). Individuals in the latter group were excluded because they likely had type 1 diabetes, for which no effective prevention strategy exists (17). Individuals in the former group, while excluded from the base-case analyses, were included in the sensitivity analysis and assumed to have incident diagnosed diabetes for a duration of $<$2 years, which is the maximum time between the beginning of one NHIS data collection cycle and the end of the corresponding MEPS data cycle. Our final study sample included 2,827 respondents with diagnosed diabetes and 29,413 respondents without.

Statistical Analysis

Estimating Annual Medical Spending by Diabetes Status

A two-part model was used to estimate the annual medical spending for all participants in the study. This model was used to account for the positive skew of nonzero values and the large proportion of reports of zero medical expenses (18). In the first part, we used logistic regression to estimate the probability of an individual having nonzero medical expenses. In the second part, a generalized linear model with a log link function was used to model the annual medical spending given an individual with nonzero expenses. We performed a modified Park test and determined that a gamma variance function for the generalized linear model was appropriate. This variance function accounted for variance increasing as medical spending increased (18). In both parts of the model, we included self-reported diabetes diagnosis, years living with diagnosed diabetes and its square, age and age squared, and interaction terms between diabetes status and age and age squared as explanatory variables (15). We adjusted for sex, race/ethnicity, U.S. region of residence (e.g., Southwest), marital status, insurance coverage, educational attainment, and annual family income. We also adjusted for current smoking and self-reported chronic medical conditions including high cholesterol, arthritis, asthma, hypertension, and any current cancer. To account for potential changes in the costs of treating these other chronic conditions due to the presence of diabetes, interaction terms between diabetes and those conditions were included in the regressions. Details of the regression models appear in the Supplementary Data.

On the basis of the regression results, we predicted the mean annual medical spending of people with diabetes, stratified by sex, age at diagnosis, and diabetes duration, using the sample of only individuals with diabetes. The medical spending of people without diabetes was predicted by using the same sample of individuals with diabetes but setting the value of the diabetes status variable to zero. This counterfactual analytical method was used to ensure comparable population characteristics between those with and without diabetes. This was done to isolate the effect of diabetes on health care expenses (19). The standard errors for predicted mean annual medical spending were estimated using 1,000 nonparametric bootstrap iterations. All statistical analyses were conducted using Stata version 12 (StataCorp., College Station, TX).

Adjusting for Differences in the Probability of Survival

Diabetic patients are at a higher risk of premature death. Therefore, we need to account for the effect of different survival rates between people with and without diabetes on lifetime medical spending. To do this, we multiplied the estimated annual spending by the probability of individuals surviving through a given age. This allowed us to obtain the survival-adjusted annual spending for people with and without diabetes, which then was aggregated over individuals' remaining life spans. By comparing the resultant lifetime spending of people without diabetes with that of people with diabetes, we obtained the lifetime medical spending attributable to diabetes.

We derived age- and sex-specific survival rates for people with and without diabetes using mortality data from the U.S. Census Bureau, the Centers for Disease Control and Prevention (20), and two published studies of the relative risks of mortality associated with diabetes over a range of ages. One of these studies, by Saydah et al. (21), estimated the relative risk of all-cause mortality for people with and without diabetes using mortality data from the National Health and Nutrition Examination Survey. The second, a more recent study by Gregg et al. (22), found that relative risk had significantly declined over the previous decade. We combined findings from these two studies to estimate the relative risk of mortality for the study period. Technical details appear in the Supplementary Data.

We used these estimates of relative risk and Centers for Disease Control and Prevention estimates (20) for total mortality among the general population to derive the annual survival rates and life expectancies of people with and without diabetes. We estimated life-years lost because of diabetes as the difference between life expectancies for people with diabetes and those without diabetes (23).

We estimated the excess lifetime spending for people diagnosed with diabetes at ages 40, 50, 60, and 65 years. We set these upper and lower age limits because a relatively small proportion of diabetes cases are diagnosed before age 40, and 65 years is the age at which most U.S. citizens become eligible for Medicare. In addition, to understand the cost implications of Medicare, we estimated excess medical spending due to diabetes that occurred after age 65 for all patients regardless of age at diagnosis. In particular, for those who were still alive at age 65, we estimated and aggregated their health care spending for each year from age 65 years to the year of death. All spending was adjusted for inflation and expressed in 2012 dollars. Future spending was discounted at 3% per year. We also reported undiscounted spending for comparison with the results from existing cross-sectional studies.

Sensitivity Analyses

We reestimated annual medical spending by participants' diabetes status, including major diabetes-related cardiovascular complications (self-reported)—coronary heart disease, stroke, and congestive heart failure—as additional explanatory variables in the two-part model. Because diabetes is a risk factor for cardiovascular diseases, we excluded those variables from the base-case specification to prevent potential underestimation of diabetes' effect on medical spending. However, many patients with cardiovascular disease do not have a history of diabetes. By including those variables, the sensitivity analysis provided a lower bound for the medical spending attributed to diabetes. In addition, to address the uncertainty associated with the mortality estimates, we reestimated lifetime spending using the 2.5% lower and 97.5% upper confidence limits for the relative risk of mortality.

RESULTS

Population Characteristics

Table 1 presents the characteristics of study participants by diabetes status. The prevalence of participants with diabetes in the study population was 7.4%, of whom 54% were diagnosed between the ages of 45 and 64 years. The mean age at diagnosis was 55 years, and the mean length of time since diagnosis was 9.4 years (39% of participants with diabetes had been diagnosed for ≤5 years, 32% for 6–15 years, and 27% for ≥16 years). Adults with diabetes were, on average, 11 years older; had lower income; were more likely to be African American, Hispanic, and Native American; were more likely to be less educated; and were more likely to be covered by health nsurance than people without diabetes. The observed annual medical spending for people with diabetes was $13,966—more than twice that for people without diabetes.

Estimated Annual Medical Spending by Diabetes Status

Figure 1 shows survival-adjusted annual medical spending after diagnosis, as well as survival probabilities for people with and without diabetes. Information on medical spending without survival adjustment appears in the Supplementary Data. Regardless of diabetes status, the survival-adjusted annual medical spending decreased after age 60 years, primarily because of a decreasing probability of survival. Because the probability of survival decreased more rapidly in people with diabetes than in those without, corresponding spending declined as people died and no longer accrued medical costs. For example, among men diagnosed with diabetes at age 40 years, 34% were expected to survive to age 80 years; among men of the same age who never developed diabetes, 55% were expected to survive to age 80 years. The expected annual expenditure for a person diagnosed with diabetes at age 40 years declined from $8,500 per year at age 40 years to $3,400 at age 80 years, whereas the expenses for a comparable person without diabetes declined from $3,900 to $3,200 over that same interval.

The annual excess medical spending attributed to diabetes, as indicated by the average distance between the cost curves of those with diabetes and those without diabetes (Fig. 1), was smaller among people who were diagnosed at older ages. For men diagnosed at age 40 years, annual medical spending was $3,700 higher than that of similar men

Table 1—Characteristics of the U.S. population ≥30 years old with and without diagnosed diabetes

Characteristics	Diagnosed diabetes (*n* = 2,827)	No diagnosed diabetes (*n* = 29,413)
Mean age (years)	64.1 (63.4–64.9)	52.8* (52.5–53.2)
Female sex	54.1 (51.1–57.0)	55.2 (54.3–56.0)
Nonwhite	21.2 (18.7–23.7)	15.8* (14.8–16.8)
Family income less than 125% of federal poverty line	23.4 (21.2–25.5)	15.0* (14.3–15.7)
Less than high school education	11.9 (10.3–13.5)	5.1* (4.7–5.5)
Uninsured	6.3 (5.2–7.4)	11.5* (10.9–12.0)
History of cardiovascular disease	29.6 (26.8–32.4)	11.2* (10.6–11.8)
Mean age at diagnosis (years)	54.8 (54.0–55.5)	—
Mean time since diagnosis of diabetes (years)	9.4 (8.9–9.9)	—
Patients diagnosed by age range (years)		
30–44	23.8	—
45–54	27.9	—
55–64	26.4	—
≥65	21.8	—
Mean annual medical spending, USD†	13,966 (12,892–15,040)	5,543* (5,332–5,755)
Mean annual medical spending by years since diagnosis, USD†		
≤5 years	11,425 (10,108–12,742)	—
6–15 years	14,404 (12,910–15,898)	—
≥16 years	18,827 (15,184–22,471)	—

Data are percentages unless otherwise indicated. 95% CIs are presented in parentheses. *Significantly different ($P < 0.01$) compared with people with diabetes. †U.S. dollars at 2012 value. Medical Expenditure Panel Survey weights were used to calculate the estimates. The values here were calculated from linked data from the 2005–2008 National Health Interview Survey and the 2006–2009 Medical Expenditure Panel Survey.

without diabetes; spending was $2,900 higher for those diagnosed at age 50 years; $2,200 higher for those diagnosed at age 60 years; and $2,000 higher for those diagnosed at age 65 years. Among women diagnosed with diabetes, the excess annual medical spending was consistently higher than for men of the same age at diagnosis.

Lifetime Excess Medical Spending for Diabetes

Table 2 summarizes life expectancy after a diagnosis of diabetes, life-years lost, and lifetime excess medical spending attributed to diabetes. People diagnosed with diabetes at age 40 years lived with the disease for an average of 34 years after diagnosis. Those diagnosed when older lived fewer years and, therefore, lost fewer years of life.

People diagnosed with diabetes at age 40 years spent $124,600 more ($211,400 if not discounted) than their counterparts without diabetes over their remaining lifetime. For people diagnosed with diabetes at age 50 years, the discounted lifetime excess medical spending was $91,200 ($135,600 if not discounted); for those diagnosed at age 60 years, it was $53,800 ($70,200); and for those diagnosed at age 65 years, it was $35,900 ($43,900). Excess lifetime medical spending due to diabetes for women was higher than that for men. Regardless of age at diagnosis, people with diabetes spent considerably more on health care after age 65 years than their nondiabetic counterparts. Health care spending attributed to diabetes after age 65 years ranged from $23,900 to $40,900, depending on sex and age at diagnosis.

We further examined the components of medical spending attributable to diabetes. Of the total excess lifetime medical spending among an average diabetic patient diagnosed at age 50 years, prescription medications and inpatient care accounted for 44% and 35% of costs, respectively. Outpatient care and other medical care accounted for 17% and 4% of costs, respectively. More details about spending components appear in Supplementary Table 4.

Sensitivity Analysis

Including major diabetes-related cardiovascular complications in the two-part model decreased lifetime excess medical spending attributable to diabetes by amounts ranging from $1,500 to $25,000. This is because including those variables diluted the marginal effect of diabetes on medical spending, a finding consistent with those of previous studies (15,19). We observed the largest reduction among women diagnosed at age 40 years. When we varied the relative risk of mortality to the lower value of the 95% confidence intervals of the estimates, the lifetime excess medical spending increased by up to $14,000 from the base case; at the upper value it decreased by up to $20,000. When we included in the analysis people who reported having diabetes in MEPS but reported having no diabetes in NHIS, the lifetime excess medical spending decreased by up to $5,300. Detailed results from the sensitivity analyses appear in the Supplementary Data.

CONCLUSIONS

Despite a shorter life expectancy, people with diagnosed diabetes accumulated substantially greater lifetime medical spending than similar people without diabetes. The excess lifetime costs were smaller for people diagnosed at older ages, primarily because they had a shorter remaining life expectancy.

Our lifetime estimates were somewhat higher than the direct medical costs of treating type 2 diabetes and

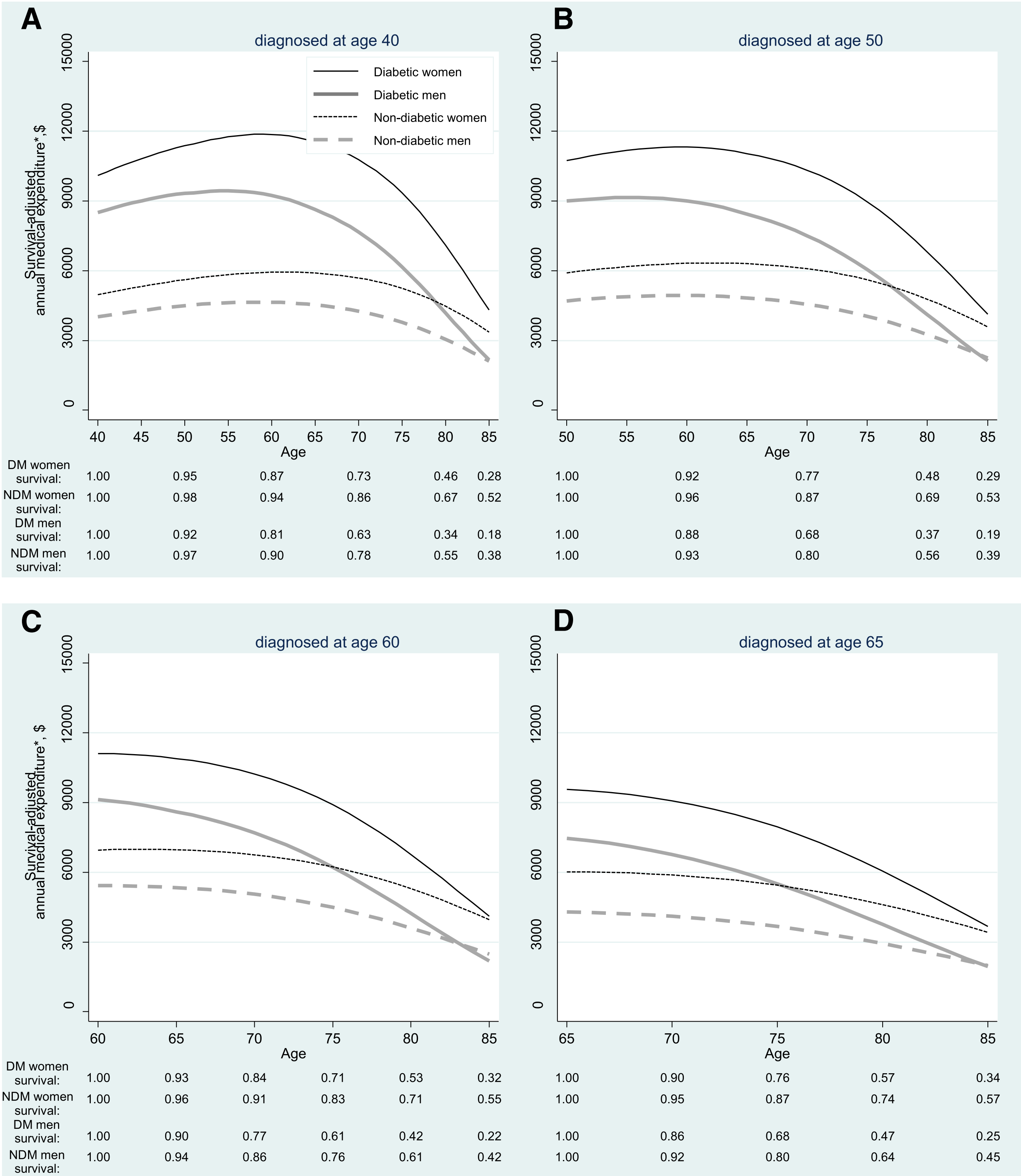

Figure 1—Average survival-adjusted annual medical expenditure (undiscounted) of people with diabetes diagnosed at age 40 (*A*), 50 (*B*), 60 (*C*), and 65 years (*D*) compared with similar people without diabetes. "Similar people" are defined as those with the same values for the characteristics that were included in our regression models. *Survival-adjusted annual medical expenditure was calculated by multiplying the probability of surviving to a given age by the expected annual medical spending at that age. It measures how much a newly diagnosed diabetic patient expect to spend at that age. Survival-adjusted annual medical expenditure in this figure is expressed in 2012 dollars but not discounted. DM, diabetes mellitus; NDM, no diabetes mellitus. Annual medical spending was estimated by the authors using linked data from the 2006–2009 Medical Expenditure Panel Survey and the 2005–2008 National Health Interview Survey. Survival rates were derived using the Centers for Disease Control and Prevention life table, Saydah et al. (21), and Gregg et al. (22).

Table 2—Life-years lost to diabetes and lifetime incremental medical spending attributed to diabetes

Age at diagnosis (years) by sex	Years with diagnosed diabetes	Life-years lost because of diabetes	Undiscounted lifetime incremental spending (SD), $	Discounted lifetime incremental spending (SD), $	Discounted spending among those aged ≥65 years (%)*
Women					
40	36.5	6.2	239,100 (50,200)	138,100 (29,200)	35,900 (26)
50	28.2	5.6	154,000 (30,100)	101,800 (20,300)	39,900 (39)
60	20.1	4.9	80,500 (17,400)	60,800 (13,400)	41,400 (68)
65	16.4	4.4	50,600 (16,900)	40,900 (13,700)	40,900 (100)
Men					
40	32.1	7.1	181,000 (38,400)	109,000 (23,300)	23,900 (22)
50	24.5	6.0	116,400 (23,200)	79,900 (16,200)	27,400 (34)
60	17.3	5.0	59,700 (13,700)	46,600 (10,700)	29,700 (64)
65	14.0	4.5	37,000 (13,400)	30,800 (10,900)	30,800 (100)
Both sexes					
40	34.3	6.7	211,400 (39,600)	124,600 (22,400)	29,900 (24)
50	26.3	5.9	135,600 (20,800)	91,200 (13,500)	33,600 (37)
60	18.7	5.0	70,200 (11,300)	53,800 (8,500)	35,600 (66)
65	15.3	4.5	43,900 (12,300)	35,900 (9,800)	35,900 (100)

All spending, except the undiscounted lifetime spending, is presented in 2012 U.S. dollars. *The percentages were calculated by dividing the incremental medical spending that occurred after age 65 by the lifetime incremental medical spending. Source: Linked data from the 2005–2008 National Health Interview Survey and the 2006–2009 Medical Expenditure Panel Survey and from published national vital statistics.

diabetes complications that we reported in a previous study (24). In that study we assessed only medical resources directly used to treat the disease, which were based on an evidence-based simulation model. Because it lacked a nondiabetic cohort for comparison, that study did not directly address the cost differences between people with and without diabetes. Those with diabetes tend to have higher medical costs because diabetes treatments are expensive. In addition, they may have higher costs because they also are treating conditions not directly related to diabetes, such as asthma. By directly comparing spending by diabetes status, the current study accounts for the latter costs. We also found that our estimated annual medical spending was comparable with the results of studies (14,15) that considered the effect of age at diagnosis and diabetes duration. However, compared with previous cross-sectional studies (13,15), our estimated annual medical spending was lower. We think that this was primarily because we considered the effect of the probability of survival. It may also be because medical expenditures collected in MEPS do not include expenses for long-term care.

Economic Importance of Diabetes Prevention

Over the past three decades, the number of Americans with diagnosed diabetes has more than tripled, from 6 million in 1980 to 21 million in 2010 (25). Given the current size of the U.S. population with diabetes, coupled with more than 79 million people with prediabetes who are at a high risk of developing type 2 diabetes (26), our lifetime cost estimates suggest that medical spending associated with diabetes will add an enormous burden to health care costs and will persist for at least the next several decades. For example, in 2011 nearly 150,000 Americans were diagnosed with diabetes between the ages of 65 and 69 years (27). Based on our estimates, this cohort of patients with newly diagnosed diabetes alone would be expected to add $4.6 billion to future medical spending, the majority of which would be paid by Medicare. Without effective diabetes prevention, increased medical spending due to diabetes will have a major fiscal impact on Medicare. As Thorpe and colleagues (28) suggested, the increasing prevalence of diabetes has been one of the leading causes of the growth in Medicare spending.

Impact of Diabetes Prevention on Costs

Cost is one consideration—but certainly not the only one—when implementing diabetes prevention strategies. However, because cost is the focus of this study, we address only the costs that could potentially be avoided if a case of diabetes is prevented. Knowing lifetime excess medical costs attributable to diabetes provides a benchmark from which to measure the maximum future medical costs that could be avoided by preventing diabetes. Assuming a sufficiently low cost of prevention, the substantial lifetime medical spending reported here implies that preventing diabetes would likely be an efficient use of health care resources. For example, prevention might avoid $124,600 in (discounted) lifetime medical spending if a new case of diabetes can be prevented at age 40 years. If prevented at age 50 years, (discounted) spending of $91,200 might be avoided over a lifetime. The actual savings from intervention, if any, certainly would depend on many factors. First, to save costs, interventions must be both effective at preventing diabetes and durable. Second, the cost of preventing a case of diabetes must be less than the potential lifetime cost of diabetes. A structured lifestyle modification program has been found to reduce the risk of diabetes by 50–58% (2,3). Furthermore, emerging studies suggest that such risk reduction could be achieved at a reasonably low cost (4). Our study adds to the existing evidence and suggests a favorable long-term financial return from diabetes prevention, if such prevention could be implemented efficiently.

Our findings differed from those of studies of the lifetime costs of other chronic conditions. For instance, smokers have a lower average lifetime medical cost than nonsmokers (29) because of their shorter life spans. Smokers have a life expectancy about 10 years less than those who do not smoke (30); life expectancy is 16 years less for those who develop smoking-induced cancers (31). As a result, smoking cessation leads to increased lifetime spending (32). Studies of the lifetime costs for an obese person relative to a person with normal body weight show mixed results: estimated excess lifetime medical costs for people with obesity range from $3,790 less to $39,000 more than costs for those who are nonobese (33,34). Two factors may help explain this difference: The impact of obesity on longevity remains unclear (35), but diabetes is known to be associated with a relatively modest loss of life-years (22). Also, obesity, when considered alone, results in much lower annual excess medical costs than diabetes (–$940 to $1,150 for obesity vs. $2,000 to $4,700 for diabetes) when compared with costs for people who are nonobese (33,34).

Implications for Medicare

Because the prevalence of diabetes is higher among people aged ≥65 years, the potential impact of the cost of diabetes prevention is particularly relevant to Medicare. Our analyses suggest that if diabetes could be efficiently prevented at age 65 years, $35,900 in medical spending could potentially be saved over the remaining lifetime (excluding prevention costs). Furthermore, similar cost savings could potentially be achieved by preventing diabetes at even earlier ages (e.g., 60 years). Although preventing diabetes among the current population aged ≥65 years might immediately save money more, investments in prevention among people who are currently younger than 65 years of age and who are at high risk for type 2 diabetes may financially benefit Medicare in the long run.

Limitations

First, we used retrospective data to extrapolate estimates for future costs, assuming that current diabetes treatment and the associated medical spending would remain stable. Diabetes treatment costs might change because of advances in medical technologies and increased longevity of people with diabetes. Our estimated lifetime excess costs from diabetes may be biased if the costs of future medical treatments for diabetes and other diseases differ from those of current treatments. Second, because data on medical costs at the age of death were not available from our sources, we could not compare differences in those costs between people with and without diabetes. However, because people with diabetes have a higher mortality, if they also have higher medical costs associated with death, the excess lifetime medical costs of diabetes would be higher than those indicated by our current estimates. Third, diabetes status was self-reported. We might have overstated the excess lifetime medical spending of diabetes if the excess costs for people with undiagnosed diabetes were less than those for people with a diabetes diagnosis. On the other hand, excess medical spending might have been understated if undiagnosed patients incurred more spending on diabetes complications in later stages. Fourth, because of limitations in the data, estimated survival rates were not based on the duration of diagnosed diabetes. Finally, MEPS is limited to the civilian noninstitutionalized population; therefore, spending for people receiving long-term care for disability-related reasons was not included in the analysis. Because people with diabetes might be more likely to be disabled, we might have underestimated the total lifetime spending.

Conclusion

Knowing the lifetime medical cost of diabetes is critical to understanding the long-term economic consequences of diabetes prevention. We found that lifetime medical costs of diabetes remain substantial, despite people with diabetes having shorter life expectancies than those without diabetes. Thus, assuming prevention costs can be kept sufficiently low, effective diabetes prevention efforts would likely lead to a reduction in long-term medical costs.

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References

1. American Diabetes Association. Economic costs of diabetes in the U.S. in 2012. Diabetes Care 2013;36:1033–1046
2. Knowler WC, Barrett-Connor E, Fowler SE, et al; Diabetes Prevention Program Research Group. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. N Engl J Med 2002;346:393–403
3. Knowler WC, Fowler SE, Hamman RF, et al; Diabetes Prevention Program Research Group. 10-Year follow-up of diabetes incidence and weight loss in the Diabetes Prevention Program Outcomes Study. Lancet 2009;374: 1677–1686
4. Ali MK, Echouffo-Tcheugui J, Williamson DF. How effective were lifestyle interventions in real-world settings that were modeled on the Diabetes Prevention Program? Health Aff (Millwood) 2012;31:67–75
5. Ackermann RT, Marrero DG. Adapting the Diabetes Prevention Program lifestyle intervention for delivery in the community: the YMCA model. Diabetes Educ. 2007;33:69, 74–75, 77–78.
6. Cohen JT, Neumann PJ, Weinstein MC. Does preventive care save money? Health economics and the presidential candidates. N Engl J Med 2008;358:661–663
7. Russell LB. Preventing chronic disease: an important investment, but don't count on cost savings. Health Aff (Millwood) 2009;28:42–45
8. Eddy DM, Schlessinger L, Kahn R. Clinical outcomes and cost-effectiveness of strategies for managing people at high risk for diabetes. Ann Intern Med 2005;143:251–264
9. Zhuo X, Zhang P, Gregg EW, et al. A nationwide community-based lifestyle program could delay or prevent type 2 diabetes cases and save $5.7 billion in 25 years. Health Aff (Millwood) 2012;31:50–60
10. Thorpe KE, Yang Z. Enrolling people with prediabetes ages 60-64 in a proven weight loss program could save Medicare $7 billion or more. Health Aff (Millwood) 2011;30:1673–1679
11. Colagiuri S, Walker AE. Using an economic model of diabetes to evaluate prevention and care strategies in Australia. Health Aff (Millwood) 2008;27:256–268
12. Lindgren P, Lindström J, Tuomilehto J, et al; DPS Study Group. Lifestyle intervention to prevent diabetes in men and women with impaired glucose tolerance is cost-effective. Int J Technol Assess Health Care 2007;23:177–183
13. American Diabetes Association. Economic costs of diabetes in the U.S. In 2007. Diabetes Care 2008;31:596–615
14. Brown JB, Nichols GA, Glauber HS, Bakst AW. Type 2 diabetes: incremental medical care costs during the first 8 years after diagnosis. Diabetes Care 1999;22:1116–1124
15. Trogdon JG, Hylands T. Nationally representative medical costs of diabetes by time since diagnosis. Diabetes Care 2008;31:2307–2311

16. Medical Expenditure Panel Survey [Internet], 2012. Rockville, MD, Agency for Healthcare Research and Quality. Available from http://meps.ahrq.gov/data_stats/download_data_files_detail.jsp?cboPufNumber=LINK_96-10MEPS/NHIS. Accessed 13 March 2014
17. National Diabetes Data Group. Diabetes in America, 2nd edition. NIH publication no. 95-14681995 [report on the Internet], updated 11 March 2013. Bethesda, MD, National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases. Available from http://diabetes.niddk.nih.gov/dm/pubs/america/contents.aspx. Accessed 13 March 2014
18. Manning WG, Mullahy J. Estimating log models: to transform or not to transform? J Health Econ 2001;20:461–494
19. Honeycutt AA, Segel JE, Hoerger TJ, Finkelstein EA. Comparing cost-of-illness estimates from alternative approaches: an application to diabetes. Health Serv Res 2009;44:303–320
20. Arias E. United States life tables, 2007. Natl Vital Stat Rep 2011;59:1–60
21. Saydah SH, Eberhardt MS, Loria CM, Brancati FL. Age and the burden of death attributable to diabetes in the United States. Am J Epidemiol 2002;156:714–719
22. Gregg EW, Cheng YJ, Saydah S, et al. Trends in death rates among U.S. adults with and without diabetes between 1997 and 2006: findings from the National Health Interview Survey. Diabetes Care 2012;35:1252–1257
23. Narayan KM, Boyle JP, Thompson TJ, Sorensen SW, Williamson DF. Lifetime risk for diabetes mellitus in the United States. JAMA 2003;290:1884–1890
24. Zhuo X, Zhang P, Hoerger TJ. Lifetime direct medical costs of treating type 2 diabetes and diabetic complications. Am J Prev Med 2013;45:253–261
25. Crude and age-adjusted percentage of civilian, noninstitutionalized adults with diagnosed diabetes, United States, 1980–2010 [Internet], updated 12 April 2013. Atlanta, GA, Centers for Disease Control and Prevention. Available from http://www.cdc.gov/diabetes/statistics/prev/national/figageadult.htm. Accessed 13 March 2014
26. National diabetes fact sheet, 2011 [report on the Internet]. Atlanta, GA, Centers for Disease Control and Prevention. Available from http://www.cdc.gov/diabetes/pubs/pdf/ndfs_2011.pdf. Accessed 13 March 2014
27. Distribution of age at diagnosis of diabetes among adult incident cases aged 18–79 years, United States, 1980–2010 [Internet], updated 18 January 2013. Atlanta, GA, Centers for Disease Control and Prevention. Available from http://www.cdc.gov/diabetes/statistics/age/fig1.htm. Accessed 13 March 2014
28. Thorpe KE, Ogden LL, Galactionova K. Chronic conditions account for rise in Medicare spending from 1987 to 2006. Health Aff (Millwood) 2010;29:718–724
29. Barendregt JJ, Bonneux L, van der Maas PJ. The health care costs of smoking. N Engl J Med 1997;337:1052–1057
30. Doll R, Peto R, Boreham J, Sutherland I. Mortality in relation to smoking: 50 years' observations on male British doctors. BMJ 2004;328:1519
31. Cancer trends progress report – 2011/2012 update [Internet], 2012. Bethesda, MD, National Institutes of Health. Available from http://progressreport.cancer.gov/index.asp. Accessed 13 March 2014
32. Goldman DP, Zheng Y, Girosi F, et al. The benefits of risk factor prevention in Americans aged 51 years and older. Am J Public Health 2009;99:2096–2101
33. Finkelstein EA, Trogdon JG, Brown DS, Allaire BT, Dellea PS, Kamal-Bahl SJ. The lifetime medical cost burden of overweight and obesity: implications for obesity prevention. Obesity (Silver Spring) 2008;16:1843–1848
34. Lakdawalla DN, Goldman DP, Shang B. The health and cost consequences of obesity among the future elderly. Health Aff (Millwood) 2005;24(Suppl. 2):W5R30–W5R41
35. Adams KF, Schatzkin A, Harris TB, et al. Overweight, obesity, and mortality in a large prospective cohort of persons 50 to 71 years old. N Engl J Med 2006;355:763–778