# Trends in Health Care Expenditure in U.S. Adults With Diabetes: 2002–2011

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EPIDEMIOLOGY/HEALTH SERVICES RESEARCH


## OBJECTIVE

**Direct medical cost of diabetes in the U.S. has been estimated to be 2.3 times higher relative to individuals without diabetes. This study examines trends in health care expenditures by expenditure category in U.S. adults with diabetes between 2002 and 2011.**

## RESEARCH DESIGN AND METHODS

**We analyzed 10 years of data representing a weighted population of 189,013,514 U.S. adults aged ≥18 years from the Medical Expenditure Panel Survey. We used a novel two-part model to estimate adjusted mean and incremental medical expenditures by diabetes status, while adjusting for demographics, comorbidities, and time.**

## RESULTS

**Relative to individuals without diabetes ($5,058 [95% CI 4,949–5,166]), individuals with diabetes ($12,180 [11,775–12,586]) had more than double the unadjusted mean direct expenditures over the 10-year period. After adjustment for confounders, individuals with diabetes had $2,558 (2,266–2,849) significantly higher direct incremental expenditures compared with those without diabetes. For individuals with diabetes, inpatient expenditures rose initially from $4,014 in 2002/2003 to $4,183 in 2004/2005 and then decreased continuously to $3,443 in 2010/2011, while rising steadily for individuals without diabetes. The estimated unadjusted total direct expenditures for individuals with diabetes were $218.6 billion/year and adjusted total incremental expenditures were approximately $46 billion/year.**

## CONCLUSIONS

**Our findings show that compared with individuals without diabetes, individuals with diabetes had significantly higher health expenditures from 2002 to 2011 and the bulk of the expenditures came from hospital inpatient and prescription expenditures.**


Diabetes is a global epidemic affecting nearly 29.1 million people in the U.S. (1–3) and about 382 million people worldwide (4). The global prevalence is projected to increase by 35% by 2035 (4). Diabetes is the seventh leading cause of death in the U.S. (5,6) and ranks ninth as a global cause of death (7). Deaths from diabetes are on the increase worldwide (7) but are decreasing in the U.S. (8).

The growing prevalence of diabetes imposes a substantial financial burden on affected individuals and their families, communities, and country (2,3). Globally, at

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least $548.5 billion was spent on diabetes-related expenditures (9), and in the U.S., direct medical costs associated with diabetes were $176 billion in 2012 (1,3). This is almost double to eight times the direct medical cost of other chronic diseases: $32 billion for COPD in 2010 (10), $93 billion for all cancers in 2008 (11), $21 billion for heart failure in 2012 (12), and $43 billion for hypertension in 2010 (13). In the U.S., total economic cost of diabetes rose by 41% from 2007 to 2012 (2). Furthermore, individuals with diabetes spend about $7,900/year on diabetes-related medical expenditures (2); high rates of inpatient hospitalization and diabetes-related complications account for a major part (14–16).

Studies examining the cost of diabetes and its related complications exist (2,16–22). However, the majority has studied either just a single year or one part of health care expenditures, such as out-of-pocket expenditures or cost trends in a managed care setting. In this study, we examine the changes over time in direct health care expenditures in U.S. adults with diabetes from 2002 to 2011 using a novel cost estimation methodology and a nationally representative survey. The cost methodology used in this study addresses the probability of observing a zero versus positive medical expenditure and a generalized linear model (GLM) was estimated conditional on having a medical expenditure.

## RESEARCH DESIGN AND METHODS

### Data Source and Sample

In this retrospective study, we analyzed a weighted population representing 189,013,514 U.S. adults aged >17 years from 2002 to 2011 using the Medical Expenditure Panel Survey Household Component (MEPS-HC). The MEPS provides nationally representative estimates of health care use, expenditures, sources of payment, and health insurance coverage for the U.S. civilian noninstitutionalized population (23). The panel design of the survey includes five rounds of interviews covering two full calendar years and provides data for examining person-level changes in selected variables such as expenditures and health status (23). The MEPS has a complex design that includes clustering, stratification, and multistage and disproportionate sampling with oversampling of minorities (24). The 2002–2011 costs were adjusted to 2014 dollar value using the consumer price index obtained from the Bureau of Labor Statistics (25).

We combined 10 years of data because they have a common variance structure necessary to ensure compatibility of our variables within the complex sample design (26). Additionally, pooled data increase the sample size and the precision of the estimates for the diabetes subpopulation and aid the evaluation of trends in health care expenditures over time (27). We adjusted the analytic sampling weight variable by dividing with the number of years pooled. The sum of these adjusted weights represents the average annual population size for the pooled period. The total of estimates was based on adjusted weights in order to reflect an "average annual" rather than the entire pooled period (28). Our study accounts for the sampling weights, clustering, and stratification design to estimate the nationally representative aggregate for unadjusted and adjusted health care expenditures in individuals with diabetes in the U.S. population (23).

### Measures

#### *Cost Variables*

The dependent variable was total direct health care expenditures for the calendar year for each individual, including out-of-pocket payments and payments by private insurance, Medicaid, Medicare, and other sources (23). Medical expenditures include office-based medical provider, hospital outpatient, emergency room (ER), inpatient hospital (including zero night stays), pharmacy, dental, home health care, and other medical expenditures (23).

#### *Diabetes*

The primary independent variable was self-reported diabetes measured as a yes response to the question, "Have you ever been diagnosed with diabetes?"

#### *Covariates*

All covariates used for this analysis were based on self-report. We included the comorbidities as binary indicators based on a positive response to the question, "Have you ever been diagnosed with hypertension, stroke, emphysema, joint pain, arthritis, or asthma?" Cardiovascular disease (CVD) indicates a positive response to a question, "Have you ever been diagnosed with coronary heart disease, angina, myocardial infarction, or other heart diseases?" Race/ethnicity groups were categorized as non-Hispanic white (NHW), non-Hispanic black (NHB), and Hispanic/other race. Education was coded as less than high school (≤grade 11), high school, and college or more (grade ≥13). Marital status was coded as married, nonmarried (divorced, separated, or widowed), and never married. Sex was coded as female versus male, and age was coded as 18–44, 45–64, and 65–85 years. Census region was categorized as Northeast, Midwest, South, and West. Metropolitan statistical area was coded as yes versus no at end of the year (31 December). Health insurance was coded in three categories: private, public only, and uninsured at all times in the year. Income level was defined as a percentage of the poverty level and coded as poor or negative income (<100%), low income (≥100 to <200%), middle income (≥200 to <400%), and high income (≥400%). Calendar year was coded in five categories: 2002/2003, 2004/2005, 2006/2007, 2008/2009, and 2010/2011 for the pooled data.

### Statistical Analyses

We followed Manning and Mullahy's recommendation of a two-part general linear model that allows for mixed discrete-continuous variables (29). A probit model was first estimated for the probability of observing a zero versus positive medical expenditure, and then a GLM was estimated conditional on having a positive medical expenditure (30–32). The model addresses the zero concentration as well as the positive skewness of expenditures (33) and allows users to calculate incremental effects and standard errors from the two parts of the model (30). Generalizability of the study findings to the U.S. population was ensured by taking into account the complex design of the MEPS via sampling weight, variance estimation stratum, and primary sampling unit (clustering). The weighted model was used to estimate trends in medical expenditures in adults with diabetes and the adjusted burden of medical expenditures for individuals with diabetes on the U.S. population. We adjusted for sociodemographic factors (age, sex, race,

marital status, education, health insurance, metropolitan statistical area, region, and income level) and comorbidities (hypertension, CVD, stroke, emphysema, joint pain, arthritis, and asthma).

A modified park test (27,29,30) was used to verify that Poisson distribution (coefficient of $\lambda = 0.8$) with a log link was the best-fitting GLM to get consistent estimation of coefficients and incremental effects of medical expenditures. The variance inflation factor for all predictors used in the two-part model ranged from 1.0 to 1.8, indicating no multicollinearity problems. The F test for the model indicated that the model was significant. All analyses used person-level weights and were performed using STATA 13.

## RESULTS

### Characteristics of U.S. population 2002–2011

Of the weighted population representing 189,013,514 U.S. adults aged >17 years, 9.5% had diabetes. As shown in Table 1, significant differences in diabetes status were found by time, specific demographic characteristics, and comorbid conditions. Diabetes was more likely in NHB and Hispanics/other race, ≥45 years of age, men, married and nonmarried, ≤high school, publicly insured, rural and southern dwellers, and poor, low, and middle income earners. Individuals with diabetes were more likely to have all comorbidities examined, and diabetes prevalence appeared to increase in 2006/2007, 2008/2009, and 2010/2011.

**Table 1—Weighted sample demographics by diabetes status among U.S. adults 2002–2011**

| Variables | All | Diabetes | No diabetes | *P* value* |
|---|---|---|---|---|
| *n* | 189,013,514 | 17,950,960 (9.5%) | 171,062,554 (90.5%) | |
| Age (years) | | | | <0.001 |
| 18–44 | 45.7 | 13.4 | 49.0 | |
| 45–64 | 35.3 | 46.6 | 34.2 | |
| 65–85 | 19.0 | 40.0 | 16.8 | |
| Sex | | | | <0.001 |
| Male | 45.6 | 48.7 | 45.2 | |
| Female | 54.4 | 51.3 | 54.8 | |
| Race/ethnicity | | | | <0.001 |
| NHW | 72.1 | 64.3 | 72.9 | |
| NHB | 10.5 | 15.4 | 10.0 | |
| Hispanic or other | 17.4 | 20.3 | 17.1 | |
| Marital status | | | | <0.001 |
| Married | 55.4 | 58.4 | 55.1 | |
| Nonmarried | 21.4 | 32.4 | 20.2 | |
| Never married | 23.2 | 9.2 | 24.7 | |
| Education | | | | <0.001 |
| <High school | 17.4 | 26.1 | 16.5 | |
| High school | 30.5 | 34.4 | 30.1 | |
| College or more | 52.1 | 39.5 | 53.4 | |
| Insurance | | | | <0.001 |
| Private | 72.0 | 60.7 | 73.2 | |
| Public | 16.5 | 31.6 | 14.9 | |
| Uninsured | 11.5 | 7.7 | 11.9 | |
| Metropolitan statistical status | | | | <0.001 |
| Urban | 82.8 | 79.8 | 83.2 | |
| Rural | 17.2 | 20.2 | 16.8 | |
| Census region | | | | <0.001 |
| Northeast | 18.7 | 18.1 | 18.7 | |
| Midwest | 22.8 | 21.1 | 23.1 | |
| South | 36.0 | 40.1 | 35.5 | |
| West | 22.5 | 20.7 | 22.7 | |
| Income | | | | <0.001 |
| Poor income | 11.0 | 14.1 | 10.7 | |
| Low income | 17.0 | 22.4 | 16.5 | |
| Middle income | 30.2 | 30.4 | 30.1 | |
| High income | 41.8 | 33.1 | 42.7 | |
| Chronic conditions | | | | |
| Hypertension | 32.9 | 72.9 | 28.7 | <0.001 |
| CVD | 13.7 | 31.8 | 11.8 | <0.001 |
| Stroke | 3.5 | 10.4 | 2.8 | <0.001 |
| Emphysema | 2.1 | 4.9 | 1.8 | <0.001 |
| Joint pain | 37.9 | 55.8 | 36.0 | <0.001 |
| Arthritis | 26.1 | 48.5 | 23.8 | <0.001 |
| Asthma | 10.5 | 13.6 | 10.1 | <0.001 |
| Year | | | | <0.001 |
| 2002/2003 | 19.2 | 15.5 | 19.6 | |
| 2004/2005 | 19.5 | 17.9 | 19.7 | |
| 2006/2007 | 19.9 | 20.2 | 19.8 | |
| 2008/2009 | 20.5 | 22.8 | 20.3 | |
| 2010/2011 | 20.9 | 23.6 | 20.6 | |

Data are % unless otherwise indicated. *Level of significance $P < 0.05$ for each category.

### Unadjusted Cost Differences Between Individuals With and Without Diabetes

The total mean unadjusted direct expenditures for individuals with diabetes increased from $11,667 (95% CI 10,970–12,363) in 2002/2003 to $12,802 (11,767–13,835) in 2004/2005, and then declined continuously to $11,751 (11,054–12,448) in 2010/2011 (Table 2 and Fig. 1). Total mean unadjusted medical expenditures for individuals without diabetes increased continuously from $4,651 (4,407–4,896) in 2002/2003 to $5,528 (5,293–5,763) in 2010/2011. Relative to individuals without diabetes ($5,058 [4,949–5,166]), individuals with diabetes had more than double ($12,180 [11,775–12,586]) the unadjusted pooled mean expenditures over the 10-year period examined (Table 2).

In people with diabetes, the unadjusted inpatient expenditures rose initially from $4,014 (95% CI 3,457–4,573) in 2002/2003 to $4,183 (3,488–4,879) in 2004/

**Table 2—Unadjusted means of total health care and health care service expenditures by diabetes status**

| | Diabetes, mean ($) | 95% CI | No diabetes, mean ($) | 95% CI | *P* value* |
|---|---|---|---|---|---|
| Total cost | | | | | |
| 2002/2003 | 11,667.0 | 10,970.4–12,363.6 | 4,651.8 | 4,407.2–4,896.2 | <0.001 |
| 2004/2005 | 12,801.6 | 11,767.2–13,835.9 | 4,959.9 | 4,698.6–5,221.2 | <0.001 |
| 2006/2007 | 12,434.9 | 11,566.4–13,303.4 | 4,978.7 | 4,790.8–5,166.6 | <0.001 |
| 2008/2009 | 12,261.8 | 11,521.7–13,001.9 | 5,146.2 | 4,968.1–5,324.1 | <0.001 |
| 2010/2011 | 11,751.4 | 11,054.4–12,448.3 | 5,528.4 | 5,293.8–5,763.0 | <0.001 |
| Pooled sample | 12,180.9 | 11,775.2–12,586.6 | 5,058.1 | 4,949.7–5,166.5 | <0.001 |
| Inpatient | | | | | |
| 2002/2003 | 4,014.7 | 3,456.8–4,572.5 | 1,444.5 | 1,238.9–1,650.0 | <0.001 |
| 2004/2005 | 4,183.2 | 3,487.9–4,878.5 | 1,423.9 | 1,298.7–1,549.2 | <0.001 |
| 2006/2007 | 4,053.6 | 3,464.2–4,643.1 | 1,427.3 | 1,304.6–1,549.9 | <0.001 |
| 2008/2009 | 3,676.5 | 3,210.0–4,142.9 | 1,378.2 | 1,267.1–1,489.2 | <0.001 |
| 2010/2011 | 3,443.8 | 2,984.0–3,903.6 | 1,632.6 | 1,469.6–1,795.6 | <0.001 |
| Pooled sample | 3,840.8 | 3,580.3–4,101.4 | 1,462.3 | 1,390.4–1,534.2 | <0.001 |
| Office based | | | | | |
| 2002/2003 | 1,973.2 | 1,847.9–2,098.5 | 1,049.0 | 1,014.4–1,083.5 | <0.001 |
| 2004/2005 | 2,568.5 | 2,170.7–2,966.2 | 1,179.3 | 1,124.0–1,234.6 | <0.001 |
| 2006/2007 | 2,343.6 | 2,168.7–2,518.6 | 1,275.4 | 1,209.7–1,341.1 | <0.001 |
| 2008/2009 | 2,443.1 | 2,268.8–2,617.5 | 1,332.3 | 1,275.8–1,388.8 | <0.001 |
| 2010/2011 | 2,377.8 | 2,151.4–2,604.2 | 1,360.6 | 1,299.5–1,421.7 | <0.001 |
| Pooled sample | 2,357.3 | 2,244.4–2,470.1 | 1,241.2 | 1,213.9–1,268.5 | <0.001 |
| Medications | | | | | |
| 2002/2003 | 3,298.4 | 3,162.0–3,434.9 | 911.2 | 876.2–946.2 | <0.001 |
| 2004/2005 | 3,546.5 | 3,366.4–3,726.7 | 1,032.1 | 983.4–1,080.9 | <0.001 |
| 2006/2007 | 3,709.7 | 3,506.7–3,912.7 | 1,041.9 | 991.4–1,092.4 | <0.001 |
| 2008/2009 | 3,624.0 | 3,436.0–3,812.1 | 1,070.5 | 1,018.8–1,122.2 | <0.001 |
| 2010/2011 | 3,601.6 | 3,382.8–3,820.4 | 1,178.6 | 1,081.4–1,275.8 | <0.001 |
| Pooled sample | 3,571.9 | 3,473.5–3,670.2 | 1,048.3 | 1,017.9–1,078.7 | <0.001 |
| Outpatient | | | | | |
| 2002/2003 | 812.9 | 693.1–932.7 | 528.4 | 489.3–567.4 | <0.001 |
| 2004/2005 | 1,079.8 | 837.8–1,321.8 | 496.9 | 462.0–531.9 | <0.001 |
| 2006/2007 | 877.9 | 758.0–997.7 | 477.9 | 440.8–515.0 | <0.001 |
| 2008/2009 | 1,039.0 | 780.1–1,297.8 | 503.1 | 448.2–558.0 | <0.000 |
| 2010/2011 | 955.8 | 772.2–1,139.3 | 528.1 | 484.8–571.4 | <0.000 |
| Pooled sample | 959.0 | 867.5–1,050.6 | 507.0 | 486.2–527.8 | <0.001 |
| Dental | | | | | |
| 2002/2003 | 281.7 | 245.8–317.6 | 338.7 | 324.9–352.5 | 0.003 |
| 2004/2005 | 313.5 | 263.6–363.4 | 338.4 | 324.3–352.5 | 0.326 |
| 2006/2007 | 337.6 | 289.4–385.8 | 345.4 | 331.0–359.9 | 0.751 |
| 2008/2009 | 329.0 | 279.9–378.0 | 342.2 | 325.0–359.4 | 0.600 |
| 2010/2011 | 332.4 | 276.8–388.0 | 324.6 | 307.2–341.9 | 0.786 |
| Pooled sample | 321.4 | 297.4–345.5 | 337.8 | 330.0–345.6 | 0.184 |
| ER | | | | | |
| 2002/2003 | 242.9 | 206.7–279.1 | 157.8 | 148.2–167.3 | <0.001 |
| 2004/2005 | 258.8 | 207.7–309.9 | 182.1 | 168.6–195.5 | 0.005 |
| 2006/2007 | 290.1 | 247.6–332.7 | 184.2 | 172.0–196.4 | <0.001 |
| 2008/2009 | 383.1 | 244.4–521.8 | 220.4 | 202.6–238.2 | 0.021 |
| 2010/2011 | 351.4 | 302.5–400.2 | 220.1 | 205.2–235.0 | <0.001 |
| Pooled sample | 312.9 | 276.6–349.2 | 193.3 | 186.6–200.1 | <0.001 |
| Home health | | | | | |
| 2002/2003 | 798.9 | 626.3–971.4 | 117.2 | 90.9–143.5 | <0.001 |
| 2004/2005 | 619.7 | 483.7–755.7 | 200.4 | 40.7–360.1 | <0.001 |
| 2006/2007 | 614.7 | 454.1–775.3 | 123.4 | 103.1–143.6 | <0.001 |
| 2008/2009 | 598.0 | 452.7–743.2 | 196.9 | 142.3–251.5 | <0.001 |
| 2010/2011 | 498.4 | 391.4–605.4 | 182.9 | 144.5–221.2 | <0.001 |
| Pooled sample | 612.8 | 542.5–683.2 | 164.5 | 128.2–200.8 | <0.001 |
| Other | | | | | |
| 2002/2003 | 244.0 | 208.2–279.8 | 104.7 | 96.5–113.0 | <0.001 |
| 2004/2005 | 231.2 | 191.7–270.7 | 106.3 | 100.3–112.6 | <0.001 |
| 2006/2007 | 207.3 | 166.9–247.7 | 102.8 | 95.5–110.0 | <0.001 |
| 2008/2009 | 168.8 | 141.7–196.0 | 102.2 | 94.7–109.7 | <0.001 |
| 2010/2011 | 189.9 | 148.3–231.6 | 100.6 | 93.0–108.2 | <0.001 |
| Pooled sample | 204.4 | 186.4–222.3 | 103.3 | 99.7–106.9 | <0.001 |

Inpatient, hospital inpatient; outpatient, hospital outpatient. *Level of significance $P < 0.05$.

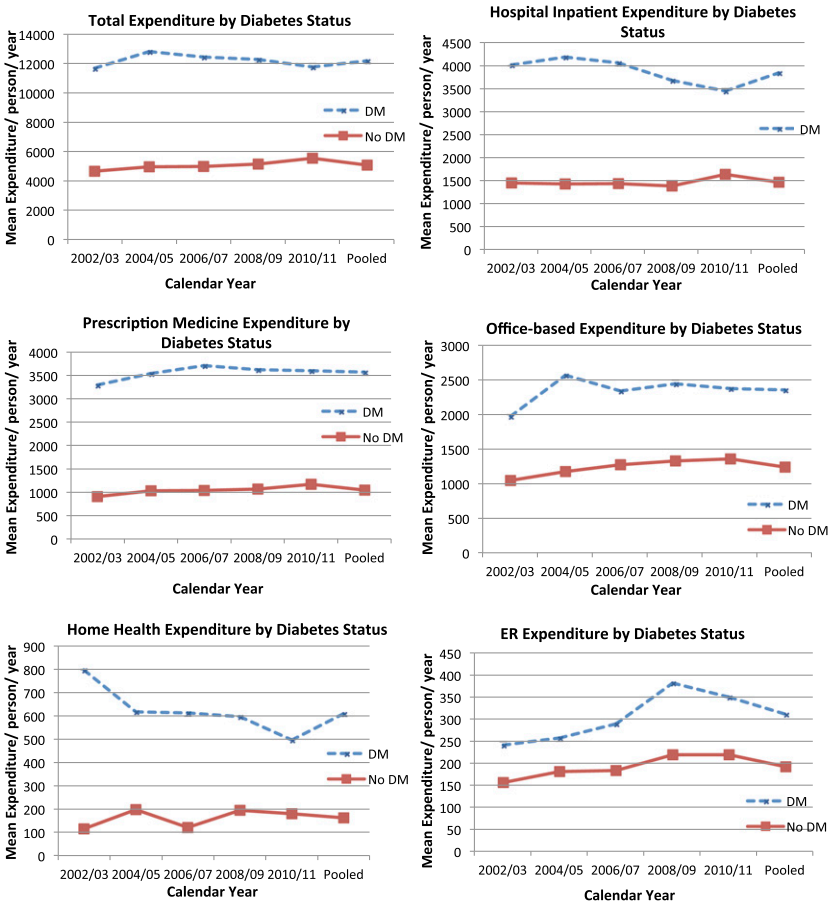


**Figure 1**—Trends in total direct health care expenditures and health care services by diabetes status. DM, diabetes.

2005, and then decreased continuously to $3,443 (2,984–3,904) through 2010/2011 (Table 2 and Fig. 1). Individuals without diabetes had declining inpatient hospital expenditures from 2002/2003 ($1,444 [1,239–1,650]) through 2008/2009 ($1,378 [1,267–1,489]) but then increased in 2010/2011 ($1,632 [1,470–1,796]), exceeding 2002–2009 levels.

As shown in Table 2, prescription medicine expenditures increased from 2002/2003 through 2006/2007 ($3,298 to $3,709) and then decreased slightly from 2006/2007 through 2010/2011 ($3,709 to $3, 601) but remained higher than 2002/2003 levels. Trends in office-based and hospital outpatient expenditures were similar; 2010/2011 expenditures were higher than 2002/2003 and 2006/2007; however, 2004/2005 and 2008/2009 expenditures were the peak years. ER expenditures rose from 2002/2003 through 2008/2009 and peaked at $383 (95% CI 244–522) and then fell to $351 (303–400) in 2010/2011 but remained higher than pre-2008 levels. Although ER expenditures in individuals without diabetes rose throughout the 10 years examined, the levels never reached the lowest ER expenditure year for people with diabetes. Trends in home health expenditures decreased from 2002/2003 through 2010/2011 among people with diabetes but showed no trend in people without diabetes.

### Adjusted Cost Differences Between Individuals With and Without Diabetes

After adjusting for relevant covariates as well as time, individuals with diabetes had $2,558 (95% CI 2,266–2,849) significantly higher expenditures compared with those without diabetes (Table 3). Individuals aged ≥45 years had significantly higher expenditures relative to those aged 18–44 years. Being female, ≥high school graduate, urban resident, and publicly insured were significantly associated with higher total health care expenditures. NHB or Hispanic/other race, nonmarried, never married, uninsured, residence in the South, and low, middle, or high income were significantly associated with lower total health care expenditures. All comorbidities were associated with significantly higher expenditures. Compared with 2002/2003, adjusted mean expenditures were significantly higher by $433 (95% CI 140–726) in 2004/2005, $373 (88–660) in 2006/2007, and $342 (53–631) in 2010/2011 (Table 3).

### Estimated U.S. Burden of Diabetes

Based on the average yearly estimate, unadjusted total direct health care expenditures for adults with diabetes in the U.S. population were approximately $218.6 billion/year and adjusted total incremental expenditures were approximately $46 billion/year.

## CONCLUSIONS

Our findings show that compared with individuals without diabetes, individuals with diabetes had significantly higher health expenditures from 2002 to 2011 and the bulk of the expenditures came from hospital inpatient and prescription expenditures. Trends in total direct health care expenditures among adults with diabetes increased initially but then declined from 2004/2005 through 2010/2011. People with diabetes had more than two times higher total direct health care expenditures compared with people without diabetes. Hospital inpatient stay, prescription medicine, and office-based visit were 2.6, 3.4, and 1.9 times higher in people with diabetes, respectively, compared with people without diabetes. Other factors associated with increased health care cost in the U.S. were age ≥45 years, ≥high school degree, public insurance status, urban dwellers, and presence of comorbidities, whereas being minority, unmarried (non- and never married), uninsured, residence in the South, and low, middle, or high income earners were associated with decreased cost.

Existing studies (2,20,21) on the cost of diabetes have examined 1–3-year periods or studied limited categories of health care expenditures. This study has several major contributions: *1*) the ability to examine trends in cost using a nationally representative survey; *2*)

**Table 3—Two-part regression model: incremental effects of health care expenditures by diabetes status among U.S. adults accounting for relevant covariates (adjusted to 2014 dollars)**

| Variables | Incremental cost | 95% CI | *P* value |
|---|---|---|---|
| Primary independent variable | | | |
| No diabetes | – | – | – |
| Diabetes | 2,557.9*** | 2,266.6 to 2,849.2 | 0.000 |
| Covariates | | | |
| Age 18–44 years | – | – | – |
| Age 45–64 years | 1,450.9*** | 1,204.0 to 1,697.7 | 0.000 |
| Age 65–85 years | 1,788.4*** | 1,511.7 to 2,065.1 | 0.000 |
| Male | – | – | – |
| Female | 582.3*** | 375.7 to 788.9 | 0.000 |
| NHW | – | – | – |
| NHB | −377.5*** | −603.8 to −151.1 | 0.001 |
| Hispanic or others | −863.6*** | −1,169.3 to −557.8 | 0.000 |
| Married | – | – | – |
| Nonmarried | −199.9** | −394.2 to −5.6 | 0.044 |
| Never married | −391.8*** | −678.6 to −105.1 | 0.007 |
| <High school | – | – | – |
| High school | 420.5*** | 171.1 to 699.9 | 0.001 |
| College or more | 649.8*** | 441.2 to 858.5 | 0.000 |
| Private | – | – | – |
| Public insured | 495.9*** | 229.9 to 762.0 | 0.000 |
| Uninsured | −3,209.7*** | −3,409.2 to −3,010.1 | 0.000 |
| Rural | – | – | – |
| Urban | 390.6*** | 188.9 to 592.2 | 0.000 |
| Northeast | – | – | – |
| Midwest | 167.2 | −152.4 to 487.0 | 0.305 |
| South | −329.0** | −625.0 to −34.7 | 0.028 |
| West | 74.0 | −299.1 to 447.2 | 0.697 |
| Poor income | – | – | – |
| Low income | −629.3*** | −949.3 to −309.2 | 0.000 |
| Middle income | −1,045.2*** | −1,371.9 to −718.4 | 0.000 |
| High income | −931.4*** | −1,289.0 to −573.7 | 0.000 |
| No hypertension | – | – | – |
| Hypertension | 1,290.4*** | 1,105.4 to 1,475.5 | 0.000 |
| No CVD | – | – | – |
| CVD | 3,373.6*** | 3,068.0 to 3,679.2 | 0.000 |
| No stroke | – | – | – |
| Stroke | 2,501.8*** | 2,042.8 to 2,960.7 | 0.000 |
| No emphysema | – | – | – |
| Emphysema | 1,854.6*** | 1,376.6 to 2,332.5 | 0.000 |
| No joint pain | – | – | – |
| Joint pain | 1,152.5*** | 934.4 to 1,370.5 | 0.000 |
| No arthritis | – | – | – |
| Arthritis | 1,538.0*** | 1,314.6 to 1,761.3 | 0.000 |
| No asthma | – | – | – |
| Asthma | 1,395.5*** | 1,039.7 to 1,751.3 | 0.000 |
| Year 2002/2003 | – | – | – |
| Year 2004/2005 | 433.1*** | 140.1 to 726.2 | 0.004 |
| Year 2006/2007 | 373.9*** | 87.8 to 660.1 | 0.010 |
| Year 2008/2009 | 102.7 | −166.2 to 371.8 | 0.454 |
| Year 2010/2011 | 342.2** | 53.2 to 631.2 | 0.020 |

Primary outcome variable in this model is total health care expenditures. ***Level of significance $P \leq 0.01$. **Level of significance $P \leq 0.05$.

the use of multiple cost categories, including inpatient, outpatient, prescription medications, dental, ER, and home health expenditures; *3*) the use of a novel cost methodology that addresses the limitation of prior studies and provides ways of evaluating incremental cost; *4*) the inclusion of a variety of comorbidities so that the effect observed is an independent effect of diabetes; *5*) the use of a pooled analysis that provides a large sample size; and *6*) the inclusion of unadjusted cost estimates that reflect the actual cost accrued by people with diabetes over time.

Our study is comparable to the few studies that have examined the medical cost of diabetes (2,20). A study by the American Diabetes Association including institutionalized people and indirect costs and using multiple data sources reports that people with diabetes have 2.3 times higher expenditures ($13,700 per year in 2012) compared with individuals without diabetes. Our pooled estimate of $12,180 was similar to this study but we did not include institutionalized adults, which could explain the difference in estimates. In a managed care organization study (20), the adjusted direct medical cost of type 2 diabetes was $2,465, which is somewhat consistent with our findings of $2,558. Another study observed annual medical spending of approximately $13,966 in people with diabetes similar to our study (19).

Some of the trends are not easy to explain. Office-based and hospital outpatient expenditures, which are both outpatient services, accounted for 19 and 8% of health care expenditures among people with diabetes, respectively. The trends observed in outpatient services remain unclear; one hypothesis could be that after the recession in 2007, unemployment may have led to decreased access to care and health care use. However, this is unlikely because one would expect a concurrent increase in inpatient expenditures from poor diabetes outcomes and complications. It is also unclear why inpatient expenditures increased from $4,014 in 2002/2003 to $4,183 in 2004/2005, and then decreased continuously to $3,443 through 2010/2011. This could be explained by decreasing rates of potentially preventable hospitalizations for conditions such as diabetes (15) and implementation of Medicare Part D. Studies suggest implementation of Medicare Part D had a positive impact on health care cost by reduced nondrug medical spending, especially inpatient and skilled nursing facility care (34), increased antihypertensive and antilipemic drug use (35,36), and increased medication possession ratios among adults with diabetes (37). Our findings of a decline in inpatient and total expenditures post–Part D implementation in 2006 for individuals with diabetes are consistent with the literature.

Other possible explanations for the decline in inpatient expenditures include macroeconomic issues (the economic decline may have prevented people from utilizing care regardless of need), better diabetic medications and medication adherence, disease management programs, implementation of quality of care standards (better physician care), and survival bias, meaning sicker people with diabetes may have died, leaving a healthier population who would have lower cost. It is important to note that these are potential explanatory factors that need to be confirmed in future studies.

There is also some evidence to support the role of self-care and medication adherence on cost reduction. A study showed that diabetes self-management education and having a regular provider are associated with a high probability of seeking appropriate care and engaging in beneficial activities (6), while another study among veterans with diabetes showed that inpatient costs can be saved (by approximately $1 billion/year) if nonadherent veterans became adherent (38). Policies investing in such interventions will improve health outcomes in people with diabetes and consequently prevent expensive hospital inpatient events. Additionally, the creation of awareness and providing insightful education to affected individuals and health care providers are ways to curb this growing pandemic and its associated financial burden.

Our study has some limitations. First, individuals with diabetes as well as comorbidities were identified based on self-report, which could be subject to bias. However, self-reported chronic diseases have been shown to be reliable (39), and also previous studies (2,21) have used similar data to estimate the prevalence of disease and cost. Second, our estimates are likely lower than the actual cost of diabetes for the following reasons: *1*) people with undiagnosed diabetes who account for 28% of the U.S. population (1) are not accounted for; *2*) we may have overcontrolled in the adjusted estimates, since CVD is a comorbidity of diabetes; *3*) MEPS does not include institutionalized individuals who are often very sick people, often die, and have higher expenditures; *4*) estimates from over-the-counter medications were not accounted for; and *5*) indirect costs such as work absenteeism, decreased productivity related to diabetes, or poor quality of life were not accounted for. Third, even though we analyzed 10-year pooled data, our results should not be interpreted longitudinally.

In conclusion, our findings show that compared with individuals without diabetes, individuals with diabetes had significantly higher health expenditures from 2002 to 2011, and the bulk of the expenditures came from hospital inpatient and prescription expenditures. We show that diabetes is an important driver of cost in the U.S. population, and based on the average yearly estimate, unadjusted total direct health care expenditures for diabetes in the U.S. population were $218.6 billion/year and the adjusted total expenditures were approximately $46 billion/year. These figures represent potential savings from interventions to improve prevention and management of diabetes in the U.S. civilian population.

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**Author Contributions.** M.N.O. and C.E.D. analyzed and interpreted data and drafted the manuscript. K.G.B. acquired, analyzed, and interpreted data and drafted the manuscript. L.E.E. conceived and designed the study; acquired, analyzed, and interpreted data; and supervised the study. All authors critically revised the manuscript for important intellectual content. L.E.E. and M.N.O. are the guarantors of this work and, as such, had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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