Nationally Representative Medical Costs of Diabetes by Time Since Diagnosis

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OBJECTIVE — This study provides nationally representative estimates for the U.S. of medical expenditures associated with diabetes by years since initial diagnosis.

RESEARCH DESIGN AND METHODS — Expenditures are estimated using cross-sectional regression analysis on the 2000–2004 Medical Expenditure Panel Survey linked to the 1998–2003 National Health Interview Survey (n = 46,203). The primary variables of interest are an indicator for self-reported diabetes and the years since diabetes diagnosis.

RESULTS — Under the base specification, a 50-year-old person just diagnosed with diabetes has medical expenditures that are 4,174 USD higher than an identical person without diabetes. On average, each additional year with diabetes increases annual medical expenditures by $158 (standard error = $38) above and beyond increases in medical expenditures due to aging. Conditional on diabetes complications, each additional year with diabetes increases annual medical expenditures by $75 (standard error = $55). Diabetes increases medical expenditures at any age, and the cumulative effect grows over time.

CONCLUSIONS — The results show the expected trajectory of medical expenditures after diagnosis of diabetes, highlighting the benefits of prevention and control as well as informing cost-effectiveness models of diabetes interventions.

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Diabetes and its complications can be costly to treat for individuals and society (1). To study the cost-effectiveness of interventions designed to prevent and treat diabetes, an estimate of the lifetime costs for individuals with diabetes, often under "usual" or "standard" care, is required. However, few studies have described how the cost of diabetes changes over time after diagnosis of diabetes.

The majority of such studies relied on health insurance databases (2–4). The typical pattern is a surge in spending initially after diagnosis of diabetes, then a leveling out, and then a rise toward the end of life. One caveat of these studies is that they may not generalize to other populations. Other studies have been based on populations from Canada (5) and the U.K. (6). To our knowledge, a nationally representative estimate of the medical costs of diabetes by time since diagnosis does not exist for the U.S.

This study provides nationally representative estimates of medical expenditures associated with diabetes by years since initial diagnosis. We link adults in the National Health Interview Survey (NHIS), which includes data on the age of first diagnosis for individuals who report having diabetes, to their medical expenditure data in the Medical Expenditure Panel Survey (MEPS). The resulting cross-section includes adults who have had diabetes for various lengths of time. We use regression methods to estimate the medical expenditure profile of individuals with diabetes by the number of years with diabetes. The results show the expected trajectory of medical expenditures after diagnosis of diabetes, highlighting the benefits of prevention and control as well as informing cost-effectiveness models of diabetes interventions.

RESEARCH DESIGN AND METHODS

Data

The primary sample for the analysis is drawn from the 2000–2004 MEPS. The MEPS is a nationally representative survey of the civilian noninstitutionalized population administered by the Agency for Healthcare Research and Quality. The MEPS provides data on participants' medical expenditures, medical conditions, and demographic characteristics (e.g., race/ethnicity, sex, and education).

The MEPS includes information on whether participants have ever been told they have diabetes but does not report the age of onset of diabetes. To find the age of onset for individuals with diabetes, we link participants in MEPS to their survey responses in the 1998–2003 NHIS adult files. The MEPS sample is drawn from a subset of the households that participate in the NHIS. The subsample of NHIS participants chosen for inclusion in MEPS enter the MEPS framework in the next year and remain for 2 years. For example, a participant in the 2000 NHIS selected for the MEPS sample will appear in the 2001 and 2002 MEPS.

The estimation sample is restricted to participants in both surveys with information about diabetes prevalence and age of onset (n = 3,790 with diabetes, n = 42,413 without diabetes). The MEPS is the primary source for diabetes prevalence; we use MEPS values when there are discrepancies between MEPS and NHIS (e.g., for new cases of diabetes that initiate between the surveys). The vast majority of self-reports for diabetes agree between MEPS and NHIS (98% of sample). We code participants who report being told they have diabetes in the MEPS but not in the NHIS as new cases of diabetes with duration <2 years, the maximum time between the two surveys. These new cases are ~1.7% of the sample. Using NHIS data, the Centers for Disease Control and Prevention (CDC) (7) report the annual incidence of diabetes in 2004 was 7.2 per 1,000 population (0.72%). Thus, a 2-year

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incidence rate of 1.7% in the MEPS-NHIS linked sample is slightly higher than that found in the NHIS alone (1.44%). If we restrict the sample to ages 18–79 years, as in the CDC report, the 2-year incidence rate is 1.65%; the remainder of the difference is likely due to methodological difference (e.g., CDC used 3-year moving averages) or to reporting error.

Neither survey distinguishes between type 1 and type 2 diabetes. In separate analyses, to try and isolate individuals with type 2 diabetes, we drop the sample of individuals whose diabetes began before age 21 years ($n = 216$) and before age 25 years ($n = 285$).

Table 1—*Summary statistics by diabetes status: 2000–2004 MEPS merged to 1998–2003 NHIS*

	With diabetes (n = 3,790)		Without diabetes (n = 42,413)	
	Mean	SD	Mean	SD
Annual medical expenditures (USD)	10,913	19,886	3,630	8,735
Age of diabetes onset	50.40	18.27	—	—
Years with diabetes	10.96	13.19	—	—
Age	61.37	15.41	46.71	16.60
	n	Weighted %	n	Weighted %
Female	2,291	55.4	24,618	55.0
White	2,050	67.4	26,829	75.0
Black	818	16.7	5,929	11.0
Hispanic	765	11.4	7,773	10.0
Asian	66	2.2	1,210	3.0
Other race	91	2.3	672	1.0
<100% poverty level	886	16.0	6,762	11.0
100–199% poverty level	1,016	25.5	8,662	17.0
200–399% poverty level	1,025	29.3	12,677	31.0
≥400% poverty level	863	29.2	14,312	41.0
Missing education	14	0.3	105	0.2
Less than high school	1,324	27.5	8,458	14.0
High school diploma	1,776	49.9	21,540	51.0
College degree	348	11.8	6,230	18.0
Graduate degree	141	4.7	3,199	9.0
Other degree	187	5.7	2,881	7.0
Medicaid	377	7.0	3,555	5.5
Medicare	1,861	48.8	7,897	18.2
Private insurance	1,086	33.1	23,178	61.1
Other public insurance	203	5.7	1,413	3.2
Uninsured	263	5.4	6,370	12.0
Heart disease	933	26.0	3,057	7.0
Stroke	174	5.0	417	1.0
Congestive heart failure	175	5.0	215	0.5
Hypertension	2,195	57.0	7,665	17.0
High cholesterol	1,234	34.0	3,858	9.0
Renal failure	74	2.0	74	0.1

MEPS survey weights are used to make the means, SDs, and frequencies (%) nationally representative of the period 2000–2004.

Statistical models

The main goal is to estimate how medical expenditures change over time with diabetes. We include participants without diabetes to help identify the effects of aging on medical expenditures separate from the effects of additional years with diabetes.

We use regression analysis to control for observable differences among participants and between individuals with and without diabetes that are likely to affect medical expenditures. Because annual medical expenditures are positively skewed, we model annual medical expenditures using a generalized linear model with log-link and gamma variance function. We also report sensitivity tests to alternative models including ordinary least squares and two-part models. Two-part models use a logit to model the probability of any expenditures and a separate regression to model expected medical expenditures conditional on having any expenditures.

The regression includes an indicator for having diabetes; that indicator interacted with the duration of diabetes and the duration of diabetes squared, age, age squared, and interaction of the diabetes indicator with age and age squared. The duration variables are of primary interest. Age and age squared control for the effects of age on annual medical expenditures common to individuals with and without diabetes. The interaction of the diabetes indicator with age and age squared provide a way to test for differences in the effect of age between individuals with and without diabetes.

Diabetes increases the risks for several medical conditions that develop over time (8). We estimate the effect of diabetes duration on annual medical expenditures two ways: unconditional on diabetes complications and conditional on diabetes complications. The latter specification includes indicators for self-reported prevalence of heart disease, stroke, congestive heart failure, hypertension, high cholesterol, and renal failure.

All regressions also include as independent variables the following demographic variables: sex, race/ethnicity (white [omitted], black, Hispanic, Asian, other), education (education missing, less than high school, high school diploma, college degree [omitted], graduate degree, other degree), family income (<100%, 100–199%, 200–399% [omitted], ≥400% of the poverty line) (9), primary source of health insurance (Medicaid, Medicare, private insurance [omitted], other public insurance, uninsured), and census region and study year indicators.

Using predictions from the regression models, we report the effects of diabetes duration on annual medical expenditures in two ways. First, we report the incremental effect of 1 additional year with diabetes, holding all other variables constant. We report the mean of the predicted incremental effects among participants with diabetes and bootstrapped standard errors from 500 replications of the model. Second, we graph the average incremental cost of diabetes by duration (years with diabetes) for the average person with diabetes. The average incremental cost is the difference in predicted expenditures between the average person with diabetes and an identical person, including comorbidities, without diabetes.

The MEPS survey weights are used in all analyses to make the results nationally representative of the period of 2000–2004. All expenditures have been converted to 2005 USD using the Medical Care Consumer Price Index (10).

RESULTS— We identified 3,790 adults self-reported to have been told they have diabetes—8.2% of the estimation sample (Table 1). The average age of onset for these adults is 50 years. The average age at which we observe their annual medical expenditures is 61 years. Whereas the mean duration for individuals with diabetes in our sample is almost 11 years, 40% of the diabetes sample has duration of ≤5 years; 25% has duration of ≤2 years. Unadjusted mean annual medical expenditures for adults with diabetes are about $7,000 higher than for adults without diabetes. However, adults with diabetes are different from adults without diabetes in a number of observable ways. Individuals with diabetes are older and more likely to be of minority ethnicity, be poor, be less educated, and have diabetes-related comorbidities.

Controlling for demographic differences between individuals with and without diabetes, individuals with diabetes have annual medical expenditures about 239% higher than individuals without diabetes (Table 2, base specification). Annual medical expenditures increase at a decreasing rate as the time with diabetes increases. Aging also increases medical expenditures at a decreasing rate. The coefficient for the interaction between diabetes and age is negative, indicating that the effect of aging on medical expenditures is smaller for individuals with diabetes than for individuals without diabetes.

Conditional on diabetes-related comorbidities, annual medical expenditures are still higher among those with diabetes (Table 2, add comorbidities). Annual medical expenditures increase at a decreasing rate as the time with diabetes increases. However, the magnitude of the coefficients for diabetes and diabetes duration are smaller than in the model that does not control for comorbidities.

An additional year with diabetes, holding demographic variables constant, increases average annual medical expenditures by $158 (standard error = $38; Table 3). The average incremental effect is unaffected by choice of alternative functional forms. Ordinary least squares, a two-part model using generalized linear model with log-link and gamma variance in the second part, and a two-part model using ordinary least squares on log expenditures with a heteroscedastic smearing retransformation (11) all yield average incremental effects of an additional year with diabetes near $158. When we restrict the sample to people whose diabetes began at age 21 years or later and at age 25 years or later, the average incremental effect of an additional year with diabetes is $184 and $173, respectively (results are available upon request).

Conditional on diabetes-related comorbidities, an additional year with diabetes increases average annual medical expenditures by $75 (standard error $55). The average incremental effect varies more with choice of functional form when comorbidities are included, but all of the slope estimates are smaller when compared with a specification unconditional on comorbidities.

Figure 1 shows the average incremental cost of diabetes as a function of the number of years with diabetes. The incremental costs are plotted separately for a person at age 50 years and at age 65 years,

Table 2—*Regression models of annual medical expenditures as a function of time with diabetes: generalized linear model with log-link and gamma variance*

	Base specification			Adjusted for comorbidities		
	Coefficient		SE	Coefficient		SE
Diabetes	2.387	*	0.736	2.185	*	0.640
Years with diabetes	0.024	*	0.006	0.011	*	0.005
Years with diabetes squared	−0.0004	*	0.0001	−0.0002	*	0.0001
Age	0.060	*	0.005	0.058	*	0.005
Age squared	−0.0004	*	0.00005	−0.0004	*	0.00005
Diabetes-age interaction	−0.050	*	0.024	−0.053	*	0.021
Diabetes-age squared interaction	0.0003		0.0002	0.0004	*	0.0002
Female	0.304	*	0.027	0.352	*	0.028
Black	−0.302	*	0.038	−0.310	*	0.040
Hispanic	−0.400	*	0.041	−0.372	*	0.041
Asian	−0.523	*	0.087	−0.474	*	0.087
Other race	0.057		0.075	0.086		0.075
<100% poverty level	0.217	*	0.049	0.211	*	0.051
100–199% poverty level	0.035		0.041	0.042		0.043
≥400% poverty level	0.023		0.031	0.047		0.032
Missing education	−0.335		0.200	−0.361		0.203
Less than high school	−0.262	*	0.050	−0.284	*	0.051
High school	−0.112	*	0.041	−0.114	*	0.040
Graduate degree	−0.016		0.057	−0.011		0.053
Other degree	−0.049		0.057	−0.046		0.056
Medicaid	0.699	*	0.062	0.635	*	0.065
Medicare	0.556	*	0.047	0.486	*	0.050
Other public insurance	0.378	*	0.060	0.319	*	0.057
Uninsured	−0.850	*	0.062	−0.817	*	0.067
Midwest	0.078	*	0.038	0.076	*	0.037
South	0.045		0.039	0.015		0.038
West	0.036		0.040	0.032		0.037
Year 2000	−0.151	*	0.046	−0.116	*	0.046
Year 2001	−0.065		0.042	−0.024		0.044
Year 2002	−0.083	*	0.034	−0.054		0.034
Year 2003	−0.015		0.037	0.005		0.035
Heart disease	—		—	0.748	*	0.042
Stroke	—		—	0.721	*	0.070
Congestive heart failure	—		—	0.709	*	0.100
Hypertension	—		—	0.345	*	0.029
High Cholesterol	—		—	0.185	*	0.030
Renal Failure	—		—	1.414	*	0.119
Constant	6.427	*	0.119	6.114	*	0.121
Sample size	46,203			46,203		

2000–2004 MEPS merged to 1998–2003 NHIS. *Significance at the 95% CI.

Table 3—*Average incremental effect of 1 additional year with diabetes among individuals with diabetes (bootstrapped standard error)*

	Generalized linear model (GLM)	Ordinary least squares (OLS)	Two-part model: GLM	Two-part model: OLS
Base specification	158 (38)	199 (45)	155 (36)	190 (25)
Adjusted for comorbidities	75 (55)	114 (58)	74 (52)	129 (40)

Results are expressed in 2005 USD. All models use the same variables as in Table 2. Both two-part models estimate a logit for the probability of any medical expenditures. Two-part model: GLM uses a GLM model on non-zero expenditures. Two-part model: OLS uses OLS on log (non-zero) expenditures with a heteroscedastic retransformation.

as well as separately for the base specification and for the specification that adds comorbidities (Table 2). Under the base specification, a 50-year-old person just diagnosed with diabetes has medical expenditures that are $4,174 higher than an identical person without diabetes. A 50-year-old person who has had diabetes for 10 years has medical expenditures that are $6,054 higher than an identical person without diabetes. Controlling for comorbidities lowers the incremental cost of diabetes at age 50 years and at age 65 years and also lowers the slope with respect to duration at both ages, which is consistent with the results reported in Table 3. For example, a 65-year-old person just diagnosed with diabetes has medical expenditures $2,361 higher than an identical person with the same comorbidities but without diabetes. The incremental cost of diabetes is $3,103 at age 65 years for a person who has had diabetes for 10 years.

CONCLUSIONS — This study is the first to provide nationally representative estimates of how annual medical expenditures increase with the length of time with diabetes. On average, each additional year with diabetes increases annual medical expenditures by $158. This is in addition to baseline increases in medical expenditures with age. Thus, not only does diabetes increase medical expenditures at any age, but the effect grows over time.

The increase in diabetes-related medical expenditures over time is likely due to two causes. First, diabetes increases the risks for several medical conditions that develop over time. When several of these conditions are included in the model, the estimate of the effect of an additional year with diabetes on annual medical expenditures falls to $75, a 53% reduction. Thus, a higher prevalence of these conditions among individuals with diabetes explains the majority of the effect of diabetes duration. However, even conditional on diabetes complications, diabetes duration has a significant effect on annual medical expenditures. The remaining significance of diabetes duration could be the result of incomplete control for complications (e.g., microalbuminuria, retinopathy, and neuropathy are not included). This result differs from two previous studies that found that controlling for diabetes complications, diabetes duration (4), and age among individuals with diabetes (12) are not significant predictors of medical expenditures.

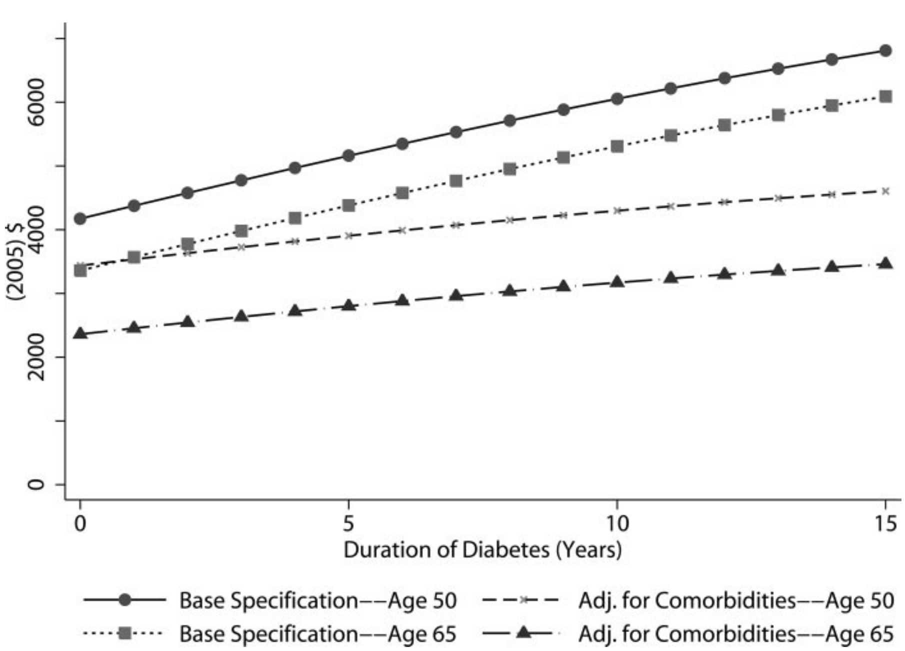

Figure 1—*Average incremental cost of diabetes: difference in expenditures with and without diabetes.*

Second, management of blood glucose and insulin levels becomes more difficult over time. Results from the UK Prospective Diabetes Study indicate that most patients will need multiple therapies to attain target control rates in the long term (13). This leads to increases in management costs for diabetes as diabetes duration increases.

All of these results suggest that while much of the increased cost of diabetes over time could be avoided by prevention of diabetes-related complications, control of diabetes itself generates costs. When the analyses above were repeated using prescription drug expenditures as the dependent variable, another year with diabetes increases prescription drug expenditures by $56 per person (results available upon request). Adjusting for comorbidities, this effect remains $52 per person. Thus, controlling for comorbidities, a large part of the increase in diabetes costs over time is the result of higher prescription drug expenditures, an essential component to diabetes control and management.

The results of this study are subject to several limitations. Medical conditions, including diabetes, are self-reported. It is not possible to distinguish between type 1 and type 2 diabetes. When individuals whose diabetes began before age 21 years (a proxy for type 1 diabetes) are dropped from the sample, the average incremental effect of an additional year with diabetes is slightly higher, but not statistically significantly different from the full sample. The data used in this study are cross-sectional, not longitudinal. Rather than following individuals for several years after onset of diabetes, the data contain a cross-section of individuals that have had diabetes for different lengths of time. This might explain the fact that we do not find the initial spike in medical expenditures around the time of diagnosis that has been observed in longitudinal studies. The data are also subject to survivorship bias. The direction of the bias will depend on the length of time spent with diabetes and the medical expenditure patterns of those who died and are not included in the survey.

To our knowledge, these are the first nationally representative estimates for the U.S. of the expected trajectory of medical expenditures after diagnosis of diabetes. They provide additional evidence highlighting the benefits of diabetes prevention and control. Delaying the development of diabetes will delay the steady rise in medical expenditures that accompanies it.

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