The Economics of Diabetes in the United States

Economic Cost of Type 1 and Type 2 Diabetes in the U.S. in 2007

Economic Cost of Undiagnosed Diabetes in the U.S. in 2007

Economic Cost of Prediabetes in the U.S. in 2007

Economic Cost of Gestational Diabetes Mellitus in the U.S. in 2007

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Distinguishing the Economic Costs Associated with Type 1 and Type 2 Diabetes

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Abstract

The objective was to estimate the economic costs of diagnosed type 1 (T1DM) and type 2 (T2DM) diabetes mellitus in the United States in 2007. Medical claims were analyzed to estimate the proportion of diagnosed diabetes cases and excess medical costs by diabetes type. Indirect costs associated with T1DM and T2DM were estimated by using findings from the literature on diagnosed diabetes, as well as differences in health per case of T1DM and T2DM. This study builds on the Cost of Diabetes Model developed for the American Diabetes Association to estimate the economic burden of diagnosed diabetes. T1DM accounts for an estimated 5.7% (1.0 million) of the 17.5 million people with diagnosed diabetes. Approximately $14.9 billion (8.6%) of the economic burden of diagnosed diabetes is associated with T1DM, including medical costs of $10.5 billion and indirect costs of $4.4 billion. Costs associated with T2DM are $159.5 billion, including medical costs of $105.7 billion and indirect costs of $53.8 billion. The economic burden per case of diabetes is greater for T1DM than for T2DM, and the difference increases with age. The prevalence of T2DM is significantly greater than the prevalence of T1DM, so T2DM is responsible for most of the economic burden of diabetes. Estimates for T1DM are sensitive to the criteria used to identify people with diabetes using claims data; estimates for T2DM are relatively stable. Improved coding of diabetes type in medical claims and identification of diabetes type in survey data could lead to more precise estimates of the economic burden by diabetes type. (*Population Health Management* 2009;12:103–110)

Introduction

The annual economic burden associated with diagnosed diabetes in the United States is estimated to be $174 billion.[1] Approximately 90%–95% of diagnosed cases are type 2 diabetes (T2DM), the form of diabetes that is largely preventable.[2] Type 1 diabetes (T1DM) comprises the remaining 5%–10%, but because onset of T1DM tends to occur at a much younger age, patients with T1DM have higher prevalence of complications than do T2DM patients of a similar age.

Challenges to identifying diabetes type in medical claims data have contributed to a paucity of large sample studies to compare use of health care services and medical costs by diabetes type.[3–5] Because T1DM constitutes a relatively small proportion of total cases, this type of diabetes often is overlooked in studies. Understanding the differences in health care use patterns and major cost drivers by diabetes type can be useful in tailoring diabetes management programs and other preventive interventions to the unique needs of people with T1DM and T2DM. Also, the differences in costs incurred by diabetes type have different implications for payers whose diabetes cases are disproportionately T1DM (eg, Medicaid) or T2DM (eg, Medicare).

The indirect costs of diabetes include increased absenteeism (missed work days), "presenteeism" (reduced productivity while at work), long-term disability (that prevents working), and early mortality.[6–13] The lack of information specifying diabetes type in survey data has contributed to a dearth of information about indirect costs by diabetes type. Distinguishing between the indirect costs per case by diabetes type provides information that can be used to help employers understand the business case for health promotion activities designed to help prevent chronic problems like T2DM.

Research Design and Methods

The data and methods used to estimate the national economic burden of diagnosed diabetes are described elsewhere.[1]

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The focus of this article is the data and methods used to estimate the proportion of diagnosed diabetes costs attributed to T1DM and T2DM, respectively. First, to obtain national prevalence estimates by diabetes type, we estimate the proportion of diagnosed T1DM cases for each demographic group (by age and sex). Second, we estimate patterns of health care use by diabetes type and demographic group. Finally, we use these estimates of health care use patterns to model productivity loss per case by diabetes type. Information from the major components of this study—diabetes prevalence by

Table 1. Summary of Data Sources Used

Source	*Description*	*Use*
2004–2006 National Health Interview Survey (NHIS)	Stratified random sample of noninstitutionalized households surveyed annually by the National Center for Health Statistics (NCHS), Centers for Disease Control and Prevention (CDC)	• Calculate national prevalence rates for diagnosed diabetes by age group, sex, and race/ethnicity • Calculate work days absent, inability to work because of permanent disability, and rates of insulin and oral agent use for people with diagnosed diabetes
The 2003–2005 Medical Expenditure Panel Survey (MEPS)	Stratified random subset of the NHIS households surveyed; this file contains more detailed information on health care use and associated costs	• Calculate average medical cost per health care event (eg, per visit) or per annum usage (eg, home health care, podiatric care, medical supplies)
2004–2005 Nationwide Inpatient Sample (NIS)	This file contains discharge records for approximately 8 million hospital stays each year from over 1000 hospitals located in 37 states; produced by the Agency for Healthcare Research and Quality	• Calculate national inpatient days and hospital costs by patient demographic and complication category
2003–2005 National Ambulatory Medical Care Survey (NAMCS)	National sample of visits to non-federally employed office-based physicians who are primarily engaged in direct patient care; produced annually by NCHS, CDC	• Calculate national physician office visits by patient demographic and complication category
2003–2005 National Hospital Ambulatory Medical Care Survey (NHAMCS)	National sample of visits to emergency and outpatient departments of noninstitutional general and short-stay hospitals; produced annually by NCHS, CDC	• Calculate national emergency and outpatient visits by patient demographic and complication category
2000 National Home and Hospice Care Survey (NHHCS)	Survey of home and hospice care agencies; produced by NCHS, CDC	• Calculate diabetes-associated national hospice visits by patient demographic
2004 National Nursing Home Survey (NNHS)	Survey of nursing homes; produced by NCHS, CDC	• Calculate total resident days in nursing facilities and the prevalence of T1DM and T2DM among the population in long-term care
2006 Ingenix MCURE database	Annual medical claims for approximately 16.2 million insured persons younger than age 65 in 2006 (approximately 650,000 with a diagnosis of diabetes)	• Calculate the proportion of diagnosed diabetes cases that are T1DM and how patterns of health care use differ by diabetes status (no diabetes diagnosis, likely T1DM, or likely T2DM)
2006 Medicare 5% Sample File	Annual medical claims for approximately 1.8 million people age 65 and older (approximately 350,000 with a diagnosis of diabetes)	• Calculate the proportion of diagnosed diabetes cases that are T1DM and how patterns of health care use differ by diabetes status
California's 2001 MediCal (Medicaid) 20% File.	Medical claims for approximately 1.3 million people who were insured under MediCal for at least 9 continuous months, of which 33,000 have a diagnosis of diabetes.	• Calculate the proportion of diagnosed diabetes cases that are T1DM and how patterns of health care use differ by diabetes status

type, health care use patterns, and lost productivity—are estimated and combined by patient age (0–17, 18–34, 35–44, 45–54, 55–59, 60–64, 65–69, and 70 older) and sex. The data sources and approach used are described in the following sections.

Data sources

This study builds on a Cost of Diabetes Model that combines information from the peer-reviewed literature, government statistics, and original analyses. Table 1 summarizes the data sources used; additional information on these sources and their use is provided later. The diabetes prevalence and cost estimates reflect population estimates from the United States Census Bureau for 2007.

Prevalence of T1DM and T2DM

The recent study of the national economic burden of diagnosed diabetes estimated the number of people in the United States with diagnosed diabetes in 2007 by age, sex, and race/ethnicity based on nationally representative data sources. To determine the portion of these cases that are T1DM, we use medical data from 3 sources: the Managed Care Utilization Rate Estimates (MCURE) database, the Medicare 5% Sample File, and the MediCal 20% File. Although we capture the uninsured population in our national prevalence of diagnosed diabetes, we have identified no data source to estimate the proportion of T1DM cases in this population and assume the proportion of cases with T1DM is similar to that of the commercially insured population, controlling for age and sex.

After reviewing methods of type classification with medical claims used in previous studies, we adopt the following criteria to categorize patients as likely T1DM, or likely T2DM.[3–5] For the MCURE, Medicare 5% Sample, and MediCal files, we analyze the ICD-9-CM codes in the annual medical claims for each patient. Patients with at least 1 claim with a code of 250.xx are assumed to have diabetes. For these patients, we then use the following criteria to define diabetes type:

(1) if a patient has a diagnosis of diabetic ketoacidosis (250.1x), then the patient is categorized as T1DM (1.1% of cases); else
(2) if a patient has an insulin resistance diagnosis (277.7x), then the patient is categorized as T2DM (1.5% of cases); else
(3) if all diabetes diagnoses during 2006 are 250.x1 or 250.x3, then the patient is categorized as T1DM (3.7% of cases); else
(4) if all diabetes diagnoses during 2006 are 250.x0 or 250.x2, then the patient is categorized as T2DM (81.9% of cases); else
(5) if a patient has both T1DM and T2DM/unspecified diagnoses and no diagnosis of ketoacidosis or insulin resistance (11.9 % of cases), then additional assumptions must be made to categorize a patient's diabetes type. As there are almost 3 times as many people in this category as are in cases (1) and (3), the prevalence of T1DM is sensitive to the assumptions used to categorize these patients. We explore alternate criteria based on the proportion of a patient's diabetes diagnoses that indicate T1DM.
    a. The approach used in this study recognizes that T2DM prevalence increases more rapidly with age than does T1DM prevalence. Consequently, all else being equal, older patients with diagnosis codes for both T1DM and T2DM are more likely than are younger patients to have T2DM. For the 88% of patients we can classify as T1DM or T2DM with some degree of certainty by applying criteria (1) through (4) above, we estimate the proportion that are T1DM. We assume that the same proportion of patients with mixed T1DM/T2DM diagnoses have T1DM as do patients classified with a greater degree of certainty. To calculate this proportion with T1DM, we categorize all patients younger than age 18 years as T1DM and patients age 55 and older as T2DM. Patients ages 18–34 are categorized as T1DM if more than 55% of their diagnoses indicate T1DM; those ages 35–44 are categorized as T1DM if more than 80% of their diagnoses indicate T1DM, and those ages 45–54 are categorized as T1DM if more than 90% of their diagnoses indicate T1DM.
    b. An alternate approach categorizes a patient as T1DM if more than half of the diabetes diagnoses indicate T1DM. Otherwise, the patient is assumed to have T2DM.

Patients with claims data indicating both T1DM and T2DM tend to be high users of health care services—making this population important for the analysis. Having multiple claims with a diabetes diagnosis, however, increases the likelihood that at least 1 diagnosis will incorrectly identify diabetes type. Approach (a) produces a prevalence rate that stabilizes after age 35 and produces a median age of T1DM onset that is consistent with published findings. Approach (b) produces a national T1DM prevalence rate that continues to increase rapidly with age. The estimates presented use approach (a), although we report prevalence and cost using approach (b) as a sensitivity analysis. Estimates of per capita health care use by diabetes type are relatively unaffected by the use of approach (a) or (b), so the impact on total diabetes costs of using approach (a) over approach (b) is primarily the different estimates produced of the proportion of cases that are T1DM.

Health care resource use associated with T1DM and T2DM

Diabetes is associated with increased risk of neurological symptoms, peripheral vascular disease, cardiovascular disease, renal complications, endocrine complications, ophthalmic complications, as well as a number of other complications.[1,14–19] People with diabetes tend to have longer hospital stays and increased numbers of encounters per capita for health problems that are not identified as complications of diabetes. In our previous paper, we estimated the total national utilization of medical services in the physician office, outpatient, emergency department, and inpatient settings, as well as the amount of utilization associated with diagnosed diabetes.[1] Primary diagnosis codes were used to categorize each of these estimates by complication group.

To determine the proportion of these costs that are associated with T1DM, we examine the difference in health care use patterns between the T1DM population and the T2DM population, compared with the population without diagnosed diabetes. We use the MCURE database to examine the population younger than age 65, and the Medicare 5% sample to examine the population age 65 and older. For each age group, sex, delivery setting, and diabetes type (T), we define the rate ratio (RR) for each complication group (C) as the ratio of the mean number of events for people with the given diabetes type to the mean number of events for people without diagnosed diabetes. Etiological fractions (ε) are calculated using diabetes prevalence rates (P) and the above rate ratios, providing estimates of the proportion of health care use associated with T1DM and T2DM in each health care delivery setting by age group and sex[20]:

$$\varepsilon_{C,T} = \frac{(RR_{C,T} - 1) \times P_T}{1 + \sum_{t=T1DM,\,T2DM} (RR_{C,t} - 1) \times P_t}$$

We then calculate the proportion of diagnosed diabetes health care use and cost attributed to T1DM, as:

$$\text{Proportion}_{C,T} = \frac{\varepsilon_{C,T}}{\varepsilon_{C,T1DM} + \varepsilon_{C,T2DM}}.$$

This proportion is applied to the cost estimates for diagnosed diabetes produced in our previous study.

Using the National Nursing Home Survey, we can identify residents with T1DM and T2DM based on admission diagnosis. We compare the diabetes prevalence rate in nursing homes to the prevalence rate among the general population to calculate the excess number of nursing home residents associated with diabetes.

The MCURE database used has medical claims data for only a portion of patients, as many employers use different insurers to manage pharmacy benefits than are used to manage other health care use. Consequently, we base our estimates of the proportion of T1DM patients who use insulin and who use oral agents on published benchmarks.[21] From the insulin and oral agent use estimates for diagnosed diabetes, we subtract the estimates of use associated with T1DM to infer the portion of T2DM patients who use insulin and oral agents. Estimates of the proportion of retail prescription costs by diabetes type are linked to differences by type in number of outpatient, office, and emergency visits.

Estimates of the cost of diabetic supplies were developed using the Medicare Expenditure Panel Survey (MEPS). While MEPS does not identify diabetes type, analysis suggests that insulin use is highly correlated with the use of diabetic supplies. Consequently, differences in prevalence of insulin use by diabetes type are used to calculate the proportion of diabetic supplies associated with T1DM.

Ambulance costs are linked to emergency visits associated with each diabetes type. For all other categories of medical costs (eg, hospice, home health, podiatric care, other equipment and supplies), costs associated with diagnosed diabetes are divided between T1DM and T2DM based on the relative prevalence of T1DM and T2DM by age and sex.

Productivity loss associated with T1DM and T2DM

Estimates of diabetes-attributed absenteeism, presenteeism, and reduced productivity among those in the workforce have been calculated previously.[1] However, these estimates are based on surveys that lack information about diabetes type. Determining the proportion of productivity loss associated with T1DM requires estimates of how productivity loss per T1DM case differs, on average, from a T2DM case. Our analysis of health care utilization shows that per capita use of medical services is higher for T1DM than for T2DM. We estimate total days spent receiving health care services associated with diabetes by age and sex, and use the proportion of these days associated with each diabetes type to estimate the proportion of diabetes-attributed lost productivity associated with T1DM and T2DM. To estimate total days spent receiving care, we assume that each office and outpatient visit is equivalent to half a day, and each emergency visit and inpatient day is equivalent to a full day. For sensitivity analysis, we report cost estimates assuming that T1DM and T2DM cases have similar rates of associated productivity loss, so the proportion of productivity loss associated with T1DM is equal to the proportion of diabetes cases that are T1DM. Accounting for differences in health yields productivity loss estimates that are 6.9% higher for T1DM (and 0.4% lower for T2DM) than estimates based solely on the relative prevalence of T1DM and T2DM.

Analysis of the National Health Interview Survey (NHIS) reveals that diabetes is associated with increased receipt of Supplemental Security Income (SSI), an indication of employment-preventing long-term disability.[1] Unfortunately, the NHIS does not contain information on diabetes type, nor is diabetes type reported by the Social Security Administration for those who qualify for SSI. To estimate the proportion of diabetes-attributed long-term disability costs associated with T1DM, we use the proportion of hospital inpatient days associated with T1DM to take into consideration differences by diabetes type in the prevalence and severity of chronic conditions. Compared with the allocation of disability costs based on the relative prevalence of T1DM and T2DM, the overall impact of using this approach is to increase the estimates of T1DM productivity loss from long-term disability by approximately 22% and lower estimates for T2DM by 2%.

Our earlier work suggests that there were 284,000 premature deaths attributed to diabetes in 2007, of which the primary cause of death was diabetes for 77,000 persons, renal failure for 25,000, cerebrovascular disease for 59,000, and cardiovascular disease for 123,000.[1,8,22,23] Two studies report that, controlling for demographic and other risk factors, the risk of mortality due to cardiovascular disease is similar for both T1DM and T2DM.[22,23] However, because T1DM is associated with higher use of health care resources for renal complications, cardiovascular disease, and other complications, we assume T1DM is more likely to be associated with the increased mortality rates resulting from these complications. To estimate the proportion of these 284,000 premature deaths associated with T1DM, we use the proportion of diabetes-attributed emergency visits associated with T1DM by complication category (ie, diabetes, renal failure, cerebrovascular disease, cardiovascular disease). This approach produces estimates of T1DM productivity loss from mortality that are approximately 8% higher (and estimates for T2DM that are 0.7% lower), compared with the allocation of mortality costs based simply on the relative prevalence of the 2 diabetes types.

Earlier work combining Bureau of Labor Statistics data on earnings and labor force participation with life expectancy

Table 2. Rate Ratios for Annual Health Care Use (for population ages 45–64 Years)

	Physician Office Visits		*Outpatient Visits*		*Emergency Visits*		*Hospital Inpatient Days*	
Complication Groups	*T1DM*	*T2DM*	*T1DM*	*T2DM*	*T1DM*	*T2DM*	*T1DM*	*T2DM*
Neurological symptoms	7.9	4.9	6.2	4.1	5.4	3.7	6.0	5.3
Peripheral vascular disease	3.5	2.9	5.6	4.3	4.0	2.5	10.9	5.8
Cardiovascular disease	1.7	2.0	1.9	2.1	3.1	3.0	7.1	6.1
Renal complications	4.1	2.9	4.0	2.9	3.1	2.8	15.3	6.7
Endocrine complications	1.3	1.4	1.3	1.4	14.7	8.3	23.0	9.8
Ophthalmic complications	5.7	3.6	6.2	4.0	2.3	2.3	7.4	7.2
Other diabetes complications	4.1	3.1	6.6	4.4	2.8	2.7	12.9	10.3
All other medical conditions	1.4	1.4	1.4	1.4	1.6	1.7	2.6	1.9
Total	2.1	1.9	2.2	2.1	1.8	1.9	3.7	2.7

Rate ratio of 1.0 means that people with diagnosed diabetes of the specified type have the same rate of health care use as the population with no diagnosis of diabetes. The diagnosis codes used to define the complication groups are documented elsewhere.[1]

data from the Centers for Disease Control and Prevention, suggests that the present value of lost productivity associated with premature mortality ranges from $14,000 (for females ages 70–74) to $1.25 million (for males younger than age 18).[1] We use age-sex specific lost lifetime productivity estimates to calculate the productivity loss associated with T1DM and T2DM premature mortality. We use a 3% discount rate, and for each 1% increase in the discount rate the national estimated lost productivity resulting from diabetes-attributed premature mortality declines by 6%–7%.

Results

In 2007, of the estimated 17.5 million people with diagnosed diabetes in the United States, approximately 1.0 million (5.7%) have T1DM and 16.5 million (94.3%) have T2DM. Our resulting overall percent T1DM of 5.7% is within the 5%–10% range found by others. The national prevalence rates suggest that the median age of diagnosis is approximately 24 years for T1DM and 57 for T2DM.

We find that the percent of diabetes cases that are T1DM varies by age, sex, and payer mix. The estimated percent with T1DM is 79.0% for the population younger than age 18, 26.2% for ages 18–34, 8.5% for ages 35–44, 4.6% for ages 45–54, 3.5% for ages 55–59, 3.6% for ages 60–64, 2.4% for ages 65–69, and 2.5% for ages 70 and older. The proportion of cases that are T1DM among children is similar to the estimate (81%) reported by the SEARCH for Diabetes in Youth Study, a study of 6379 youth and adolescents with diabetes.[24] Analysis of the MediCal file found that only 43% of youth with a diabetes diagnosis had an ICD-9 code indicating T1DM—an estimate significantly below the 79% and 81% estimates above. This low estimate for youth from the MediCal data likely reflects data limitations, and for our analysis we assume that 79% of children with diabetes in the Medicaid population have T1DM. No recent estimates of T1DM among adults were found, but a 1995 study estimates that 0.3% of adults ages 30 to 74 have T1DM (compared to our estimate of 0.4% of all adults).[25]

For most complication categories and age groups, per capita use of health care services is higher for people with T1DM relative to people with T2DM. Using the population age range of 45 to 64 for illustration, people with T1DM have 7.9 times as many physician office visits for neurological symptoms, on average, compared with people without diabetes (Table 2). This is nearly twice the ratio (4.9) for a person with T2DM.

The national economic burden of diagnosed diabetes was estimated at $174 billion in 2007, including $116 billion in the form of higher medical costs and $58 billion in reduced national productivity (Table 2). Approximately $159.5 billion (91.4%) is attributed to T2DM; the remaining $14.9 billion (8.6%) is associated with T1DM. Although T1DM constitutes only 5.7% of diagnosed cases and the skew of T1DM is toward younger populations, T1DM accounts for 9.1% ($10.5 billion) of excess medical costs associated with diagnosed diabetes, and 7.5% ($4.4 billion) of excess productivity costs.

While the average diabetes-associated medical cost per year increases with age, the average cost of productivity loss *decreases* with age so that the average total cost per case of T2DM per year is relatively constant, at $9200 to $9700 across 3 aggregate age groups (Table 3). However, for T1DM, the average medical cost per case increases rapidly with age—from $4044 for people younger than age 44 to $35,365 for the population age 65 and older. The high cost per case for T1DM among those age 65 and older is attributed to the high use of costly nursing and residential facilities, as well as the increased incidence of inpatients stays. Whereas T1DM is responsible for about 9% of medical costs associated with diabetes, T1DM is responsible for 59% of nursing/residential facility costs associated with diabetes due to the greatly increased prevalence of T1DM among the nursing home population as compared to the noninstitutionalized population.

We conducted sensitivity analysis on 2 key assumptions. First, for the approximately 12% of patients who have diagnoses indicating both T1DM and T2DM/unspecified, we classify patients as likely T1DM if more than 50% of the diabetes diagnoses indicate T1DM (regardless of patient age).

Table 3. Economic Burden of Diagnosed Diabetes in 2007 (millions of dollars)

Cost Component*	Total Costs Attributed to Diabetes: All Diagnosed Diabetes	Total Costs Attributed to Diabetes: Type 1	Total Costs Attributed to Diabetes: Type 2	Total Costs Incurred by Population: All Diagnosed Diabetes	Total Costs Incurred by Population: Type 1	Total Costs Incurred by Population: Type 2	Total Costs Incurred by Population: No Diagnosis of Diabetes	Total Costs Incurred by Population: US Total
Total*	174,418	14,926	159,492					
Medical Costs	116,258	10,548	105,710	205,092	13,960	191,133	846,412	1,051,504
Institutional care	65,831	7,769	58,062	115,499	9,478	106,020	389,593	505,092
Hospital inpatient	58,344	3,322	55,022	96,974	4,738	92,236	332,902	429,875
Nursing/residential facility	7,487	4,447	3,040	18,525	4,740	13,784	56,692	75,216
Outpatient care	22,743	1,237	21,505	46,743	2,342	44,401	312,356	359,099
Physician's office	9,897	544	9,353	21,739	1,065	20,674	132,984	154,723
Emergency department	3,870	234	3,636	8,065	489	7,576	73,381	81,446
Ambulance services	103	4	100	370	13	358	1,726	2,096
Hospital outpatient	2,985	279	2,705	6,770	491	6,279	60,054	66,824
Home health†	5,586	167	5,419	9,391	272	9,119	31,149	40,540
Hospice†	28	1	27	—	—	—	—	12,033
Podiatry†	273	8	265	408	13	395	1,028	1,437
Outpatient medications and supplies	27,684	1,541	26,143	42,851	2,139	40,712	144,463	187,314
Insulin	3,733	528	3,205	3,733	528	3,205	0	3,733
Diabetic supplies	1,783	128	1,654	1,783	128	1,654	0	1,783
Oral agents	8,586	266	8,320	8,586	266	8,320	0	8,586
Retail prescriptions	12,692	584	12,108	26,035	1,113	24,921	127,562	153,597
Other equipment and supplies†	890	35	855	2,714	103	2,611	16,901	19,615
Nonmedical costs	58,160	4,378	53,782	—	—	—	—	—
Absenteeism	2,597	127	2,470	—	—	—	—	—
Presenteeism	19,955	1,240	18,715	—	—	—	—	—
Inability to work from disability	7,949	674	7,276	—	—	—	—	—
Premature mortality	26,902	2,298	24,604	—	—	—	—	—
Reduced productivity for those not in labor force	757	39	718	—	—	—	—	—
Medical costs per person with diabetes	6,649	10,495	6,414	—	—	—	—	—
Age 0 to 44	3,808	4,044	3,755	—	—	—	—	—
Age 45 to 64	5,094	8,169	4,966	—	—	—	—	—
Age 65 and older	9,713	35,365	9,061	—	—	—	—	—
Total costs per person with diabetes	9,975	14,856	9,677	—	—	—	—	—
Age 0 to 44*	9,099	8,649	9,202	—	—	—	—	—
Age 45 to 64*	9,868	13,881	9,701	—	—	—	—	—
Age 65 and older*	10,473	36,349	9,815	—	—	—	—	—

Numbers do not necessarily sum to totals because of rounding. Proportion of diagnosed diabetes costs associated with T1DM estimated based on differences in health care use patterns (*) or relative prevalence of T1DM versus T2DM (†). "–" = not available.

This alternate approach yields 1.4 million T1DM cases (8.2% of diagnosed diabetes cases) and $19.5 million in attributed costs (11.2% of all diabetes attributed costs). Compared to the approach used, this alternate approach results in a higher T1DM prevalence rate among the elderly and a lower T1DM prevalence rate among children and young adults. Second, using relative prevalence of T1DM and T2DM to estimate the proportion of diabetes-attributed productivity loss associated with T1DM lowers estimates of the indirect costs associated with T1DM by $398 million (9%) and raises the estimated indirect cost associated with T2DM by $398 million (0.7%).

Conclusions

This study suggests that the average economic burden per person with diabetes is larger for T1DM than for T2DM. However, because 94.3% of diagnosed diabetes cases are T2DM, the national economic burden is much greater for

T2DM, suggesting that effective measures to prevent, delay, or manage T2DM have the potential to substantially reduce the overall burden of diabetes.

On a per person basis, costs among the population younger than age 45 are similar for T1DM and T2DM. Although annual medical cost per person increases with age, the medical costs increase at a much faster rate for those who have T1DM. Medical costs for those age 65 and older with T1DM are 8.7 times higher than costs for T1DM patients younger than age 45; medical costs for T2DM are 2.4 times higher for those age 65 and older compared to the population younger than age 45.

The large increase in annual cost per person for T1DM is driven by an increased utilization of institutional care. We find that of the estimated 165,000 T1DM patients age 65 and over, approximately 62,600 live in year-round nursing home facilities (not including residential care facilities), and another 47,600 will spend some portion of the year (about 4 months on average) in a nursing facility. One possible explanation for this finding is that, on average, older people with T1DM have had diabetes for a longer time period than their peers with T2DM and, as reported by the National Institutes of Health, the risk of complication increases with diabetes duration.[26]

The overall cost of diagnosed diabetes could be conservative. Because of data limitations, the medical cost estimates exclude over-the-counter medications, optometry and dental costs, expenditures for preventive services (eg, disease management programs), and administrative costs for government and commercial insurers. The nonmedical cost estimates exclude the cost of informal care, fringe benefits, and personnel costs incurred when a person is absent from work, costs associated with underemployment and early retirement due to poor health, and the costs of absenteeism and presenteeism incurred when a family member or friend has diabetes (ie, only absenteeism and presenteeism associated with one's own diabetes are included).

Other limitations of this study include the following:

1. Analyzing medical claims to identify diabetes type can lead to misidentification of individual cases of T1DM and T2DM. T1DM comprises a relatively small portion of the total population with diagnosed diabetes, and thus prevalence estimates for the T1DM population are sensitive to underlying assumptions, while estimates for T2DM are relatively stable.
2. The primary databases used to analyze health care use differences by diabetes type—MCURE for the commercially insured population and the Medicare 5% Sample for the Medicare population—cover approximately 77% of diagnosed cases. The remaining 23% of cases occur among Medicaid and uninsured populations. The etiological fractions assume that the rate ratios are independent of insurance type, although the national estimates of total health care use to which the etiological fractions are applied do take into consideration the impact of insurance status and payer type.
3. Insufficient data exist to analyze differences in health care utilization by diabetes type for home health, hospice, podiatry, and other equipment and supplies. Our use of relative prevalence of disease type to estimate the proportion of the diagnosed diabetes costs associated with T1DM likely underestimates the burden of T1DM for these cost components.
4. Survey data to estimate the indirect costs of diagnosed diabetes lack information on diabetes type. Consequently, we use differences in health care utilization to estimate differences between T1DM and T2DM in per capita productivity loss.

Suggested areas for future research include:

1. Refining the criteria to identify patients by diabetes type using medical claims data;
2. Modeling the lifetime costs associated with T1DM and T2DM; and
3. Analyzing whether children with T2DM are more likely to experience future rates of complication and economic cost similar to older patients with T2DM, or similar to older patients with T1DM.

These estimates highlight the extensive economic burden associated with diabetes. The total cost to society, however, is higher than the estimate provided here when the impact of diabetes on reduced quality of life is considered.

There are approximately 16 times as many people with T2DM as with T1DM; therefore, policies targeting the prevention and management of T2DM have the greatest potential to lower the overall economic impact of diagnosed diabetes. Among the T1DM population, medical costs increase substantially with age (and duration of diabetes), highlighting the importance of diabetes management directed toward the prevention of costly complications.

Disclosures

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The Economic Costs of Undiagnosed Diabetes

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Abstract

The objective is to estimate the national economic costs associated with undiagnosed diabetes mellitus (UDM). UDM is defined as unknowingly having an elevated glucose level that meets the definition of diabetes. National Health and Nutrition Examination Survey (NHANES) data are used to estimate the prevalence of UDM. Because UDM cannot be directly observed in medical claims for analyzing per capita patterns of health care use, we analyze annual medical claims from a proxy population—people within 2 years of first diagnosis of diabetes. For a commercially insured population first diagnosed with diabetes in 2006 (n = 29,770), we compare their annual health care use in 2004 and 2005 to that of patients with no history of diabetes between 2004 and 2006 (n = 3.2 million). We combine estimates of UDM prevalence from NHANES with health care use patterns from the proxy population to estimate etiological fractions that reflect the portion of national health care use associated with UDM. Approximately 6.3 million adults in the United States have UDM in 2007. Annual per capita use of health care services for the UDM proxy population is higher than for a comparable group with no history of diabetes, but lower than for a comparable group with a history of diabetes. The estimated economic costs of UDM in 2007 is $18 billion ($2864 per person with UDM), including medical costs of $11 billion and indirect costs of $7 billion. Although the high prevalence of UDM makes it an important health issue to be studied, data limitations have contributed to a dearth of information on the health care use patterns and economic costs of UDM. By omitting UDM, estimates of the total national cost of diabetes are underestimated. (*Population Health Management* 2009;12:95–101)

Introduction

One-fourth of the approximately 23.6 million people with diabetes in the United States are unaware they have the disease. While much is known about the population with diagnosed diabetes mellitus (DDM), data limitations have contributed to a paucity of information on the health care use patterns and economic burden associated with undiagnosed diabetes mellitus (UDM)— defined as unknowingly having an elevated glucose level that meets the definition of diabetes. A recent estimate that diabetes costs the nation $174 billion per year in higher medical costs ($116 billion) and lost productivity ($58 billion) understates the total cost of diabetes because costs associated with UDM are omitted.[1]

Chronic complications linked to diabetes are present in many people who are newly diagnosed with diabetes—including retinopathy, proteinuria, neuropathy, arterial disease, cardiovascular disease, and coronary heart disease.[2–6] A claims-based study suggests that incremental costs of diabetes begin at least 8 years before diagnosis and grow at an accelerating rate as diagnosis approaches and immediately after diagnosis, and that the majority of these costs are for conditions not normally associated with diabetes or its complications.[7] A matched cohort study found evidence of increased rates of primary care consultations and pharmaceutical use up to 5 years before first diagnosis of diabetes.[8] Little is known about the average length of time between diabetes onset and diagnosis.

Estimation of national medical costs associated with UDM requires estimates of UDM prevalence (which are available from survey data) and estimates of the ratio of per capita health care use for people with UDM compared to a comparable population without diabetes. UDM, by definition, cannot be directly observed in medical claims data due to the lack of diagnosis. This data limitation has hindered research on the health care use patterns of people with UDM. For our

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study, we use the observed health care use patterns for people who are within 2 years of being diagnosed with diabetes as a proxy for the health care use patterns of the UDM population.

Just as the lack of diagnosis hinders analysis of health care use, the inability to identify oneself with UDM in self-report surveys presents challenges to estimate whether people with UDM have higher rates of missed work days or reduced productivity related to their diabetes. To estimate productivity loss associated with UDM, we extrapolate from estimates for people with DDM taking into consideration differences in health and demographics.

Our study findings represent, to our knowledge, a first attempt to quantify the national economic burden associated with UDM. A better understanding of this economic burden provides information to encourage creation of policies to more quickly diagnose diabetes so that more timely medical care and counseling can be provided to reduce the risk of diabetes-related complications.

Research Design and Methods

This study builds on previous work on the national costs associated with diagnosed diabetes mellitus.[1] We use a Cost of Diabetes Model that combines data from multiple sources to estimate the national prevalence of UDM in 2007; to quantify differences in health care use patterns for a proxy for the population with UDM compared to a population with no history of diabetes; to estimate the proportion of national health care use and expenditures associated with UDM; and to estimate the loss in national productivity. Information from these different analyses are combined in the model by age group (ages 18–34, 35–44, 45–54, 55–59, 60–64, 65–69, and 70 and older), sex, and insurance type.

Data

As will be described, we analyzed 6 major data sources for this study: the 2003–2006 National Health and Nutrition Examination Survey (NHANES) to estimate national UDM prevalence; the Ingenix Research DataMart (RDM) to analyze annual per capita health care use patterns for the UDM proxy population compared to a population with no history of diabetes; and the 2003–2005 National Ambulatory Medical Care Survey, the 2003–2005 National Hospital Ambulatory Medical Care Survey, the 2004–2005 Nationwide Inpatient Sample, and the 2003–2005 Medical Expenditure Panel Survey (MEPS) to obtain national estimates of health resource use and associated medical costs. With the exception of RDM, these data sources are publicly available and documented extensively.

RDM is a longitudinal database that contains historical medical claims and patient demographic information for a population that is largely commercially insured, with a minority of beneficiaries insured through Medicaid. Using the RDM, we identified over 3.5 million beneficiaries who were continuously enrolled with a health plan participating in the RDM between January 1, 2004 and December 31, 2006.

National prevalence of UDM

The NHANES sample is a stratified random sample of the noninstitutionalized population in the United States. A portion of the survey participants receive a medical examination that includes a fasting plasma glucose (FPG) test. Using NHANES, we identify adults (age 18 and older) with UDM if they have a FPG result $\geq$126 mg/dl and they respond "no" to the question of whether they have ever been told by a doctor or other health professional that they have diabetes.[9, 10] People with gestational diabetes are excluded from UDM estimates.

To obtain a sample of sufficient size to produce reliable estimates by demographic, we combine 2 waves of NHANES data to calculate UDM prevalence by age group, sex, and race and ethnicity (non-Hispanic white, non-Hispanic black, non-Hispanic other, and Hispanic). We multiply UDM prevalence rates by Census Bureau population estimates in 2007, by demographic, to produce national estimates of the number of people with UDM.

Health care utilization patterns from a proxy population for UDM

Practical and ethical constraints prevent using a prospective research design to identify a population without diabetes and to track this population over time through the stages of prediabetes, UDM, and diagnosis. Using a retrospective study design to identify a population with UDM also presents challenges as, by definition, there are no markers in historical medical claims data to identify time of diabetes onset.

To estimate health care use associated with UDM, we identified a proxy for the health care utilization patterns of the UDM population—average annual health care use per capita for people who are within 2 years of first being diagnosed with diabetes. Specifically, we identified people with a diagnosis of diabetes in 2006 (using ICD-9 diagnosis code of 250.xx) but who had no claims history of diabetes in 2004 and 2005 (n = 29,770). Pharmacy claims (prescriptions for insulin and oral agents) also are used to identify people with diabetes.

This proxy population will contain people with UDM, people with prediabetes, and people who progressed from "normal" glucose tolerance through prediabetes to UDM within the 2 years prior to first diagnosis. "Contamination" of the analytic sample by people who do not have UDM raises the question of whether per capita health care use patterns for this population are representative of the UDM population, conservative (ie, lower than the UDM population), or high.

A recent study shows that about 11% of people with impaired glucose tolerance develop type 2 diabetes each year.[11] This suggests that at most 22% of the proxy population could in theory have prediabetes. Presumably, they tend to be those patients with glucose levels that are close to the clinical threshold for diabetes. To the extent that our proxy population contains people with prediabetes or people with normal glucose tolerance who progress from prediabetes to diabetes within the 2-year window, observed health care use patterns might underestimate the actual health care use patterns of the UDM population.

To our knowledge, no longitudinal studies have estimated the duration of UDM. If UDM duration averages longer than 2 years, then using a 2-year window to identify the proxy population could result in a proxy population whose average health care use is greater than that of the typical UDM patient.

To properly attribute health care use, patterns of annual health care use among the UDM proxy sample are compared to patterns of health care use for people with no diagnosis of diabetes during the period 2004 to 2006 (n = 3.2 million). The analytical file also includes people with a history of diabetes prior to 2006 (n = 179,000).

Health resource use and cost attributed to UDM

Estimation of national health care use associated with UDM consists of 3 steps: (1) estimate differences in annual average use of health resources by people with UDM compared to people with no history of diabetes; (2) estimate total national health care use and associated costs from national sources; and (3) combine national estimates of UDM prevalence with information on health care use patterns to calculate etiological fractions that represent the proportion of national health care use associated with UDM.

Patterns of Health Resource Use

We use a Poisson regression on medical claims for 2004 and 2005 in the RDM to estimate differences in annual utilization of health care services between the UDM proxy population and the population with no history of diabetes, controlling for other determinants of health care use such as age, sex, census region, insurance type, pregnancy status, and presence of high-cost health conditions such as neoplasm, transplantation, and HIV/AIDS. We analyzed 3 categories of medical services: ambulatory visits (ie, physician office visits, hospital outpatient visits, freestanding ambulatory surgical center visits), emergency visits, and hospital inpatient days. For each service type we analyzed 7 broad categories of complications linked to diabetes: neurological symptoms, peripheral vascular disease, cardiovascular disease, renal complications, endocrine complications, ophthalmic complications, other complications, as well as an "all other" category. We use a primary diagnosis code to determine the complication group. These codes are documented elsewhere.[1]

The estimating equation can be expressed:

$$\log(\text{annual visits}) = \beta_0 + \beta_1 \times \text{UDM}_i + \beta_2 \times \text{DDM}_i + \beta_3 \times \text{control variables}$$

where UDM and DDM are dichotomous variables [UDM = 1 if in the proxy population (ie, first diagnosed with diabetes in 2006 and no history of diabetes in 2004 and 2005, and 0 otherwise; DDM = 1 if a history of diagnosed diabetes prior to 2006, and 0 otherwise]. The comparison group (UDM = 0 and DDM = 0) consists of people with no history of diabetes between 2004 and 2006. The term *control variables* represents an array of indicator variables including age group, sex, type of insurance (commercial or public), census region, year, and the presence of other health conditions.

The UDM coefficient (β_1) is a logged rate ratio, representing average annual health care use for the UDM proxy population divided by average annual health care use for people with no history of diabetes. The ratio adjusts for differences between the 2 groups in demographics and other determinants of health care use. There are 24 service-by-complication combinations. The UDM rate ratio is statistically greater than 1 at the 0.05 level for 14 combinations, and for these we estimate separate regressions (and thus age-specific rate ratios) for 3 broad age groups (age 18 to 44, age 45 to 64, and age 65 and older). For the 7 service-by-complication combinations for which the UDM rate ratio is greater than 1 but not statistically significant and the 3 combinations that are less than 1 and not statistically significant, for modeling purposes we use a rate ratio of 1 with the assumption that UDM is unassociated with use of health care services for these complications in these settings.

Sensitivity analysis was conducted to examine the impact of potential outliers in the claim database. The impact of excluding individuals who had unusually high health care utilization on a yearly basis from the analytic sample is examined. High users are defined based on the distance from the sample mean, in terms of their annual hospital days. Two sets of exclusion criteria have been tested: distance greater than 2 times or 3 times of the sample standard deviation. Our sensitivity analysis suggests that the observed health care utilization patterns are not noticeably driven by these outliers.

Several potential confounders (eg, obesity, lifestyle, personal preference) are not sufficiently adjusted for in the regression analysis. Therefore, the rate ratios from the Poisson regression might only reflect association but not causality. Prior work on diagnosed diabetes found that for 3 complication groups (general medical conditions, hypertension, and renal complications) the relationship between health care use and diabetes is biased high when controlling for demographics alone.[1] We used regression analysis with MEPS data to estimate rate ratios that reflect health care use patterns for people with diabetes compared to patterns for people without diabetes. Regressions that controlled for both lifestyle and demographics produced smaller rate ratios than regressions that controlled only for demographics. Using these regression results, we created scalars that lower the estimated relationship between diabetes and health care use for general medical conditions, hypertension, and renal complications.[1] We use these same scalars to reduce the rate ratios in this UDM analysis.

Health Resource Use and Cost

Using the approach outlined in a previous study on the economic costs of diagnosed diabetes,[1] we estimate total national ambulatory visits, emergency visits, and hospital inpatient days by complication group by estimating per capita use rates from national surveys by age group and sex. Then, we multiply these rates and Census Bureau population estimates for 2007. Physician office visits per capita come from analysis of National Ambulatory Medical Care Survey (NAMCS) data; outpatient visits and emergency visits per capita come from analysis of National Hospital Ambulatory Medical Care Survey (NHAMCS) data; and inpatient days per capita come from analysis of National Immunization Survey (NIS) data. Estimates of prescriptions per ambulatory visit come from the NAMCS and NHAMCS. Costs per visit, costs per prescription, and costs for professional services per inpatient day are estimated using MEPS data. We calculate estimates of the average cost per inpatient day from the NIS, using hospital-specific cost-to-charge ratios to convert discharge-level charges into estimates of cost per day. Cost estimates are inflated to 2007 dollars using the medical cost component of the consumer price index.

Etiological Fractions

The Poisson regressions discussed produce rate ratios (RR) that reflect the ratio of average annual visits (or inpatient days) for people with UDM compared to people with no history of diabetes. Similarly, we use rate ratios comparing people with diagnosed diabetes to people with no diagnosis of diabetes from prior published work.[1] We use these rate ratios in combination with the prevalence (P) of DDM and UDM to calculate etiological fractions (ε) for UDM by age group, sex, complication group, and service setting using the following equations[12]:

$$\varepsilon_{UDM} = (1 - I_{DDM}) \times \frac{(RR_{UDM} - 1) \times P_{UDM}}{1 - P_{DDM} + (RR_{UDM} - 1) \times P_{UDM}},$$

where

$$I_{DDM} = \frac{RR_{DDM} \times P_{DDM}}{1 + (RR_{DDM} - 1) \times P_{DDM}}.$$

Prior research suggests that for hypertension, renal complications, and general medical conditions the rate ratios produced when controlling only for demographics overstate the impact of diabetes on use of health care services by 20%–40%.[1] Obesity, for example, is a risk factor for diabetes and these 3 complication groups, and obesity can increase the risk for hypertension and renal complications through pathways other than diabetes. We scale down the estimated UDM impact on these 3 complication groups using these published adjustment factors.

Multiplying national total health care use and the etiological fractions produces estimates of excessive utilization associated with UDM.

Lost Productivity Associated with Undiagnosed Diabetes

Studies have found that DDM is associated with productivity loss from absenteeism (sick days from work), "presenteeism" (reduced productivity while at work), reduced productivity of those not in the workforce, long-term disability (which prevents working), and early mortality.[1,13–17] The inability to identify people with UDM in self-report surveys prevents directly measuring the impact of UDM on lost productivity. Therefore, to determine productivity loss associated with UDM we extrapolate productivity loss from the DDM population to the UDM population controlling for differences in demographics and the prevalence and severity of chronic health problems.

For the adult population with DDM, we previously estimated the average productivity loss per year due to absenteeism, presenteeism, and lost productivity for those not in the labor force.[1] To extrapolate productivity loss to the UDM population, we calculate a ratio of average annual inpatient days per person, by age group and sex, using the following equation:

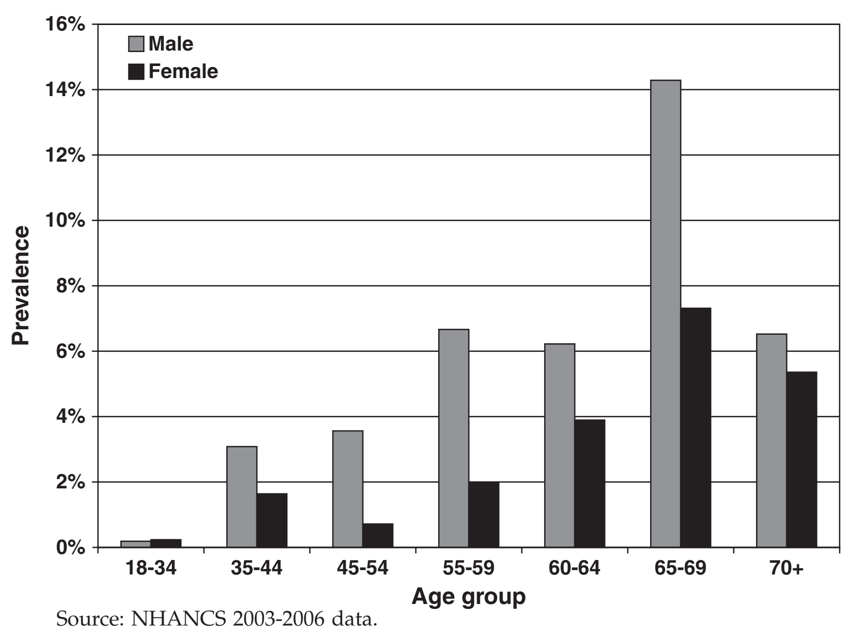
$$\text{Ratio} = \frac{\text{inpatient days}_{\text{UDM}}}{\text{inpatient days}_{DDM}}.$$

Conceptually, this ratio reflects the difference in prevalence and severity of chronic health problems among people with undiagnosed and diagnosed diabetes. The use of inpatient days is based on the assumption that they contribute more directly to productivity loss than would ambulatory visits. Use of inpatients days is conservative—creating smaller results than using ambulatory visits or overall costs.

We apply this ratio to the average cost per DDM case for absenteeism, presenteeism, and lost productivity for those not in the labor force to create per person estimates of indirect costs associated with UDM. We make the conservative assumption that UDM is not associated with unemployment from long-term disability or early mortality.

Results

In 2007, an estimated 6.3 million adults have glucose levels that meet the definition of diabetes, but are unaware that



Source: NHANCS 2003-2006 data.

FIG. 1. Prevalence of undiagnosed diabetes by age and sex.

they have the disease. This estimate varies slightly from other estimates,[9] reflecting that our estimate applies to the population ages 18 and older, uses NHANES data from 2003 to 2006, and applies prevalence rates by demographic to Census Bureau population estimates for 2007. UDM prevalence increases with age until age 70, and is consistently higher among men (Fig. 1). About 4%–6% of males ages 35 to 64 have UDM; this percentage rises to as high as 14% for males ages 65 to 69. UDM prevalence is higher for non-Hispanic blacks than for other major race or ethnicity groups (results not presented).

The regression results suggest that, relative to a population with no history of diabetes, being within 2 years of diagnosis increases the rates of ambulatory visits for all major complication categories. (Pertinent regression results for each of the 3 major age groups are summarized in Table 1). The increase in rate is statistically significant for all complication groups except ophthalmic complications. The rate ratios are highest for people ages 18 to 44, and tend to decline with age. The regression results show that the increase in visit rates for the UDM proxy population is less than the increase among the population with a history of diabetes.

Being within 2 years of diagnosis is associated with a statistically significant increase in emergency visits for only 3 categories (cardiovascular disease, hypertension, and general medical visits), and a statistically significant increase in per capita inpatient days for all categories except endocrine complications and ophthalmic complications. For rate ratios that are not statistically different from 1.0, we use a ratio of 1.0 for modeling the cost of UDM. Although use of 1.0 is a conservative assumption, the impact on cost estimates is relatively small, as categories with statistically insignificant results tend to be categories with low rates of health care encounters.

Combining these health care use patterns with UDM prevalence rates, by demographic, to estimate the proportion of national health care use associated with UDM suggests that the national cost of UDM exceeds $18 billion, or approximately $2864 per adult with UDM (Table 2). Excess medical spending for the direct cost components included in this study total $11 billion ($1745 per adult with UDM) and indirect costs total $7 billion ($1119 per adult with UDM). Medical costs associated with UDM are for general medical conditions ($6.8 billion), cardiovascular disease ($2.3 billion), hypertension ($720 million), renal complications ($443 million), peripheral vascular disease ($433 million), neurological symptoms ($293 million), and endocrine/metabolic complications ($37 million). These costs account for about 1.5% of national health care expenditures for the aforementioned major medial conditions.

The average cost per adult with UDM ($1745) varies by age group: $1908 for ages 18 to 45, $2962 for ages 45 to 64, and $579 for age 65 and older. In comparison, the average cost associated with diagnosed diabetes per adult ($6667) is $3761 for ages 18 to 45, $5094 for ages 45 to 64, and $9713 for ages 65 and older.[1] The large difference between UDM and DDM in average diabetes-attributed cost for the older age group likely is a reflection that many older people with diagnosed diabetes have had the disease for many years. Also the UDM analysis excludes costs associated with nursing homes, home health, long-term disability, and premature mortality.

TABLE 1. POISSON REGRESSION RATE RATIOS SUMMARY

	Ambulatory Visits				Emergency Visits				Inpatient Days			
Complication Group	*Age 18 to 44*	*Age 45 to 65*	*Age 65+*	*Total*	*Age 18 to 44*	*Age 45 to 65*	*Age 65+*	*Total*	*Age 18 to 44*	*Age 45 to 65*	*Age 65+*	*Total*
Neurological symptoms	2.19**	1.31**	1.25	1.38**	0.00†	0.96†	0.92†	0.93	0.70†	1.76*	1.12	1.48*
Peripheral vascular disease	2.24**	1.51**	1.29**	1.51**	1.27†	1.42†	1.41†	1.45	7.65*	2.22*	2.28**	2.62**
Cardiovascular disease	2.74**	1.72**	1.05	1.42**	5.42**	1.43	1.05	1.44*	3.20**	2.22**	1.19	1.79**
Hypertension	3.28**	1.73**	1.18	1.65**	12.20**	2.12**	1.65	2.57**	2.63	2.98**	1.07	2.32**
Renal complications	1.60**	1.54**	2.17**	1.74**	2.28**†	1.25†	0.65†	1.33	2.42**	2.14**	1.92**	2.18**
Endocrine complications	1.96**	1.28**	0.89†	1.26**	0.00†	2.52†	5.43†	2.92	0.00†	2.37†	0.45†	1.79
Ophthalmic complications	1.13†	1.02†	0.96†	1.01	0.00†	0.92†	0.43†	0.66	0.00†	0.00†	0.46†	0.16
General medical visits	1.30**	1.06**	1.01	1.09**	1.67**	1.13*	1.17	1.28**	1.63**	1.54**	1.24**	1.47**

*significant at 5%; **significant at 1% based on robust standard error; †Number assumed 1.0 for modeling.

Table 2. Total cost of undiagnosed diabetes among adults, 2007

Cost Component	*US Total Health Expenditures($ millions)*	*Total cost of UDM($ millions)*	*Cost per person with UDM ($)*	*Percent of National Cost Associated with UDM (%)*
Total costs*	NA	18,043	2864	NA
Total medical costs (for cost components modeled)*	741,270	10,992	1745	1.5
Hospital inpatient	372,134	8366	1328	2.2
Physician office-based care	126,090	705	112	0.6
Emergency care	61,217	629	100	1.0
Hospital outpatient & freestanding ambulatory surgical center	49,057	268	43	0.5
Retail prescriptions	132,770	1024	163	0.8
Total nonmedical costs*	NA	7051	1119	NA
Workdays absent	NA	769	122	NA
Reduced performance at work	NA	6021	956	NA
Reduced productivity for those not in labor force	NA	261	41	NA

Cost components omitted include nursing/residential care, ambulance service, home health, hospice, podiatry, dental, equipment and supplies, and over-the-counter medications and supplies. *Numbers do not necessarily sum to totals because of rounding. NA, not available; UDM, undiagnosed diabetes mellitus.

Discussion

The main contribution of this study is to estimate the magnitude of the burden of UDM on the health care system and the nation. These findings suggest that given UDM prevalence and associated costs, additional research on UDM is warranted. To the best of our knowledge, no study has investigated the health care use patterns and economic costs for patients with UDM, although present research does show an increase in medical costs in the years leading up to diagnosis. The paucity of national research on UDM reflects the challenge of studying a disease in people for whom, by definition, there is no record of the disease. Data limitations present several challenges.

First, to estimate per capita health care use we use a proxy for the UDM population—people within 2 years of diabetes diagnosis. Using a 2-year window might potentially under- or overstate the increased risk of medical complications among UDM patients. Rate ratios to estimate the impact of UDM on health care use are slightly higher when using only 2005 data (the year immediately preceding diagnosis) and slightly lower when using only 2004 data. Using a larger observation window (eg, 3 or 4 years prior to first diagnosis) presumably would reduce the estimated excess medical cost per patient that is attributed to the soon-to-be diagnosed diabetes, but would increase the proportion of the proxy population who likely have prediabetes or normal glucose tolerance.

Second, several potential confounders (eg, obesity, lifestyle, personal preference) are not sufficiently adjusted for in the regression analysis. Therefore, the rate ratios from the Poisson regression might only reflect association but not causality. As discussed in the methods section, we adjust the health care rate ratios for 3 complication groups (general medical conditions, hypertension, and renal complications) to reflect that the relationship between health care use and diabetes is biased high when controlling for demographics alone.[1]

Third, the UDM proxy group for the health care use analysis underrepresents people with public insurance and omits the uninsured. We used the relative increase in health care use for the UDM population (compared to the population with no history of diabetes) to estimate the etiological fractions applied to national estimates of total health care use by demographic group.

Fourth, home health, nursing homes, and skilled nursing facilities, care from nonphysician providers (eg, podiatry and dental care), and nonprescription medications are omitted from this analysis for lack of data. This omission makes the cost estimates more conservative.

A recent Centers for Disease Control and Prevention study found that limited access to health care, especially being uninsured and going without insurance for a long period, was significantly associated with being a "missed patient" with diabetes.[18] Examining health care utilization patterns from a largely insured population will inform what the economic costs would be if barriers for health care among the uninsured were removed.

This study identified research questions that require further analysis: (1) What is the average length of time between diabetes onset and diagnosis? (2) What patient characteristics or health care utilization patterns can help identify patients with potential UDM who are candidates for glucose level testing?

To the extent that UDM might be associated with early stages of chronic conditions, there are potential opportunities to mitigate the severity of these comorbidities through early intervention and prevention. If diabetes is detected earlier and treated properly, the disease burden could potentially be reduced.

Although the UDM cost estimates should be considered preliminary and require additional research for validation, these findings suggest that the total national economic cost of diabetes could exceed $192 billion in 2007 ($174 billion associated with DDM and over $18 billion associated with UDM). Because people with UDM cannot be observed directly, requiring that we identify a proxy for the population with UDM, the medical cost estimates for UDM are less precise than the estimates for DDM. Similarly, the indirect costs for UDM cannot be observed directly and are extrapolated from productivity loss estimates associated with diagnosed diabetes, taking into account differences in health and demographics.

Disclosure Statement

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Medical Cost Associated with Prediabetes

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Abstract

In this article, we estimate national health care resource use and medical costs in 2007 associated with prediabetes (PD), defined as either fasting plasma glucose between 100 and 125 or oral glucose tolerance test between 140 and 200.

We use Poisson regression with medical claims for an adult population continuously insured between 2004 and 2006 to analyze patterns of health care resource use by PD status. Combining rate ratios that reflect health care use patterns with national PD prevalence rates from the National Health and Nutrition Examination Survey, we calculate etiological fractions to estimate the portion of national health resource use associated with PD. The findings suggest that PD is associated with statistically higher rates of ambulatory visits for hypertension; endocrine, metabolic, and renal complications; and general medical conditions. PD is associated with a slight increase in visit rates for neurological symptoms, peripheral vascular disease, and cardiovascular disease, but the increase is not statistically significant. There is no indication that PD is associated with an increase in emergency visits and inpatient days. Extrapolating these patterns to the 57 million adults with PD in 2007 suggests that national annual medical costs of PD exceed $25 billion, or an additional $443 for each adult with PD.

PD is associated with excessive use of ambulatory services for comorbidities known to be related to diabetes. Our findings strengthen the business case for lifestyle interventions to prevent diabetes by adding additional economic benefits that potentially can be achieved by preventing or delaying PD. (*Population Health Management.* 2009;12:157-163)

An estimated 57 million people in the United States have prediabetes (PD), which is characterized by elevated blood glucose levels with either fasting plasma glucose between 100 and 125 or oral glucose tolerance test between 140 and 200.[1] Concerns regarding PD have focused on its role as a precursor to type 2 diabetes, a disease associated with increased risk for cardiovascular disease, renal complications, peripheral vascular disease, neurological complications, endocrine complications, and numerous other chronic health problems.[2–7]

There is growing evidence that even slightly elevated blood glucose levels, as is the case with PD, are associated with higher medical costs[8,9] and increased risk for certain comorbidities of diabetes—coronary heart disease,[10–14] retinopathy,[15,16] hypertension,[17] and even mortality.[18] With nearly 1 in 4 adults (57 million out of 224 million) having PD, even a slight increase in per capita health care use and disease risk has significant implications for the health system.

While recent work highlights the significant economic burden associated with diabetes,[19,20] few studies have investigated the economic burden of PD.[8,9] We use recent medical claims data to estimate per capita excess health care use associated with PD, and combine this information with national estimates of health care use and medical costs to calculate national expenditures associated with PD. Such cost information is paramount to understanding the business case for interventions directed to improve prevention, screening, and treatment associated with PD.

Research Design and Methods

This study uses a Cost of Diabetes Model, originally developed to quantify the national cost of diagnosed diabetes, that contains estimates of national health care use and costs for comorbidities of diabetes. The data sources and methods used to develop this model, the national health care use and

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cost estimates in the model, and the etiological fractions used to determine the proportion of national costs attributed to diagnosed diabetes are described elsewhere.[19] Following is a description of the data and methods used to adapt this model to quantify the national medical costs associated with PD.

Data

The primary national data sources used are Census Bureau population estimates for 2007; the 2003–2006 National Health and Nutrition Examination Survey (NHANES) to estimate national PD prevalence; and the 2003–2005 National Ambulatory Medical Care Survey (NAMCS), the 2003–2005 National Hospital Ambulatory Medical Care Survey (NHAMCS), and the 2003–2005 Medical Expenditure Panel Survey to obtain national estimates of health resource use and associated medical costs. These data sources are publicly available and documented extensively.[21]

To calculate etiological fractions that reflect the proportion of national health care use associated with PD, we require estimates of the ratio of health care use for people with PD to health care use for people without PD, adjusting for potential confounders. To calculate these rate ratios, we analyze medical claims in the Ingenix Research DataMart (RDM) for a population of 3.5 million adults continuously insured from January 1, 2004 to December 31, 2006. The RDM population is largely commercially insured through UnitedHealth, although the database contains beneficiaries of other commercial and public insurers. Claim records for lab tests are available for all beneficiaries; however lab results are available only for tests processed by 2 national lab vendors. Among patients with no diagnosis of diabetes, a total of 796,487 patients had either a fasting plasma glucose (FPG) or an oral glucose tolerance test (OGTT) in 2004 (with test results available for 10,502 patients). In 2005, a total of 782,521 patients without a diagnosis of diabetes had either a FPG or an OGTT (with test results available for 11,406 patients). Additional detail on the RDM population is provided in the following section.

Identifying the PD and potential comparison groups

To estimate national PD prevalence, we identified people in the NHANES with a FPG between 100 and 125 mg/dL. NHANES is a stratified random sample of the US population, and a FPG test is administered to a random subset of NHANES participants. The latest wave of NHANES also contains OGTT results for a sample of participants, but for consistency with the Centers for Disease Control and Prevention estimates, we use only FPG to estimate PD prevalence for the adult population older than age 20.[1] PD prevalence rates are estimated by age, sex, and race/ethnicity (non-Hispanic white, non-Hispanic black, non-Hispanic other, and Hispanic). We use age groups 20–34, 35–44, 45–54, 55–59, 60–64, 65–69, and 70 and older. Prevalence rates are multiplied by Census Bureau population estimates for 2007 to estimate the total number of people with PD.

We used the same FPG threshold to identify individuals with PD in the RDM. To increase the accuracy of patient identification, we also use OGTT test results to capture individuals who would likely have been identified as having PD if they had had a FPG test. According to the American Diabetes Association Clinical Guideline, the comparable threshold is OGTT between 140 and 200 mg/dL.[22] People in the RDM with an FPG or OGTT test result are a nonrandom sample of the population. Among the population with a glucose test, pregnant women and people with ophthalmic complications are overrepresented, reflecting health care use and referral patterns for glucose testing. We address the nonrandom nature of the data in 2 ways. First, we use data from one year (2004 or 2005) to categorize patients by PDM status, and then use data from the following year (2005 or 2006) to analyze health care use patterns. Receiving a glucose test is endogenous to health care use in the year the test is administered. Second, we use Poisson regression analysis to statistically control for differences in health care use patterns among 5 mutually exclusive groups of patients:

- Group #1: Confirmed with PD ($n = 1642$ in 2004 and $n = 1923$ in 2005): This population meets the clinical definition of PD as confirmed by at least 1 abnormal FPG or OGTT test during the PD identification years (ie, 2004 or 2005). We exclude women with any gestational diabetes diagnosis code (648.8x).
- Group #2: Presumed no PD (comparison group 1; $n = 8860$ in 2004 and $n = 9483$ in 2005): This group consists of people with FPG below 100 mg/dL or OGTT below 140 mg/dL in the PD identification years. This group overrepresents pregnant women who receive a glucose test as part of normal prenatal care, and could possibly overrepresent those at high risk for diabetes whose physicians recommended a glucose test, as well as those who are more likely to seek medical services. To the extent that this comparison group uses more health care services than the typical non-PD person, comparing health care use patterns for this group to the confirmed PD group could bias toward 0 estimates of health care use associated with PD.
- Group #3: Had FPG, but no results available (comparison group 2; $n = 785{,}985$ in 2004 and $n = 771{,}115$ in 2005): This group consists of nondiabetic individuals who had at least 1 FPG or OGTT test, but test results are unavailable in the RDM database. This group is contaminated by those who would have been identified as PD if their test results were estimates of health care use associated with PD.
- Group #4: Patients with diagnosed diabetes (comparison group 3 used for validation; $n = 278{,}257$): This group consists of people with any ICD-9 diagnoses of 250.x or HbA1c test result that exceeds 7.0% during the 2004 to 2006 period.
- Group #5: No glucose test (comparison group 4; $n = 2{,}448{,}775$ in 2004 and $n = 2{,}462{,}721$ in 2005): This group consists of nondiabetic individuals who had no FPG or OGTT test in 2004 or 2005. This group is contaminated by the presence of people with PD who did not have a glucose test in 2004 or 2005; comparing PD health care use to this comparison group could bias low estimates of excess health care use associated with PD.

Analysis of health resource care use patterns

We used Poisson regression to analyze patterns of health care resource use associated with neurological symptoms, peripheral vascular disease, cardiovascular disease, renal complications, endocrine complications, ophthalmic complications, and other complications of diabetes. The diagnosis codes used to define these complication categories are described elsewhere.[19] In addition, we analyze an "other" category that includes care provided for all reasons not included in the 8 categories previously specified but excluding care associated with injuries and pregnancy.

For each comorbidity group we estimate separate regressions for ambulatory visits, emergency visits, and inpatient days. Poisson regression allows us to isolate the relationship between PD status and health care service use, controlling for other determinants of health care use. The estimating equation is:

$$\text{Log(annual visits}_i) = \beta_0 + \beta_1 \times \text{PD}_i + \beta_2 \times \text{Gr1}_i + \beta_3 \times \text{Gr2}_i + \beta_4 \times \text{Gr3}_i + \underline{\beta_5} \times \underline{\text{control}}_i$$

where PD, and Gr1 through Gr3 are dichotomous variables: PD = 1 if identified with PD in identification year and 0 otherwise; Gr1 through Gr3 correspond to being in comparison groups 1 through 3 (1 in comparison group, 0 otherwise). Comparison group 4 has been omitted as the reference group. The row vector control_i represents an array of dichotomous variables indicating age group, sex, health insurance type (either commercial or public), Census region, year, and the presence of select diabetes complications and costly health conditions during the PD identification year (ie, peripheral vascular disease, cardiovascular disease, hypertension, endocrine complications, ophthalmic complications, pregnancy, neoplasm, HIV/AIDS, and organ transplantation).

In addition to regressions that included all 3.5 million adults, to test the sensitivity of our findings we estimated separate regressions for males, non-pregnant females, and pregnant females.

Estimating attributable cost

The data and methods used to calculate national estimates of health care use (eg, ambulatory visits, medications), by diagnosis category, are described elsewhere.[19] The approach combines per capita estimates of physician office visits (from the NAMCS) and outpatient visits (from the NHAMCS) with Census Bureau population estimates for 2007 by age and sex. We use the primary diagnosis code to place the visit into one of the 8 aforementioned diagnosis categories.

We calculate etiological fractions to determine the portion of national visits associated with PD.[23] Health care use attributed to PD is calculated as the proportion of visits incurred (I) by people with PD minus the visits that are likely to have occurred even in the absence of PD. To derive these estimates from national totals, we must also determine the proportion of visits incurred by people with diagnosed diabetes mellitus (DDM) and undiagnosed (UDM) diabetes mellitus. The DDM population is defined as individuals with an FPG that exceeds 125. UDM is defined as unknowingly having elevated glucose levels that meet the definition of diabetes.

The Poisson regressions, described later, produce rate ratios (RR) that reflect the ratio of annual ambulatory visits ($\overline{visits}$) for people with PD compared with people with assumed normal glucose levels (NGL). Estimates of prevalence and rate ratios for DDM come from work by Dall et al[19]; rate ratios for UDM come from other work by the authors.[24]

Combining rate ratios and prevalence rates (P), we calculate etiological fractions (ε) for PD by age group, sex, and complication group:

$$\varepsilon_{PDM} = (1 - I_{DDM} - I_{UDM}) \times \frac{(RR_{PDM} - 1) \times P_{PDM}}{1 - (P_{DDM} + P_{UDM}) + (RR_{PDM} - 1) \times P_{PDM}}$$

where

$$I_{DDM} = \frac{RR_{DDM} \times P_{DDM}}{1 + (RR_{DDM} - 1) \times P_{DDM}}$$

$$I_{UDM} = (1 - I_{DDM}) \times \frac{RR_{UDM} \times P_{UDM}}{1 - P_{DDM} + (RR_{UDM} - 1) \times P_{UDM}}$$

$$RR_{DDM} = \frac{\overline{Visits}_{DDM}}{\overline{Visits}_{UDM+PDM+NGL}}$$

$$RR_{UDM} = \frac{\overline{Visits}_{UDM}}{\overline{Visits}_{PDM+NGL}}$$

and

$$RR_{PDM} = \frac{\overline{Visits}_{PDM}}{\overline{Visits}_{NGL}}$$

Multiplying total visits and the etiological fractions produces estimates of excess visits associated with PD by demographic and complication group. Estimates of the national average cost (including pharmaceuticals) associated with each visit, by complication group, are estimated using the Medical Expenditure Panel Survey and are described elsewhere.[19]

Results

When multiplied by population estimates for 2007 from the Census Bureau, PD prevalence rates from the NHANES suggest there are 57 million adults living with PD. Prevalence rates vary by demographic, ranging from approximately 9% for women age 20–34 to over 42% for males age 65 and older.

The RDM data contain 10,502 people with a glucose test result in 2004 in the normal or PD range. This represents only 0.3% of the analyzed population. The comparison group (ie, those with no test or no test results) therefore contains a significant number of people with PD (which could bias toward 0 the estimates of differences between the PD and comparison groups). Pregnant women are overrepresented in the population receiving a glucose test in 2004; they constitute 6% of the population who test positive for PD and 14.7% of the population who test negative for PD. Women with a glucose level indicating gestational diabetes are excluded from the analysis (Table 1).

The Poisson regression analysis suggests that PD is associated with increased ambulatory visits, but we found no consistent evidence of an association between PD and increased risk of emergency visits and inpatient days. Consequently, we assume PD is not associated with medical

Table 1. Sample Summary Statistics for Three-Year Continuously Insured Individuals in RDM as of 2004 Baseline Identification Period

	Test positive for PD	*Test negative for PD*	*Glucose tested, results unavailable*[1]	*Established diabetes*	*No glucose test*
Number of RDM Individuals	1,642	8,860	785,985	278,492	2,448,775
Age group					
20–34	37.0%	36.0%	47.4%	7.6%	18.6%
35–64	49.8%	57.7%	50.1%	57.6%	64.7%
65+	13.2%	6.3%	2.4%	34.8%	16.7%
Gender					
Female	52.3%	15.2%	9.5%	52.0%	42.6%
Male	47.7%	84.8%	90.5%	48.0%	57.4%
Region					
Northeast	21.7%	20.3%	24.5%	12.0%	9.6%
Midwest	16.6%	17.0%	14.7%	30.9%	29.6%
South	59.1%	59.7%	58.6%	45.3%	46.9%
West	2.6%	2.9%	2.2%	11.7%	13.9%
Insurance type					
Private	99.6%	99.7%	99.9%	96.5%	97.6%
Medicaid	0.4%	0.3%	0.1%	3.5%	2.4%
Health status at baseline					
Pregnant	6.0%	14.7%	19.7%	1.2%	1.9%
Have neoplasm	12.8%	19.3%	18.2%	22.8%	22.3%
Have HIV/AIDS	0.4%	0.2%	0.3%	0.3%	0.5%
Have organ transplantation	0.0%	0.0%	0.0%	0.2%	0.1%
Have peripheral vascular disease	0.9%	1.8%	1.5%	4.7%	2.4%
Have cardiovascular disease	7.7%	5.4%	2.6%	15.0%	7.4%
Have hypertension	20.0%	12.1%	5.9%	28.9%	20.0%
Have endocrine or metabolic complications	15.7%	13.3%	8.3%	25.5%	24.4%
Have ophthalmic complications	5.5%	3.7%	2.8%	15.6%	6.7%

[1]The research team obtained lab results from only 2 national lab vendors.
RDM, Research DataMart; PD, prediabetes.

services that might stem from emergency visits and hospitalizations (eg, hospice care, nursing home care, home care).

Regression coefficients in the form of rate ratios are reported in Table 2. A coefficient greater than 1 implies an increased rate of health care use associated with that characteristic. The increase in per capita ambulatory visits from PD for the 7 complication categories is slight, and for some complication groups the increase is not statistically significant (Table 2). With the exception of hypertension and endocrine-related care, we observed a dose-response relationship by comparison group, where people diagnosed with diabetes have the greatest adjusted rates for ambulatory visits in the follow-up year, followed by individuals who had at least 1 glucose test, and individuals who had no test. People who had a glucose test in the year preceding analysis of medical claims, regardless of the results, have higher rates of health care use than the population who did not have a glucose test, even after controlling for baseline health status, demographics, and other factors.

We use the adjusted rate ratio between confirmed PD and the reference group (ie, individuals without either diabetes diagnosis or glucose test) to calculate the incremental ambulatory visits associated with PD. Patients with confirmed PD have approximately 34% more ambulatory visits per year compared to the reference population—ranging from 9% more visits for cardiovascular disease and peripheral vascular disease to 92% more visits for hypertension.

The additional visits associated with PD translate into approximately 1 additional physician office visit per year, $1/10^{th}$ of an additional hospital outpatient visit per year, and 2.7 additional prescriptions per year—for a total additional cost of $443 per case of PD (Table 3). The majority of PD-associated costs per year are for general medical conditions that are not identified comorbidities of diabetes ($355), followed by hypertension ($57), endocrine and metabolic complications ($11/person year), and renal complications ($9/person year) (Table 3).

Extrapolated to the national level by patient demographics, the national cost of PD would exceed $25 billion, with about $21 billion associated with general medical conditions not directly linked to diabetes. For diagnosed diabetes, approximately one third of the cost of ambulatory care associated with diabetes is attributed to excess visits for general medical conditions.[19] Close to half of the total cost is in the form of medications prescribed during ambulatory visits.

Discussion

Our findings differs from those of Nichols et al who report that predicted impaired glucose tolerance is associated with

Table 2. Poisson Regression Rate Ratios for Ambulatory Visits

Rate Ratio from Poisson Regression	*Neurological Symptoms*	*Peripheral Vascular Disease*	*Cardiovascular Disease*	*Hypertension*	*Renal Complications*	*Endocrine Complications*	*Ophthalmic Complications*	*General Medical Visits*	*All Comorbidities Combined*	*All Visits*
Nondiabetic with no glucose test (reference group)										
Glucose test results unavailable	1.48**	1.42**	1.28**	1.28**	1.91**	1.45**	1.12**	1.66**	1.40**	1.60**
No PDM based on FPG/OGTT Test	1.23	1.86**	1.03	1.31**	1.84**	1.68**	1.23	1.42**	1.06*	1.33**
Has PDM based on FPG/OGTT Test	1.41	1.09	1.09	1.92**	1.60**	1.73**	0.47	1.40**	1.16**	1.34**
Confirmed diabetes	2.97**	2.69**	1.87**	1.34**	4.69**	1.24**	1.62**	2.01**	1.88**	1.98**
Male	1.25**	0.94*	0.58**	0.96*	1.87**	0.77**	1.08**	1.69**	1.00	1.50**
Census region (reference group = Northeast)										
Midwest	1.31**	1.41**	1.11**	1.02	1.39**	0.80**	1.33**	0.98	0.97	0.98
South	1.18**	1.04	0.92**	1.11**	1.29**	0.99	1.23**	0.90**	0.92**	0.90**
West	1.03	1.04	0.83**	0.79**	1.18**	0.88**	1.27**	0.94*	0.93**	0.94*
Payer type (reference group = private)										
Medicaid	1.15	1.10	1.22**	2.28**	1.13	0.53**	1.17**	1.16**	1.19**	1.16**
Year (reference year = 2005)	1.14**	1.17**	1.09**	1.09**	1.16**	1.01	1.13**	1.10**	1.09**	1.10**
Age group (reference group = 20–34)										
35–44	4.37**	3.40**	3.41**	4.73**	0.96	4.88**	2.46**	1.38**	1.21**	1.34**
45–54	7.75**	5.03**	8.12**	6.81**	0.98	6.70**	5.54**	1.52**	1.51**	1.52**
55–59	10.19**	6.21**	13.53**	7.84**	1.05	7.55**	11.75**	1.56**	1.78**	1.60**
60–64	12.36**	6.69**	17.19**	8.35**	1.18**	7.73**	17.83**	1.58**	1.95**	1.65**
65–69	12.11**	6.01**	16.38**	6.24**	1.10	5.39**	24.47**	1.47**	1.92**	1.55**
70+	17.47**	6.31**	20.16**	4.99**	1.24**	2.46**	38.52**	1.48**	2.49**	1.69**
Have cancer	1.27**	1.23**	1.10**	1.09**	1.49**	1.20**	1.14**	1.98**	1.25**	1.79**
Have HIV/AIDS	0.98	1.50**	1.02	0.69**	3.02**	0.59**	1.58**	2.02**	1.18**	1.82**
Have transplantation	1.37	1.18	3.48**	1.06	22.16**	0.74	2.44**	4.07**	4.18**	4.07**
Pregnant	0.98	1.50**	1.02	0.69**	3.02**	0.59**	1.58**	2.02**	1.18**	1.82**
Baseline health condition										
Peripheral vascular disease	2.21**	24.00**	1.45**	1.34**	3.01**	0.97	1.23**	1.55**	1.93**	1.65**
Cardiovascular disease	1.83**	1.50**	12.04**	0.97	2.67**	1.01	1.15**	1.42**	2.00**	1.58**
Hypertension	1.36**	1.12**	1.10**	10.11**	1.41**	1.02	1.10**	1.08**	1.57**	1.19**
Endocrine complications	1.07*	0.82**	1.04*	1.04**	0.86**	8.24**	0.99	1.07**	1.41**	1.14**
Ophthalmic complications	1.36**	1.18**	1.11**	1.08**	1.55**	1.04**	5.63**	1.27**	1.47**	1.32**
Number of unique observations	3,523,754									

Logged rate ratios are reported.
*significant at 5%; **significant at 1% based on robust standard error.
Separate regressions for split samples for males, nonpregnant females, and pregnant females found consistent coefficient estimates with the overall model.
PDM, prediabetes mellitus; FPG, fasting plasma glucose; OGGT, oral glucose tolerance test.

Table 3. Per Capita Ambulatory Medical Costs for the Adult Population in 2007

Cost Component	*US Average for Adults*	*Excess Associated with PD*
By service type*	$1,296	$443
Outpatient visit	$215	$67
Physician office visit	$553	$183
Medications	$528	$194
By complication group*	$1,296	$443
Neurological symptoms	$16	$5
Peripheral vascular disease	$15	$1
Cardiovascular disease	$49	$5
Hypertension	$74	$57
Renal complications	$21	$9
Endocrine/metabolic complications	$16	$11
Ophthalmic complications	$41	$0
All other medical conditions (excluding pregnancy and injury related visits)	$1,017	$355

*Numbers may not sum to totals because of rounding.
PD, prediabetes.

a significant increase in hospital inpatient days but only a modest increase in ambulatory visits.[9] The increase in hospital days observed by Nichols et al, however, disappears after controlling for hypertensive status.

The lack of statistical significance for some complication groups, despite the consistent pattern of higher rates of visits for people with PD, is not surprising for several reasons, including: (1) PD is hypothesized to be associated with the early stages of diabetes-related complications, therefore the magnitude of PD's impact on health care use is anticipated to be modest; (2) the comparison group is contaminated in that it contains people with PD for whom there is no glucose test result in the baseline year; and (3) visit rates for some complication groups are relatively low, so modest differences in health care use patterns are undetectable due to insufficient sample size.

For one complication group—ophthalmic complications—the visit rates for people with PD are lower than the rate for those with confirmed normal glucose levels. This unexpected finding may reflect an artifact of referral patterns by ophthalmologists for patients with ophthalmic problems. PD is associated with higher visit rates for general medical conditions even controlling for the presence of major chronic conditions at baseline.

Our estimate is likely conservative for several reasons. The comparison group includes people with PD who did not have a glucose test in 2004 (and who thus, by default, are placed in the comparison group).

These cost estimates understate the true cost of PD to society, as higher use of health care services and prevalence of chronic conditions such as cardiovascular disease are associated with increases in missed work days and lower productivity.[25–28] Additionally, health problems associated with PD may result in intangible costs such as reduced quality of life.

In addition to the data limitations above that make the PD cost estimates conservative, study limitations include the following:

- The elderly, the uninsured, and the publicly insured are underrepresented in the medical claims analysis—although the regression analysis does control for insurance type, age group, and other health and demographic factors correlated with the elderly and publicly insured populations.
- We did not control for body weight status in the multivariate regression analyses. This presents challenges to isolate the impact of glucose intolerance on health outcomes independent of the changes in health outcomes via pathways other than PD. The regression analysis does control for hypertension status at baseline (which is highly correlated with body mass index).[29]

These limitations and gaps in the literature suggest areas for additional research.

We compare use of medical services by people with PD to people with normal glucose levels. Research using a more continuous measure, such as actual glucose test results, could better determine whether there is a dose-response relationship between level of glucose impairment and use of health care services.

Although this study found no association between PD and increased use of emergency or hospital inpatient services, additional research with a larger sample is needed to verify this finding.

Small sample size limited the calculation of visit rate ratios by PD status across beneficiary characteristics (age in particular). Future research might explore the interaction between PD and other beneficiary characteristics including demographics and the presence of other complications.

Conclusions

The findings suggest that PD is associated with statistically higher rates of ambulatory visits for hypertension, endocrine and metabolic complications, renal complications, and general medical conditions. PD is associated with a slight increase in visit rates for neurological symptoms, peripheral vascular disease, and cardiovascular disease, but the increase is not statistically significant. There is no indication that PD is associated with an increase in emergency visits and/or inpatient days. Extrapolating these patterns to the 57 million adults with PD in 2007 suggests that national medical costs of PD could exceed $25 billion, or approximately $443 per adult with PD.

Research suggests that PD is associated with an increased risk of developing diabetes.[2–7] Whereas adults in the United States with normal glucose levels have a 0.7% average annual risk of developing type 2 diabetes,[2] this risk rises to between 10% and 15% for those with PD.[3–5] As many as 83% of persons with impaired glucose tolerance will eventually develop diabetes, barring a lifestyle intervention such as weight loss, but this lifetime risk falls to 65% among persons who lose weight and engage in moderate physical activity.[6,7] Our findings strengthen the business case for lifestyle interventions targeted at preventing diabetes by adding additional economic benefits that can potentially be achieved by preventing or delaying PD cases.

Disclosures

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Cost of Gestational Diabetes Mellitus in the United States in 2007

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Abstract

The objective of this study was to estimate the national medical costs associated with gestational diabetes mellitus (GDM) in 2007. We analyzed the National Hospital Discharge Survey to estimate the national prevalence of GDM. Using Poisson regression analysis with medical claims for about 27,000 newborns and their mothers, we estimated rate ratios that reflect the increase in use of health care services associated with GDM. Combining GDM prevalence rates with these rate ratios, we calculated etiological fractions that reflect the proportion of national health care resource use associated with GDM. We then multiplied these fractions by estimates of national health care use and costs in 2007.

GDM prevalence increases with age, rising from 1.3% of pregnancies of women younger than age 21 to 8.7% of pregnancies of women older than age 35. For the estimated 180,000 GDM pregnancies resulting in delivery, average expenditures increased $3,305 per pregnancy plus $209 in the newborn's first year of life. GDM increased national medical costs by $636 million in 2007—$596 million for maternal costs and $40 million for neonatal costs. Approximately $230 million (36%) of GDM-related medical costs are covered by government programs (primarily Medicaid), $355 million (56%) are covered by private insurers, and $51 million (8%) are covered by self-pay and charity care.

GDM imposes a significant economic burden. These estimates of the economic burden of GDM are likely conservative because we focus on near-term medical costs, omitting the increased risk for long-term sequelae. (*Population Health Management.* 2009;12:165–174)

Introduction

Gestational diabetes mellitus (GDM), defined as any degree of glucose intolerance with onset or first recognition during pregnancy, is present in approximately 4%–7% of pregnancies.[1–4] The prevalence of GDM has risen over time, due in part to the rising prevalence of obesity among women of child-bearing age.[3,5,6]

GDM is associated with increased risk for perinatal morbidity, maternal trauma, preeclampsia and eclampsia, and operative deliveries.[2,7] Poor control of glycemic levels increases rates of delivery by cesarean and shoulder dystocia.[8] GDM is a significant predictor of type 2 diabetes.[9] After pregnancy, 5% to 10% of women with GDM are found to have type 2 diabetes, and women with GDM have a 20% to 50% probability of developing diabetes in the 5 to 10 years following pregnancy (although these rates partially reflect correlation with other risk factors).[10]

An elevated glucose level is toxic to the developing fetus and contributes to embryopathy.[11] Adverse outcomes may include macrosomia, neonatal intensive care unit admission, and perinatal death (stillbirths and neonatal deaths).[12–15] Macrosomia is present in 20% of patients with GDM, but present in only 12% of pregnancies in which GDM is absent.[14] Neonates have increased risk of hypoglycemia, jaundice, polycythemia, hypocalcemia, hypomagnesemia, and

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respiratory distress syndrome.[13] Maternal obesity and GDM may increase the risk of a range of structural birth defects through shared causal mechanisms.[12,15] Adult offspring of mothers with GDM have increased risk of type 2 diabetes and cardiovascular disease.[16–20]

While the studies referenced and others have found an increase in rate of pregnancy and newborn complications associated with GDM, few have analyzed the economics of GDM and we identified no studies that estimate the national economic burden associated with GDM.[21–24] Such information is needed to better understand the business case for initiatives to improve screening, awareness, and treatment of GDM to meet the Healthy People 2010 goal to decrease the proportion of pregnant women with GDM.[25]

Research Design and Methods

This analysis focuses on pregnancies that result in delivery (including both live births and stillbirths). Analysis of mothers' health care use covers the period 9 months preceding delivery through 12 months following delivery. The newborn analysis covers perinatal outcomes and associated health care use during the 12 months following delivery.

We estimate national maternal and newborn health service use and cost associated with GDM using an attributable risk method widely used in cost of illness studies.[26–28] This approach requires the calculation of etiological fractions constructed from estimates of (1) GDM prevalence rates, and (2) rate ratios that reflect per capita health care use when GDM is present divided by per capita health care use when GDM is absent, controlling for other determinants of health care use. Multiplying estimates of national health care use by these fractions provides estimates of national health resource use provided to GDM mothers and their newborns in excess of the required level of care if GDM were absent. For estimates of maternal and perinatal costs associated with GDM, we combine information from each component of the analysis by mother's age ($\leq$20, 21–25, 26–30, 31–35, and $\geq$36) at delivery or by newborn's sex.

We analyze national health care use and costs associated with GDM for the following complication categories[29]:

- direct treatment of GDM;
- 8 categories of maternal outcomes—cesarean delivery, polyhydramnios, urinary tract infection, amniotic cavity infection, preeclampsia and eclampsia, other hypertension complicating pregnancy, other pregnancy-related events, and all other events with pregnancy codes shown in secondary diagnosis fields; and
- 10 categories of perinatal outcomes—intrauterine hypoxia and birth asphyxia, macrosomia, endocrine and metabolic disturbances specific to the fetus and newborn, birth trauma due to long gestation and high birth weight, fetus or newborn affected by other complications of labor and delivery, respiratory distress syndrome, jaundice, congenital anomalies, other neonatal events, and all other events with neonatal codes shown in secondary diagnosis fields.

Primary and secondary diagnosis codes and procedure codes are used to assign medical claims to these complication categories, with the codes provided in Appendix Table A-1.

Etiological fractions

The etiological fractions (ε) are constructed using the following equation that combines GDM prevalence rates (P) with the health care use rate ratios (RR):

$$\varepsilon_{c,d,o} = \frac{P_d \times (RR_{c,d,o} - 1)}{P_d \times (RR_{c,d,o} - 1) + 1}.$$

Separate fractions are calculated for women and newborns by complication category (c) and demographic (d) for 3 outcome (o) measures—hospital inpatient days, emergency visits, and other ambulatory visits (ie, hospital/clinic outpatient visits and physician office visits combined). The demographic dimension consists of mother's age (for the maternal analysis) and newborn's sex (for the newborn analysis).

Estimating GDM prevalence

GDM is defined as any degree of glucose intolerance with onset or first recognition during pregnancy, which acknowledges the possibility that patients may have previously undiagnosed diabetes mellitus or may have developed diabetes coincidentally with pregnancy.[30]

To estimate total cases of GDM in 2007, we first combined the 2003 through 2005 samples of the National Hospital Discharge Survey to estimate the proportion of deliveries in which the mother has GDM. Pregnancies with GDM are identified using the discharge diagnosis for GDM (*International Classification of Diseases,* Ninth Revision, Clinical Modification [ICD-9-CM] code 648.8) at time of delivery.[3,31,32] Included in the GDM prevalence rates are pregnancies that result in delivery—whether singleton live birth, multi-fetal live birth, or stillbirth. We calculated this proportion by mothers' age group, and race and ethnicity (non-Hispanic White, non-Hispanic Black, non-Hispanic Other, and Hispanic). Then, we multiplied these proportions by Census Bureau projected birth counts for 2007 for each demographic group.[33]

Estimating rate ratios for health resource use

The rate ratios describe how per capita use of health care services differs by GDM status, controlling for other determinants of care. The rate ratios come from a series of Poisson regressions of medical claims from a longitudinal database, the Ingenix Research Data Mart (RDM).

The RDM contains medical records for 32,735 women who gave birth in 2005 and who were continuously enrolled from January 1, 2004 through December 31, 2006. The population in RDM is largely commercially insured, a limitation discussed later. The number of multi-fetal live births in the RDM is relatively small, so we restrict our medical claims analysis to singleton live births. The Poisson regressions are based on medical records for 26,911 deliveries (82% of deliveries in 2005 in the original data extraction). The final sample excludes 105 stillbirths, 6 women with multiple pregnancies in 2005, 717 multi-fetal live births, 1,853 cases for which a missing family identification code prevents linking newborns to their mothers, and 3,143 cases in which more than 1 infant shares a same family identification code although there are no multi-fetal diagnosis codes to indicate a multi-fetal birth.

Mother's GDM status is determined by the presence of ICD-9-CM diagnosis code 648.8 in claims data during the 9 months preceding and including delivery.

We estimated 39 Poisson regressions (19 for the maternal analysis and 20 for the newborn analysis) reflecting the 39 combinations of health care measures and complication categories. The regression specifications and results are summarized in Appendix Tables A-2 and A-3.

The dependent variables are the health care service measures (ie, hospital inpatient days, emergency visits, other ambulatory visits) for the 8 maternal and 10 perinatal complication groups (not all health care service measures apply to each complication group). Health care use covers the period 9 months preceding delivery through 12 months following delivery for mothers, and the 12 months following delivery for newborns.

The explanatory variables in the Poisson regressions are dichotomous variables for mother's GDM status (1 = present, 0 = absent), mother's age group at time of delivery (for the maternity analysis only), sex of the newborn (for the newborn analysis only), Census Region, presence of HIV/AIDS, presence of cancer, presence of other pregnancy related high risk (for the maternity analysis only), presence of preterm or post-term conditions (for the newborn analysis only), and presence of maternal or perinatal complications. Race and ethnicity are unavailable for most records, so these characteristics are excluded from the regressions. Also, the study population is primarily covered by private insurers (>99%), so no variables reflecting payer type are included in the regressions.

The coefficient for GDM represents an adjusted, logged rate ratio: average health care use when GDM is present, divided by average health care use when GDM is absent, controlling for demographics and other determinants of care.

Estimating national health resource use and cost

Using multiple nationally representative surveys of health care use, we estimate annual national maternal and newborn hospital inpatient days, hospital/clinic outpatient visits, emergency visits, and physician office visits by outcome category. These estimates include care provided for all women in pregnancy and postpartum periods and infants no older than 1 year, including both GDM and non-GDM cases. Estimates are based on survey data for years prior to 2007, but are extrapolated to 2007 based on the Census Bureau's estimates of total births in 2007 compared to total births in prior years.

Estimates of total physician office visits come from an analysis of the 2000 to 2005 National Ambulatory Medical Care Survey (NAMCS). We combined multiple years of data to increase sample size, thereby obtaining more reliable estimates of the prevalence of rare complications. Estimates of outpatient visits and emergency visits come from an analysis of the 2000 to 2005 National Hospital Ambulatory Medical Care Survey (NHAMCS). We analyzed the 2005 Nationwide Inpatient Sample (NIS) to estimate total hospital inpatient days. Estimates of prescriptions per ambulatory visit are from the NAMCS and NHAMCS. Excluded from the analysis are home health, hospice, and nursing home care.

We combined the 2003 to 2005 samples of the Medical Expenditure Panel Survey to calculate national estimates of the average medical cost per outpatient, emergency, and physician office visits, as well as the average cost per prescription. The average cost per inpatient day was calculated using the NIS, and converted from discharge-level charges using hospital-specific cost-to-charge ratios. Cost estimates are calculated for each outcome category, reflecting the total spending and the mix of payers for care (ie, private insurers, Medicaid, Medicare, other insurance programs, self-pay, charity care). All cost estimates are inflated to 2007 dollars using the medical cost component of the consumer price index.

We calculate medical expenditures associated with GDM by combining the etiological fractions, total national health resource use, and average cost per unit per service using the following formula:

$$\text{Cost Attributed to GDM} = \sum_{c}\sum_{d}\sum_{o} \varepsilon_{c,d,o} \times TotalUtilization_{c,d,o} \times AverageCost_{c,o}$$

Results

Our analysis finds that GDM is present in approximately 4.5% of pregnancies that result in delivery (Table 1). This rate is at the lower bound of the 4% to 7% range reported in the literature, but also reflects GDM prevalence among pregnancies resulting in delivery versus all pregnancies.[3,4,32,34,35] In 2007, there were an estimated 180,000 cases of GDM (higher than the 135,000 estimated in previous years to reflect population growth and higher GDM prevalence, and lower than the 200,000 estimated for all pregnancies).[2,4,36] GDM prevalence increases with the mother's age. Although not shown, GDM prevalence is highest among Hispanics, followed by the non-Hispanic Other group, followed by non-Hispanic Blacks, and with prevalence lowest among non-Hispanic Whites.

To prevent double counting when health care use involves multiple outcome categories (eg, cesarean delivery with urinary tract infection present), we use the primary ICD-9-CM diagnosis code to categorize each medical claim. For some outcomes, we use a combination of diagnosis codes and procedure codes (see Appendix Table A-1).

Rate ratios from the Poisson regression (full regression results are in Appendix Tables A-2 and A-3) suggest that, relative to women with no indication of glucose intolerance during their pregnancy, GDM significantly increases rates of hospital inpatient days for cesarean delivery, preeclampsia

Table 1. Prevalence and Population with GDM in the United States, 2007

Mother's Age at Delivery	*GDM Prevalence in All Deliveries*	*GDM Population in 2007*
Age ≤20	1.3%	8,000
Age 21–25	2.5%	27,000
Age 26–30	4.7%	55,000
Age 31–35	5.9%	50,000
Age ≥36	8.7%	40,000
Total	4.5%	180,000

GDM, gestational diabetes mellitus.

Table 2. Rate Ratios (from Poisson Regression) of Health Care Use for GDM Women and Their Offspring

	Hospital Inpatient Day	*Emergency Visit*	*Other Ambulatory Visit*
Mother			
Cesarean delivery	1.195**	NA	1.221**
Polyhydramnios	1.440	NA	1.855**
Urinary tract infection	0.683	1.170	1.119**
Amniotic cavity infection	0.466*	NA	0.950
Preeclampsia and eclampsia	1.499**	NA	1.454**
Other hypertension complicating pregnancy	1.560*	NA	1.495**
Other pregnancy-related event	1.286**	1.187	1.368**
All other events with pregnancy codes shown in secondary diagnosis fields	1.101	1.426**	1.123**
Newborn			
Intrauterine hypoxia and birth asphyxia	NA	NA	0.805
Macrosomia	NA	NA	1.826**
Endocrine and metabolic disturbances	2.907**	NA	3.443**
Birth trauma	NA	NA	0.620*
Fetus or newborn affected by other complications of labor and delivery	2.550	NA	1.315**
Respiratory distress syndrome	0.701**	NA	0.820**
Jaundice	1.754**	1.590	1.213**
Congenital anomalies	0.676**	NA	1.127**
Other neonatal event	1.035**	0.590	1.027**
All other events with neonatal codes shown in secondary diagnosis fields	0.977	0.824	1.002

*$P < 0.05$, **$P < 0.01$.
GDM, gestational diabetes mellitus.

and eclampsia, other hypertension complicating pregnancy, and other pregnancy-related events for mothers (Table 2). For example, a rate ratio of 1.195 for hospital inpatient days for cesarean delivery means that the presence of GDM increases inpatient days associated with cesarean delivery by 19.5%. GDM also is associated with a significant increase in ambulatory visits for 7 of the 8 complication categories. Due to the rare incidence of certain complications in some health service settings, rate ratios may not be applicable or may be large but statistically insignificant for some complications by setting combinations.

GDM appears to increase newborns' average inpatient days for endocrine and metabolic disturbances, "other" complications of labor and delivery that affect the fetus or newborn, jaundice, other neonatal events, and all other events with a neonatal diagnosis in the secondary diagnosis field. The increase is statistically significant for endocrine and metabolic disturbances, jaundice, and other neonatal events identified by primary diagnosis. GDM also increases ambulatory visits associated with 7 newborn complication categories, with the increase statistically significant in 6 categories.

For some outcome categories, women with GDM and their newborns have significantly lower use of health care services (eg, inpatient days for amniotic cavity infection for women; ambulatory visits for birth trauma, inpatient days, and ambulatory visits for respiratory distress syndrome; inpatient days for congenital anomalies for newborns). One possible explanation for these anomalies is that these outcomes are rarely listed as the primary diagnosis.

Applying the etiological fractions to total national maternal and neonatal resource use in 2007, we calculate the proportion of health care utilization and cost attributed to GDM (Table 3). For example, of the total predicted 17 million hospital inpatient days for new mothers, approximately 4.8% (838,000 days) are incurred by women with GDM and 1.5% (269,000 days) reflect higher per capita use of services that are attributed to GDM.

The total national cost estimates attributable to GDM are $596 million for mothers (approximately $3,305 per woman with GDM) and $40 million for their newborn offspring (approximately $209 per newborn whose mother has GDM).

We estimate that about 36% ($230 million) of GDM-attributed medical costs are paid for through government programs (primarily Medicaid); 56% ($355 million) are paid by private insurers; and 8% ($51 million) are incurred by uninsured and self-pay patients, which includes charity care for patients unable to pay.

Discussion

The findings of the medical claims analysis are generally consistent with findings in the literature—that GDM is associated with increased risk for select pregnancy and newborn complications, which increases use of health care services. Our national estimate of $636 million in excess medical costs associated with GDM suggests that GDM is responsible for approximately 1% of all pregnancy-related and neonatal-related costs. GDM increases the medical cost of a pregnancy by an average of $3,305. Newborn medical costs during the first year rise by an average $209 per newborn of a GDM mother.

The major strengths of our study include: (1) analysis of a comprehensive list of pregnancy and newborn complications that the literature suggests may be associated with GDM; (2) use of multiple, nationally representative data sources to provide estimates of national health care use and spending

Table 3. Health Care Use and Expenditures in the United States in 2007

Health Resource Use	Attributable to GDM: Unit (thousands)	Attributable to GDM: % US Total	Incurred by Pregnant Women with GDM and Their Offspring: Unit (thousands)	Incurred by Pregnant Women with GDM and Their Offspring: % US Total	US Total Pregnant Women and Their Offspring: Unit (thousands)
Mother					
Hospital inpatient day	269	1.54%	838	4.81%	17,423
Emergency visit	36	0.95%	170	4.47%	3,808
Ambulatory visit	651	1.57%	1,958	4.73%	41,438
Prescription	735	1.91%	2,085	5.43%	38,435
Newborn					
Hospital inpatient day	28	0.15%	873	4.60%	18,969
Emergency visit	1	0.62%	8	4.63%	169
Ambulatory visit	30	0.56%	248	4.62%	5,372
Prescription	27	0.55%	227	4.61%	4,928
Medical Cost	*Dollars (millions)*	*% U.S. Total*	*Dollars (millions)*	*% U.S. Total*	*Dollars (millions)*
Mother					
Hospital inpatient day	$386	1.52%	$1,260	4.95%	$25,452
Emergency visit	$20	0.93%	$92	4.31%	$2,125
Ambulatory visit	$130	1.49%	$418	4.81%	$8,699
Prescription	$60	1.91%	$171	5.43%	$3,146
Subtotal	$596	1.51%	$1,940	4.92%	$39,423
Newborn					
Hospital inpatient day	$28	0.12%	$1,092	4.50%	$24,287
Emergency visit	$1	0.70%	$4	4.50%	$100
Ambulatory visit	$9	0.55%	$70	4.48%	$1,566
Prescription	$2	0.53%	$19	4.47%	$416
Subtotal	$40	0.15%	$1,185	4.50%	$26,368
Total (Mother and Newborn)	$635	0.97%	$3,125	4.75%	$65,791

Numbers might not add to totals because of rounding.
GDM, gestational diabetes mellitus.

for pregnancy and neonatal care; (3) a large ($n \approx 27{,}000$) sample of women (and their newborns) with multiple years of medical claims data to analyze the impact of GDM on per capita use of health care services; and (4) use of a standardized method that recently was used to calculate the national cost associated with diagnosed cases of diabetes.[26]

The database used to analyze differences in per capita health resources use by GDM status consists primarily of a privately insured population. The implicit assumption in this analysis, therefore, is that the percent increase in per capita use of health resources attributed to GDM is similar for the privately insured population and for the Medicaid and other payer type populations. This analysis omits long-term sequelae. Women with GDM are at high risk of developing diabetes and cardiovascular diseases after pregnancy[18,20]; while their offspring are prone to developing childhood obesity, glucose intolerance, and diabetes later in life.[2,16,37] An independent association between exposure to maternal obesity in uterus and the development of type 2 diabetes in offspring has recently been reported.[38,39]

This study focuses on medical costs, but to the extent that women with GDM have higher rates of complications and higher use of health care services, GDM might also have indirect costs—such as increased time off from work or school, psychological stress, and reduced performance by offspring in school. Therefore, these findings might underestimate the total national economic burden of GDM.

The national economic burden of GDM can potentially be reduced through prevention of GDM and improved control of glucose levels among women diagnosed with GDM.[40–43] Universal screening for GDM has been recommended, although this recommendation is controversial as the business case for universal screening has yet to be established.[44–46]

Our study suggests that, together, the average pregnancy and newborn costs per case of GDM exceed $3,500. This information is particularly important to conclude whether any form of diagnosis and treatment is cost-effective or has a positive cost/benefit ratio. Such interventions could include a combination of screening and education for all pregnant women, with particular emphasis on high-risk groups and treatments directed at controlling glucose levels among diagnosed cases of GDM.

The potential of prevention and treatment of GDM to impact the current epidemic of childhood obesity cannot be ignored.[47] Prevention of and interventions targeted at GDM may be keys to interrupting the generational succession of obesity and type 2 diabetes and have far-reaching economic implications.

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Appendix

Table A-1. Diagnosis and Procedure Codes Used to Define Complications and Conditions

#	*Mother*	*ICD-9-CM Diagnosis*	*DRG*	*MDC*	*ICD-9-CM Procedure*	*CPT*	*Note*
M1	Pregnancy	630–677, V22–V24, V27–V29, 792.3, 796.5	370–384				Apply to any code fields, to define the scope of pregnancy health care use
M2	Cesarean delivery		370–371		74.0–74.2, 74.4, 74.99	59510, 59514, 59515, 59618, 59620, 59622	
M3	Polyhydramnios	657					
M4	Urinary tract infection	599.0, 646.6, 996.64, V13.02					
M5	Amniotic cavity infection	658.4					
M6	Preeclampsia and eclampsia	642.4, 642.5, 642.6					
M7	Other hypertension complicating pregnancy	642.3					
M8	Other pregnancy-related event	Any primary diagnosis codes for pregnancy that are captured in M1 but not shown in maternal complication groups					
M9	All other events		Pregnancy codes shown in secondary diagnosis fields				

#	*Newborn*	*ICD-9-CM Diagnosis*	*DRG*	*MDC*	*ICD-9-CM Procedure*	*CPT*	*Note*
N1	Newborn	760–779, V30–V39, 277.01, 747.83	385–391,469	15			Apply to any code fields, to define the scope of newborn health care use
N2	Intrauterine hypoxia and birth asphyxia	768.0–768.6, 768.9					
N3	Macrosomia	766.0, 766.1					
N4	Endocrine and metabolic disturbances	775.0, 775.4–775.9					
N5	Birth trauma	767.0–767.9					
N6	Fetus or newborn affected by other complications of labor & delivery	763.0–763.9					
N7	Respiratory distress syndrome	769					
N8	Jaundice	782.4, 774.2, 774.5, 774.6					
N9	Congenital anomalies	740–759					
N10	Other neonatal event	Any primary diagnosis codes for newborn that are captured in N1 but not shown in neonatal complication groups					
N11	All other events		Neonatal codes shown in secondary diagnosis fields				

The codes based on DRG, MDC, ICD-9-CM Procedure, and CPT were verified against the primary ICD-9-CM diagnosis codes.
DRG, diagnosis related group; MDC, Major Diagnostic Categories; CPT, Current Procedural Terminology.

Table A-2. Poisson Regression for Maternal Analysis

Utilization	*Variable*	*Category*	*Cesarean delivery*	*Polyhydramnios*	*Urinary tract infection*	*Amniotic cavity infection*	*Preeclampsia and eclampsia*	*Other hypertension complicating pregnancy*	*Other pregnancy-related event*	*All other non pregnancy related event*
Inpatient Day	GDM status	Present vs. absent	1.20 **	1.44	0.68	0.47 *	1.50 **	1.56 *	1.29 **	1.10
	Age Group (vs. Age ≤20)	Age 21–25	1.12 *	NA	0.14 **	0.33 **	0.73 **	NA	0.49 **	0.50 **
		Age 26–30	1.29 **	NA	0.15 **	0.31 **	0.46 **	NA	0.44 **	0.54 **
		Age 31–35	1.47 **	NA	0.09 **	0.30 **	0.47 **	NA	0.37 **	0.45 **
		Age > 35	1.72 **	NA	0.04 **	0.24 **	0.46 **	NA	0.42 **	0.39 **
	Cancer	Present vs. absent	0.99	0.73	1.68 **	1.35	0.91	0.53 *	1.00	1.82 **
	Other pregnancy related high risk	Present vs. absent	1.31 **	1.79 **	2.12 **	1.50 *	1.83 **	2.05 **	2.68 **	1.27 **
	HIV/AIDS	Present vs. absent	0.84	6.47 **	0.00	0.00	2.40 **	0.00	3.72 **	3.50 **
	Region (vs. Northeast)	Midwest	0.80 **	0.38 **	1.03	0.84	1.11	0.98	0.93	1.48 **
		South	0.99	0.54 **	0.97	0.90	1.31 **	1.97 *	1.15 **	1.78 **
		West	0.86 **	0.39 **	1.01	0.93	0.91	0.42 *	1.15 **	1.24 *
Emergency Visit	GDM status	Present vs. absent	NA	NA	1.17	NA	NA	NA	1.19	1.43 **
	Age Group (vs. Age ≤20)	Age 21–25	NA	NA	0.30 *	NA	NA	NA	0.42 **	0.52 **
		Age 26–30	NA	NA	0.09 **	NA	NA	NA	0.30 **	0.38 **
		Age 31–35	NA	NA	0.09 **	NA	NA	NA	0.18 **	0.29 **
		Age > 35	NA	NA	0.04 **	NA	NA	NA	0.17 **	0.25 **
	Cancer	Present vs. absent	NA	NA	1.73	NA	NA	NA	0.93	1.35 **
	Other pregnancy related high risk	Present vs. absent	NA	NA	2.38 **	NA	NA	NA	1.49 **	1.49 **
	HIV/AIDS	Present vs. absent	NA	NA	0.00	NA	NA	NA	0.00	0.00
	Region (vs. Northeast)	Midwest	NA	NA	NA	NA	NA	NA	4.71 **	3.52 **
		South	NA	NA	NA	NA	NA	NA	0.40 **	0.78
		West	NA	NA	NA	NA	NA	NA	0.11 **	0.67 *
Other Ambulatory Visit	GDM status	Present vs. absent	1.22 **	1.85 **	1.12 **	0.95	1.45 **	1.50 **	1.37 **	1.12 **
	Age Group (vs. Age ≤20)	Age 21–25	1.22 *	1.27	0.76 **	0.53 *	0.81	1.13	1.00	0.94 **
		Age 26–30	1.43 **	1.04	0.58 **	0.55 *	0.64 **	0.95	0.96 **	0.96 **
		Age 31–35	1.61 **	1.07	0.48 **	0.47 **	0.67 **	0.87	0.97 *	1.00
		Age > 35	1.85 **	1.34	0.40 **	0.52 *	0.57 **	0.72 *	1.02	1.08 **
	Cancer	Present vs. absent	1.00	1.09	1.18 **	0.95	0.92	1.00	1.03 **	1.47 **
	Other pregnancy related high risk	Present vs. absent	1.20 **	1.86 **	1.23 **	1.24	2.01 **	1.60 **	1.26 **	1.35 **
	HIV/AIDS	Present vs. absent	0.93	1.42	1.14	0.00	0.00	0.00	0.90 **	1.11 **
	Region (vs. Northeast)	Midwest	0.80 **	0.70 **	0.82 **	1.45 *	0.91	1.70 **	0.88 **	0.85 **
		South	1.09 **	0.87	1.08 *	0.70	1.37 **	1.46 **	0.88 **	0.79 **
		West	0.95	0.73 **	0.81 **	1.15	0.86	1.05	0.90 **	0.85 **

*$p < 0.05$, **$p < 0.01$.
GDM, gestational diabetes mellitus.

Table A-3. Poisson Regression for Newborn Analysis

Utilization	Variable	Category	*Intrauterine hypoxia and birth asphyxia*	*Macrosomia*	*Endocrine and metabolic disturbances*	*Birth trauma*	*Newborn affected by other complications*	*Respiratory distress syndrome*	*Jaundice*	*Congenital anomalies*	*Other neonatal event*	*All other non-neonatal care related event*
Inpatient Day	GDM status of newborn's mother	Present vs. absent	NA	NA	2.91**	NA	2.55	0.70**	1.75**	0.68**	1.04**	0.98
	Cancer	Present vs. absent	NA	NA	4.00	NA	14.90*	0.00	0.46	26.55**	1.41**	15.61**
	Sex	Male v. Female	NA	NA	1.12	NA	7.94*	2.70**	1.20*	1.25**	1.03**	1.32**
	HIV/AIDS	Present vs. absent	NA	NA	0.00	NA	0.00	0.00	0.00	0.00	1.07	0.00
	Post-term	Present vs. absent	NA	NA	3.29	NA	0.00	0.91	1.28	0.76	0.84**	0.81
	Preterm	Present vs. absent	NA	NA	0.00	NA	0.00	0.00	0.00	61.54**	7.52**	14.06**
	Region (vs. Northeast)	Midwest	NA	NA	0.30**	NA	NA	10.81**	0.97	0.67**	0.91**	0.51**
		South	NA	NA	0.10**	NA	NA	5.98**	0.69*	0.65**	0.97*	0.73**
		West	NA	NA	0.42*	NA	NA	19.20**	0.87	0.84*	0.70**	0.61**
ED Visits	GDM status of newborn's mother	Present vs. absent	NA	NA	NA	NA	NA	NA	1.59	NA	0.59	0.82
	Cancer	Present vs. absent	NA	NA	NA	NA	NA	NA	0.00	NA	0.00	0.79
	Sex	Male vs. Female	NA	NA	NA	NA	NA	NA	1.14	NA	1.38	1.19**
	HIV/AIDS	Present vs. absent	NA	NA	NA	NA	NA	NA	0.00	NA	0.00	0.00
	Post-term	Present vs. absent	NA	NA	NA	NA	NA	NA	0.00	NA	0.00	0.66
	Preterm	Present vs. absent	NA	NA	NA	NA	NA	NA	0.00	NA	0.00	0.00
	Region (vs. Northeast)	Midwest	NA	NA	NA	NA	NA	NA	NA	NA	NA	52.47**
		South	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.99**
		West	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.04
Other Ambulatory Visits	GDM status of newborn's mother	Present vs. absent	0.80	1.83**	3.44**	0.62*	1.32**	0.82**	1.21**	1.13**	1.03**	1.00
	Cancer	Present vs. absent	1.41	1.86	2.01*	0.39	1.27	2.65**	1.03	4.78**	1.58**	2.16**
	Sex	Male vs. Female	0.96	1.99**	0.82*	1.05	0.97	1.57**	1.13**	1.40**	0.99	1.13**
	HIV/AIDS	Present vs. absent	0.00	0.00	0.00	0.00	10.30**	0.00	0.00	0.00	0.91	1.05
	Post-term	Present vs. absent	1.72	3.23**	2.58**	4.50**	1.52*	0.06**	0.62**	0.59**	0.84**	1.03
	Preterm	Present vs. absent	0.00	0.00	0.00	0.00	2.48	9.10**	1.26	12.03**	7.03**	1.19
	Region (vs. Northeast)	Midwest	0.95	0.70	0.80	0.68*	0.65**	1.54**	1.28**	0.96	0.92**	0.89**
		South	1.32	0.89	1.07	0.46**	1.33**	3.87**	1.25**	0.83**	1.05**	0.90**
		West	1.05	0.61*	0.99	0.35**	1.06	2.33**	1.42**	0.73**	0.99	0.87**

*$P < 0.05$, **$P < 0.01$.

GDM, gestational diabetes mellitus.