POPULATION HEALTH MANAGEMENT
Volume 12, Number 2, 2009

DOI: 10.1089/pop.2009.12202

The Economic Costs of Undiagnosed Diabetes

Yiduo Zhang, Ph.D.,[1] Timothy M. Dall, M.S.,[1] Sarah E. Mann, B.S.,[1] Yaozhu Chen, M.P.A.,[1]
Jaana Martin, B.A.,[1] Victoria Moore, B.S.,[2] Alan Baldwin, M.A.,[2]
Viviana A. Reidel, M.D.,[3] and William W. Quick, M.D., F.A.C.P., F.A.C.E.[3]

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

[1]The Lewin Group, Falls Church, Virginia.
[2]Ingenix/i3 Pharmainformatics, Cary, North Carolina.
[3]Ingenix/i3 Research, Basking Ridge, New Jersey.
Funding for this study was provided by the Novo Nordisk National Changing Diabetes Program.

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:

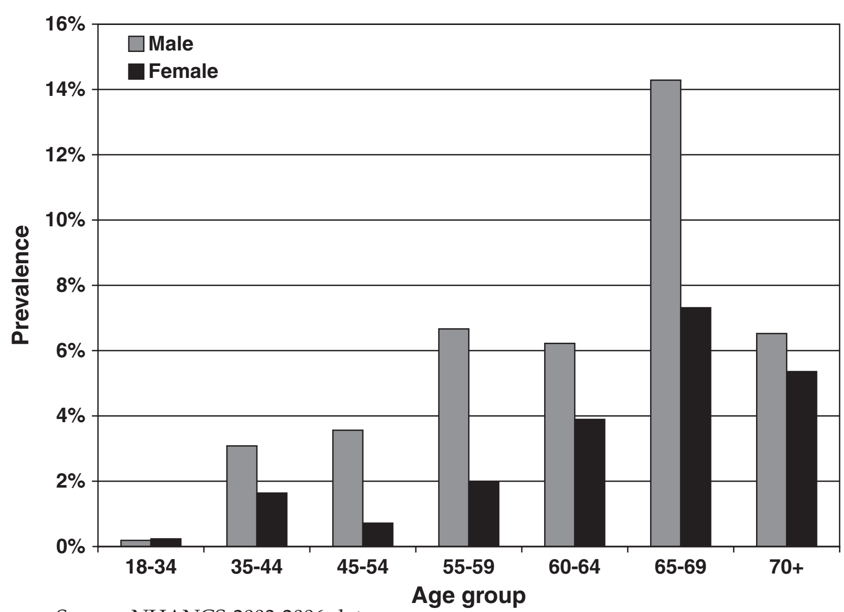
$$\text{Ratio} = \frac{\text{inpatient days}_{\text{UDM}}}{\text{inpatient days}_{DDM}}.$$

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

Dr. Reidel, Dr Quick, Ms. Moore, and Mr. Baldwin acknowledge that i3 Research has grants from sanofi-aventis, Takeda, Transition Therapeutics Inc., Andromeda Biotech Ltd., and other similar organizations to conduct research in diabetes. These organizations do not have control over this paper. The other authors are employed by the Lewin Group, and have no conflicts of interest to report with regard to this paper.

References

1. Dall T, Mann SE, Zhang Y, Martin J, Chen Y, Hogan P. Economic costs of diabetes in the U.S. in 2007. *Diabetes Care* 2008;31:1–20.
2. Baltali M, Gokcel A, Kiziltan HT, Korkmaz ME, Topcu S, Yalcin F, Demircan S, Yigit F, Ozin B, Muderrisoglu IH. Association between the metabolic syndrome and newly diagnosed coronary artery disease. *Diabetes Nutr Metab* 2003;16:169–175.
3. Mykkanen L, Haffner SM, Kuusisto J, Pyorala K, Laakso M. Microalbuminuria precedes the development of NIDDM. *Diabetes* 1994;43:552–557.
4. Koopman RJ, Mainous AG, III, Liszka HA, Colwell JA, Slate EH, Carnemolla MA, Everett CJ. Evidence of nephropathy and peripheral neuropathy in US adults with undiagnosed diabetes. *Ann Fam Med* 2006;4:427–432.
5. Hu FB, Stampfer MJ, Haffner SM, Solomon CG, Willett WC, Manson JE. Elevated risk of cardiovascular disease prior to clinical diagnosis of type 2 diabetes. *Diabetes Care* 2002; 25:1129–1134.
6. Gulliford MC, Latinovic R, Charlton J. Diabetes diagnosis, resource utilization, and health outcomes. *Am J Manag Care* 2008;14:32–38.
7. Nichols GA, Glauber HS, Brown JB. Type 2 diabetes: incremental medical care costs during the 8 years preceding diagnosis. *Diabetes Care* 2000;23:1654–1659.
8. Gulliford MC, Charlton J, Latinovic R. Increased utilization of primary care 5 years before diagnosis of type 2 diabetes: A matched cohort study. *Diabetes Care* 2005;28:47–52.
9. Cowie CC, Rust KF, Byrd–Holt DD, Eberhardt MS, Flegal KM, Engelgau MM, Saydah SH, Williams DE, Geiss LS, Gregg EW. Prevalence of diabetes and impaired fasting glucose in adults in the U.S. population: National Health and Nutrition Examination Survey 1999–2002. *Diabetes Care* 2006;29:1263–1268.
10. American Diabetes Association. Diagnosis and classification of diabetes mellitus. *Diabetes Care* 2008;31:S55–S60.
11. Knowler WC, Barrett–Connor E, Fowler SE, Hamman RF, Lachin JM, Walker EA, Nathan DM, Diabetes Prevention Program Research Group. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med* 2002;346:393–403.
12. Benichou J. A review of adjusted estimators of attributable risk. *Stat Methods Med Res* 2001;10:195–216.
13. Boles M, Pelletier B, Lynch W. The relationship between health risks and work productivity. *J Occup Environ Med* 2004;46:737–745.
14. Goetzel RZP, Long SRM, Ozminkowski RJP, Hawkins KP, Wang SP, Lynch WP. Health, absence, disability, and presenteeism cost estimates of certain physical and mental health conditions affecting U.S. employers. *J Occup Environ Med* 2004;46:398–412.
15. Ng YC, Jacobs P, Johnson JA. Productivity losses associated with diabetes in the US. *Diabetes Care* 2001;24:257–261.
16. Von KM, Katon W, Lin EH, Simon G, Ciechanowski P, Ludman E, Oliver M, Rutter C, Young B. Work disability among individuals with diabetes. *Diabetes Care* 2005;28: 1326–1332.
17. Tunceli K, Bradley CJ, Nerenz D, Williams LK, Pladevall M, Elston LJ. The impact of diabetes on employment and work productivity. *Diabetes Care* 2005;28:2662–2667.
18. Zhang X, Geiss LS, Cheng YJ, Beckles GL, Gregg EW, Kahn HS. The missed patient with diabetes: How access to health care affects the detection of diabetes. *Diabetes Care* 2008; 31:1748–1753.

Address reprint requests to:
Yiduo Zhang, Ph.D.
The Lewin Group, Falls Church
3130 Fairview Park Drive, Suite 800
Falls Church VA 22042

E-mail: Yiduo.Zhang@lewin.com