EPIDEMIOLOGY/HEALTH SERVICES RESEARCH

Life Years Lost and Lifetime Health Care Expenditures Associated With Diabetes in the U.S., National Health Interview Survey, 1997–2000

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OBJECTIVE

This study analyzed the lifetime health care expenditures and life years lost associated with diabetes in the U.S.

RESEARCH DESIGN AND METHODS

Data from the National Health Interview Survey (NHIS), the Medical Expenditure Panel Survey from 1997 to 2000, and the NHIS Linked Mortality Public-use Files with a mortality follow-up to 2006 were used to estimate age-, race-, sex-, and BMI-specific risk of diabetes, mortality, and annual health care expenditures for both patients with diabetes and those without diabetes. A Markov model populated by the risk and cost estimates was used to compute life years and total lifetime health care expenditures by age, race, sex, and BMI classifications for patients with diabetes and without diabetes.

RESULTS

Predicted life expectancy for patients with diabetes and without diabetes demonstrated an inverted U shape across most BMI classifications, with highest life expectancy being for the overweight. Lifetime health care expenditures were higher for whites than blacks and for females than males. Using U.S. adults aged 50 years as an example, we found that diabetic white females with a BMI >40 kg/m^2 had 17.9 remaining life years and lifetime health expenditures of $185,609, whereas diabetic white females with normal weight had 22.2 remaining life years and lifetime health expenditures of $183,704.

CONCLUSIONS

Our results show that diabetes is associated with large decreases in life expectancy and large increases in lifetime health care expenditures. In addition to decreasing life expectancy by 3.3 to 18.7 years, diabetes increased lifetime health care expenditures by $8,946 to $159,380 depending on age-race-sex-BMI classification groups.

The prevalence of diabetes has imposed a substantial health and economic burden to patients and society. It is a public health concern that the prevalence of diabetes remains high in high-income countries and has been increasing in low- and middle-income countries. In 2011, it was estimated that there were a total of 366 million

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people living with diabetes in the world, and this is expected to increase to 552 million by 2030 (1).

In the U.S., the prevalence of diabetes among adults aged 18 years or older has risen 11-fold in the last five decades (from 0.63% in 1958 to 7.0% in 2010) (2) and has increased by 150% in the last two decades (from 3.6% in 1991 to 9.0% in 2011) (3). In 2011, it was reported that 20.9 million Americans were diagnosed with diabetes (3). Data show a doubling of the incidence and prevalence of diabetes during 1990–2008 and a leveling off during 2008–2012 (4). In 2010, diabetes was estimated to be the seventh leading cause of death in the U.S. (5). In terms of medical expenditures, diabetes was a leading economic burden among heart disease, cancer, asthma, and hypertension in 2010 (6). The estimated economic cost of diabetes in 2012 was $245 billion, a 41% increase from a 2007 estimate of $174 billion (7).

The dramatic increase in the prevalence of diabetes is closely related to the increase in the number of overweight and obese populations (8). Studies have shown that overweight and obesity are key risk factors for the development of diabetes (8,9). The health and economic consequences of obesity (10,11) and diabetes (7,12–14) have been extensively studied separately, but little is known about the lifetime risk of obesity and diabetes in terms of life years lost and lifetime economic costs.

The aim of our study is to examine the burden of diabetes on the expected remaining life years and the associated expected health care expenditures for individuals by age, race, sex, and BMI. Previous studies such as by Narayan et al. (12) and Morgan et al. (14) have examined life years lost associated with diabetes by age, race, and sex. However, they did not take into account the effect of BMI, which impacts life expectancy through other chronic conditions. Because diabetes is closely related to degree of obesity, it is important to incorporate the impact of BMI in the analysis, in addition to age, race, and sex differences. Finkelstein et al. (15) computed life years lost associated with overweight and obesity but was not focused on life years lost associated with diabetes. In terms of cost estimation, various studies have provided estimates of economic costs of diabetes in the U.S. Zhuo et al. (16) attempted to estimate the economic burden of diabetes; however, their study only examined the direct medical costs of treating type 2 diabetes and diabetes complications. Using 2001–2011 claims data, Østbye et al. (17) examined the relationship between BMI and costs by major diagnostic categories, which included kidney and urinary tract diseases, controlling for age, sex, and race/ethnicity. However, none of the existing studies examined the total lifetime health care expenditures associated with diabetes by age-race-sex-BMI classification groups. Birnbaum et al. (18) estimated the incremental lifetime medical cost of treating a woman with diabetes, but they focused on women only and did not stratify their analysis by age, race, and BMI. A recent study by Zhuo et al. (19) estimated the excess lifetime medical spending attributed to diabetes, but their analysis was stratified by sex and age at diagnosis only. Daviglus et al. (20) and Lakdawalla et al. (21) studied the consequences of obesity on total health care cost and expenditures; however, the former was not focused on diabetes-related expenditures, and the latter only focused on diabetes-related average medical charges in people above the age of 65 years. The American Diabetes Association provided estimates of total lifetime health care expenditures associated with diabetes, but their study focused on the variations of lifetime health care expenditures of diabetes by age-group only (7). Our study is the first to investigate life years lost and lifetime health care expenditures associated with diabetes by age, race, sex, and BMI.

RESEARCH DESIGN AND METHODS

Data

Our data were extracted from *1*) the Sample Adult Data Files from the National Health Interview Survey (NHIS), a national probability sample of U.S., civilian, noninstitutionalized adults aged 18 years and older (22); *2*) the NHIS Linked Mortality Public-use Files, which provide mortality follow-up data for the NHIS sample up to 31 December 2006 (23); and *3*) the Household Component of the Medical Expenditure Panel Survey (MEPS-HC), which is a survey conducted by the Agency for Healthcare Research and Quality that provides detailed individual medical expenditure data (24). The NHIS is an ongoing, continuous, nationwide, cross-sectional survey of the U.S. population conducted by the National Center for Health Statistics and the Bureau of Census. A multistage probability sampling strategy is used each year to select households and individuals for the sample in the NHIS (22).

Personal identification numbers of the sample were used to link the individuals between the NHIS and the NHIS Linked Mortality Public-use Files (23). The individuals were further linked to the MEPS-HC. The set of households selected for each panel of the MEPS-HC is a subsample of households participating in the previous year's NHIS; it provides nationally representative estimates of health care use, expenditures, sources of payment, and health insurance coverage (24).

The sample in our study was retrieved from NHIS years 1997–2000. We combined 4 years of data to increase our sample size to allow for stratified analyses (25). The NHIS years 1997–2000 were chosen to allow a longer mortality follow-up period to estimate the probability of death for patients with diabetes and those without diabetes. The exclusion criteria were as follows: *1*) individuals with any missing data on the target variables; *2*) individuals who have ever been diagnosed with cancer, because their BMI levels are less stable due to cancer treatments and appetite loss (11); *3*) women pregnant at the time of survey, because BMI levels are unstable during pregnancy (11,26); and *4*) underweight individuals, because this group may include heavy smokers, those with severe chronic diseases, and people with malignancies (26,27).

Risk Estimation

The probability of developing diabetes and the probability of death for individuals with and without diabetes were estimated by fitting an exponential survival function, controlling for sex, race (white, black, and other races), diabetes status, age at survey (age $\leq$19, 20$\leq$ age $\leq$29, 30$\leq$ age $\leq$39, 40$\leq$ age $\leq$49, 50$\leq$ age $\leq$59, 60$\leq$ age $\leq$69, and age $\geq$70 years), and BMI. BMI was categorized based on the standards established by the World Health Organization: normal weight (18.5$\leq$ BMI $<$25 kg/m^2); overweight (25$\leq$ BMI $<$30 kg/m^2); and class I (30$\leq$ BMI $<$35 kg/m^2), class II

(35≤ BMI <40 kg/m^2), and class III (BMI ≥40 kg/m^2) obese (28). In addition to the aforementioned covariates, the probabilities of death for individuals with and without diabetes were estimated by controlling for insurance status (with or without any form of health insurance), duration, and squared duration of diabetes.

Cost Estimation

Because a significant fraction of individuals (13.0%) had zero medical expenditures, the age-, race-, sex-, and BMI-specific annual health care expenditures for both patients with diabetes and those without diabetes were estimated using a two-part model (29,30). We estimated a logistic model in the first part and a generalized linear model with log-link and gamma-variance function for the second part, controlling for sex, race, BMI, age, diabetes status, insurance status, duration of diabetes, and squared duration of diabetes.

Markov Model

A three-state (no diabetes, diabetes, and death) Markov model was built. Transitions between states took place at a discrete interval of 1 year. The predicted values of age-, race-, sex-, and BMI-specific probabilities of developing diabetes, the probabilities of death, and the estimated annual health care expenditures with and without diabetes were used to populate the Markov model to compute life years lost and medical expenditure differentials between patients with diabetes and without diabetes. The probability of recovering from diabetes is small (31); therefore, it was assumed to be zero in this study.

The model was bootstrapped 1,000 times and the means and SEs of the following were computed for each age-race-sex-BMI classification group: *1*) expected remaining life years, *2*) expected total health care expenditures incurred during the remaining life years, *3*) life years lost associated with diabetes, and *4*) cost differentials between patients with diabetes and without diabetes. Life years lost associated with diabetes was calculated by subtracting the remaining life years of the individuals without diabetes with those of the patients with diabetes for each age-race-sex-BMI classification group. Cost differentials were obtained by taking the difference in lifetime medical costs between the patients with diabetes and those without diabetes. ANOVA tests have been conducted to compare the means of the predicted life years lost and cost differentials across age-race-sex-BMI classification groups (see details in Supplementary Table 20).

All estimations were adjusted for the complex sampling design in the NHIS (22). All dollar values are presented in U.S. dollars and at 2010 price levels, based on the Consumer Price Index for All Urban Consumers. Future costs were discounted to present values using an annual rate of 3%. STATA (StataCorp 2012, College Station, TX) was used to estimate risk probabilities and annual health care expenditures, and MATLAB (MATLAB Release 2012b; MathWorks, Natick, MA) was used to perform the Markov cohort analysis.

RESULTS

Descriptive Statistics

Table 1 presents the summary statistics of our sample and the estimated population for both NHIS and MEPS data from 1997 to 2000. The NHIS sample contained 110,844 individuals, representing a population of 168,741,800 U.S. adults. Within the estimated population, 50.8% were male, 81.3% were white, 11.6% were black, and 7.1% were other races (including 2.3% Chinese, 1.4% Filipino, 0.7% Asian Indian, and 0.6% Indian American). The average BMI of the population estimates was 26.7 kg/m^2; 42.5% were normal weight; 36.4% were overweight; and 14.4, 4.5, and 2.3% of the sample belonged to class I, II, and III obese, respectively. About 6.0% of the sample reported ever being diagnosed with diabetes. About 85% of the sample had health insurance coverage of any form. The mean age at diagnosis of diabetes was 46.8 years. The mean duration of diabetes was 9.25 years. The mean age at death was 70.6 years.

Table 1 also shows the summary statistics for the MEPS sample. It contained 29,369 individuals, representing 80,361,966 U.S. adults. Within the estimated population, 47.7% were male, 59.7% were white, 9.3% were black, and 31.0% were other races. The distribution of the sample across BMI classifications in the MEPS was comparable with that in the NHIS, where 42.6% were normal weight; 36.1% were overweight; and 14.3, 4.5, and 2.5% of the sample belonged to class I, II, and III obese, respectively. About 89% were insured in the sample. The mean of total health care expenditures was $3,770 with an SD of $10,205. Whereas 13.0% of the sample had $0 annual health care expenditures, the majority (26.0%) spent $1–$499 on health care annually.

Predicted Life Years Lost Associated With Diabetes

Tables 2 and 3 show the bootstrapped means and SEs of life years lost and the health care expenditure differentials associated with diabetes across age-race-sex-BMI classification groups for insured U.S. adults. Figure 1 demonstrates the patterns of life years lost associated with diabetes. Our results showed that whites lost more life years than blacks. Females lost more life years than males. White females, on average (computed as the arithmetic mean across age-race-sex-BMI classification groups), lost 14.77 life years compared with 13.90 life years for black females. White males lost 9.03 life years compared with 7.71 life years for black males. The life years lost associated with diabetes was higher for females than males. The average difference in life years lost was 5.74 years between white females and white males, 6.19 years between black females and black males, and 5.54 years between females and males of other races.

In terms of BMI, the life years lost associated with diabetes demonstrated an inverted U shape across BMI for most age-race-sex-BMI classification groups, with the largest number of life years lost in the overweight group. On average, those of normal weight lost 12.44 years (from 4.94 to 18.10 years); the overweight lost 12.70 years (from 5.85 to 18.13 years); and the class I, II, and III obese lost 12.09 years (from 5.22 to 17.92 years), 11.45 years (from 4.59 to 17.19 years), and 9.84 years (from 3.30 to 15.20 years), respectively. The life years lost associated with diabetes decreased with age. The average life years lost for the 20–29 age-group was 11.92 years, and the average years lost for age 70+ was 8.94 years. Uninsured individuals showed a similar pattern in life years lost compared with the insured. In general, people with insurance had around two times higher health care expenditure differentials than people without

Table 1—Descriptive statistics for U.S. adults in the sample and the population for NHIS and MEPS data, 1997–2000

	NHIS and mortality data			MEPS data		
	*n** (%)	*N*† (%)		*n** (%)		*N*† (%)
Total	110,844	168,741,800		29,369		80,361,966
Sex						
Male	50,887 (45.9)	85,684,842 (50.8)		13,432 (45.7)		38,358,002 (47.7)
Female	59,957 (54.1)	83,056,958 (49.2)		15,937 (54.3)		42,003,964 (52.3)
Race						
White	86,110 (77.7)	137,141,051 (81.3)		16,426 (55.9)		47,951,365 (59.7)
Black	15,933 (14.4)	19,617,639 (11.6)		3,154 (10.7)		7,466,723 (9.3)
Others	8,801 (7.9)	11,983,110 (7.1)		9,789 (33.3)		24,943,878 (31.0)
BMI classification						
Normal weight	46,585 (42.0)	71,673,006 (42.5)		11,778 (40.1)		34,246,694 (42.6)
Overweight	40,087 (36.2)	61,341,287 (36.4)		10,767 (36.7)		28,995,809 (36.1)
Class I obese	16,202 (14.6)	24,239,950 (14.4)		4,524 (15.4)		11,517,485 (14.3)
Class II obese	5,145 (4.6)	7,583,885 (4.5)		1,469 (5.0)		3,584,154 (4.5)
Class III obese	2,825 (2.6)	3,903,572 (2.3)		831 (2.8)		2,017,824 (2.5)
Ever diagnosed with diabetes	7,368 (6.7)	10,087,533 (6.0)		2,078 (7.1)		4,902,475 (6.1)
Insured‡	92,340 (83.5)	142,933,464 (84.9)		25,404 (86.5)		71,101,764 (88.5)
NHIS	*n*	*N*	Min	Max	Mean	SD
BMI (kg/m^2)	110,844	168,741,800	18.5	85.8	26.7	5.29
Age at diabetes diagnosis§	6,254	8,547,464	1	84	46.8	17.2
Duration of diabetes‖	6,254	8,547,464	0	83	9.25	11.8
Age at death	6,071	7,903,792	20	93	70.6	16.2
MEPS	*n** (%)	*N*† (%)				
Total annual health care expenditures at 2010 price levels						
$0	4,209 (14.3)	10,172,135 (13.1)				
$1-$499	7,572 (25.8)	20,313,181 (26.0)				
$500-$999	4,007 (13.6)	11,009,942 (14.1)				
$1,000–$1,499	2,622 (8.9)	7,430,583 (9.4)				
$1,500–$1,999	1,815 (6.2)	4,954,863 (6.3)				
$2,000–$2,499	1,342 (4.6)	3,620,516 (4.7)				
$2,500–$2,999	1,041 (3.5)	2,917,876 (3.7)				
$3,000–$3,499	821 (2.8)	2,206,638 (2.8)				
$3,500–$3,999	677 (2.3)	1,783,732 (2.3)				
$4,000–$4,499	560 (1.9)	1,438,713 (1.9)				
$4,500–$4,999	485 (1.7)	1,365,389 (1.7)				
>$5,000	4,218 (14.4)	10,984,086 (14.1)				
	n	*N*	Min	Max	Mean	SD
Total health care expenditures at 2010 price levels¶	29,369	80,361,966	0	$349,748	$3,770.3	$10,204.7

*n, sample size. †N, estimated population size. ‡Individuals with any form of health insurance coverage. §Age first diagnosed with diabetes. ‖Duration of diabetes, defined as the difference between age at interview and age first diagnosed with diabetes. ¶Based on the Consumer Price Index for All Urban Consumers.

insurance (see Supplementary Table 17 for bootstrapped means of life years lost associated with diabetes for uninsured individuals).

Health Care Expenditure Differentials Associated With Diabetes

Figure 2 demonstrates the lifetime health care expenditures with and without diabetes for individuals by age-race-sex-BMI classification groups. Lifetime health care expenditure differentials were higher for whites than blacks and for females than males. For example, the average health care cost differentials for white females were $85,001 compared with $81,545 for white males across age and BMI groups. The average health care expenditure differentials were $72,045 for black females and $66,515 for black males.

On average, the health care expenditure differentials were $74,623 (from $21,239 to $117,651) for the normal weight, $77,954 (from $23,674 to $117,794) for the overweight, $85,782 for the class I obese (from $26,880 to $137,074), $85,451 for the class II obese (from $24,128 to $145,620), and $89,087 for the class III obese (from $8,946 to $159,380). The uninsured population showed similar patterns of expenditure differentials across BMI classifications (see Supplementary Table 18 for details of expenditure differentials for uninsured population). ANOVA tests showed that the differences between the means of predicted life years lost are significant across age-race-sex-BMI classification groups. For expenditure differentials, the differences between the means of predicted values are significant across age and race groups (see details in Supplementary Table 20).

Life years lost and lifetime economic costs are two widely accepted measures of population health impact (32,33). We estimated both measures for individuals with and without diabetes by age-race-sex-BMI classification groups that were not previously reported. The results

Table 2—Bootstrapped means and SEs of life years lost associated with diabetes for insured U.S. adults, 1997–2000

		White female		Black female		Other female		White male		Black male		Other male	
Age‡	BMI class	LYL	SE	LYL	SE	LYL	SE	LYL	SE	LYL	SE	LYL	SE
20–29	Normal weight	14.50	2.69	14.96	2.88	13.16	3.96	11.60	2.82	10.73	3.11	11.86	4.07
	Overweight	13.64	2.65	14.06	2.67	12.04	3.83	11.87	2.70	11.09	3.03	11.79	4.09
	Class I obese	13.20	2.70	13.43	2.70	11.50	3.86	11.18	3.02	10.38	3.22	11.00	4.22
	Class II obese	13.16	3.05	13.16	2.83	11.52	3.88	10.66	3.62	9.86	3.76	10.51	4.33
	Class III obese	13.74	2.79	13.15	2.56	12.70	3.77	9.38	4.15	8.65	4.06	9.05	4.38
30–39	Normal weight	17.33	1.98	16.90	2.19	17.21	3.28	11.20	2.50	10.00	2.74	11.81	3.81
	Overweight	16.94	1.98	16.48	2.01	16.53	3.25	11.74	2.43	10.58	2.70	12.14	3.92
	Class I obese	16.44	2.05	15.83	2.07	15.94	3.27	10.98	2.75	9.84	2.89	11.24	4.05
	Class II obese	15.96	2.38	15.18	2.22	15.54	3.23	10.36	3.35	9.24	3.42	10.60	4.16
	Class III obese	14.73	2.25	13.70	2.10	14.74	3.10	8.90	3.85	7.89	3.68	8.96	4.22
40–49	Normal weight	17.96	1.57	17.04	1.84	18.74	2.74	10.23	2.27	8.81	2.45	11.06	3.59
	Overweight	17.91	1.56	16.95	1.67	18.51	2.69	10.95	2.23	9.56	2.46	11.62	3.73
	Class I obese	17.43	1.67	16.37	1.76	17.92	2.75	10.19	2.55	8.82	2.65	10.72	3.89
	Class II obese	16.71	2.03	15.58	1.94	17.19	2.77	9.50	3.15	8.17	3.15	10.03	4.01
	Class III obese	14.58	2.00	13.39	1.90	15.20	2.82	7.96	3.64	6.75	3.39	8.34	4.11
50–59	Normal weight	16.91	1.30	15.79	1.59	18.10	2.43	9.14	2.02	7.55	2.13	10.14	3.35
	Overweight	17.07	1.30	15.91	1.43	18.13	2.40	10.00	2.00	8.43	2.18	10.88	3.52
	Class I obese	16.65	1.43	15.43	1.55	17.61	2.49	9.24	2.32	7.70	2.35	10.01	3.70
	Class II obese	15.87	1.81	14.62	1.74	16.81	2.54	8.52	2.91	7.01	2.81	9.28	3.83
	Class III obese	13.34	1.79	12.10	1.70	14.31	2.63	6.92	3.31	5.55	2.93	7.56	3.89
60–69	Normal weight	14.95	1.06	13.77	1.35	16.33	2.19	8.03	1.77	6.38	1.83	9.14	3.09
	Overweight	15.25	1.08	14.03	1.23	16.54	2.19	8.98	1.79	7.31	1.92	10.02	3.30
	Class I obese	14.89	1.22	13.65	1.36	16.11	2.29	8.24	2.10	6.62	2.09	9.19	3.49
	Class II obese	14.13	1.62	12.88	1.57	15.31	2.36	7.51	2.67	5.93	2.52	8.45	3.63
	Class III obese	11.46	1.60	10.28	1.52	12.63	2.44	5.93	3.00	4.50	2.55	6.76	3.69
70+	Normal weight	12.35	0.81	11.18	1.09	13.79	1.90	6.54	1.42	4.94	1.44	7.69	2.66
	Overweight	12.72	0.83	11.52	0.98	14.11	1.91	7.52	1.47	5.85	1.55	8.64	2.90
	Class I obese	12.43	1.00	11.22	1.13	13.77	2.03	6.82	1.74	5.22	1.69	7.86	3.07
	Class II obese	11.70	1.37	10.51	1.33	13.01	2.10	6.11	2.27	4.59	2.07	7.13	3.20
	Class III obese	9.11	1.33	8.03	1.26	10.32	2.13	4.64	2.49	3.30	2.03	5.53	3.19

LYL, life years lost associated with diabetes. ‡Age refers to the age of patients entering into the Markov model.

showed that the life years lost and health care expenditures associated with diabetes were substantial, which suggest that diabetes imposes a persistent economic burden over a life span and highlight the potential economic return of diabetes prevention.

We found that diabetes decreased life years by 3.30 to 18.74 years depending on age, sex, race, and BMI. Our findings showed that the life years lost associated with diabetes was greater for females than males and whites than blacks. Life years lost also declined with age. Similarly, Narayan et al. (9) showed that females lost more life years compared with males and life years lost diminished with age; on the other hand, they found that non-Hispanic blacks lost more life years compared with non-Hispanic whites. Using individuals of age 50 years as an example, they found that the life years lost associated with diabetes was 11.8 years for non-Hispanic white females and 13.6 years for non-Hispanic black females, whereas the life years lost was 8.8 years for non-Hispanic white males and 10.1 years for non-Hispanic black males. However, their study differs from ours in several ways: *1*) Narayan et al. (9) compared differences in life years lost across age, sex, and race but not BMI; they eliminated obesity as an important risk factor for diabetes; and *2*) they classified race as non-Hispanic white, non-Hispanic black, Hispanic, and other, whereas our study classified race as white, black, and racial groups other than white and black.

We also observed that life years lost was about two times higher for females than males. This disparity can be explained by the larger differences in probabilities of death between males and females observed for patients with diabetes relative to those without diabetes. This finding is consistent with the finding in Gregg et al. (34), who used data from the NHIS and demonstrated that the age-adjusted difference in mortality rates between patients with diabetes and without diabetes was higher in men than in women.

Diabetes increased lifetime health care expenditures by $8,946 to $159,380 depending on age, sex, race, and BMI. Our results are comparable with the estimates from previous studies. Zhuo et al. (16) estimated the lifetime direct medical costs of managing type 2 diabetes and treating diabetes complications. They reported that the age-sex weighted average of the lifetime medical costs was $85,200. A recent study by Zhuo et al. (19) estimated the discounted excess lifetime medical spending for people with diabetes ranged from $35,900 to $124,600 depending on the age at diagnosis. Similar to our results, they found that the excess lifetime medical spending associated with diabetes was higher for females than males. However, their estimates were consistently larger in comparison with ours as we modeled disease transition using a Markov model, which allowed individuals without diabetes to develop diabetes in future ages. Additionally, a previous study (7)

Table 3—Bootstrapped means and SEs of cost differentials (in 2010 U.S. dollars) associated with diabetes for insured U.S. adults, 1997–2000

		White female		Black female		Other female		White male		Black male		Other male	
Age‡	BMI class	$*	SE	$	SE	$	SE	$	SE	$	SE	$	SE
20–29	Normal weight	117,651	25,686	105,397	25,346	115,781	24,367	75,281	26,778	66,207	26,566	89,550	32,210
	Overweight	117,794	25,331	104,695	25,477	114,435	24,384	76,416	25,982	68,167	25,503	89,565	30,893
	Class I obese	137,074	31,197	120,465	29,309	131,781	29,191	81,932	30,396	72,845	30,325	94,931	35,540
	Class II obese	145,620	38,027	126,617	36,259	139,237	35,176	80,638	30,412	70,827	28,848	93,318	34,956
	Class III obese	113,592	32,693	97,094	29,757	109,519	31,076	127,148	73,809	109,679	64,082	145,992	82,330
30–39	Normal weight	111,324	24,354	98,320	24,527	112,399	24,125	80,252	29,076	69,400	28,761	97,445	35,831
	Overweight	112,910	24,372	99,080	25,038	112,727	24,539	82,742	28,356	72,440	27,731	98,958	34,564
	Class I obese	131,787	30,286	114,576	28,994	130,417	29,613	88,197	33,264	76,827	33,025	104,481	39,939
	Class II obese	139,193	37,370	119,860	36,135	137,159	35,918	86,170	33,296	74,388	31,457	102,067	39,311
	Class III obese	104,837	31,498	89,136	29,116	104,104	31,277	133,672	80,908	113,148	69,682	157,507	92,647
40–49	Normal weight	96,031	23,347	83,397	23,484	99,795	23,987	80,697	30,540	68,017	29,674	100,526	38,544
	Overweight	98,659	23,478	85,248	24,083	101,501	24,530	84,872	30,226	72,319	29,009	104,059	37,700
	Class I obese	115,304	29,231	98,859	28,003	117,731	29,698	89,661	35,315	75,903	34,401	109,106	43,529
	Class II obese	120,696	36,400	102,491	35,061	122,828	36,118	86,678	35,516	72,921	32,924	105,581	43,008
	Class III obese	86,952	30,109	73,140	27,791	89,255	31,007	131,207	85,410	108,156	72,255	159,380	100,428
50–59	Normal weight	75,536	21,848	64,125	21,845	81,449	23,259	75,005	30,885	61,027	29,074	96,456	39,899
	Overweight	78,705	22,162	66,552	22,537	84,036	23,964	80,890	31,022	66,455	28,899	102,246	39,577
	Class I obese	91,845	27,552	77,122	26,277	97,425	29,062	84,443	36,077	68,850	34,065	106,202	45,674
	Class II obese	94,672	34,452	78,578	32,878	100,201	35,261	80,493	36,477	65,410	32,796	101,474	45,292
	Class III obese	63,973	27,638	52,800	25,339	68,449	29,596	118,104	85,106	94,411	70,062	148,817	103,097
60–69	Normal weight	48,061	18,662	38,602	18,578	55,930	21,079	60,342	28,543	45,134	25,695	82,277	38,739
	Overweight	51,451	18,990	41,312	19,154	59,093	21,769	68,207	29,340	51,972	26,357	90,716	39,199
	Class I obese	59,638	23,829	47,518	22,595	68,207	26,699	69,427	34,002	52,078	30,768	92,445	45,273
	Class II obese	59,159	29,814	46,106	28,061	67,959	32,058	64,168	34,175	47,780	29,497	86,146	44,591
	Class III obese	33,364	22,901	25,405	20,688	39,996	26,271	86,628	75,475	62,322	58,890	118,050	96,609
70+	Normal weight	28,449	15,443	21,239	15,414	36,405	18,508	47,603	25,210	33,241	22,030	68,081	35,514
	Overweight	31,488	15,797	23,674	15,928	39,473	19,225	55,878	26,320	40,094	23,075	77,514	36,487
	Class I obese	36,132	20,094	26,880	19,028	45,258	23,856	55,788	30,606	39,118	26,882	77,883	42,384
	Class II obese	33,971	25,442	24,128	23,718	43,315	28,599	50,337	31,047	34,865	26,025	71,190	41,930
	Class III obese	14,168	19,046	8,946	17,022	20,764	23,166	63,462	65,640	41,448	49,297	92,515	87,517

*Health care cost differentials between patients with diabetes and those without diabetes. ‡Age refers to the age of patients entering into the Markov model.

showed that people with diabetes had medical expenditures ~2.3 times higher on average than those without diabetes, whereas our estimates showed that remaining lifetime health care expenditures for patients with diabetes were 1.19–2.75 times higher than for those without diabetes, depending on age, sex, race, and BMI.

Our results are consistent with the literature that women have a longer life expectancy, and there is an inverted U-shaped relationship between BMI and life years lost, with the largest life years lost in the overweight for most of the age, sex, and race groups (9). This relationship was also found between BMI and life years lost associated with diabetes, demonstrating that life years lost was the most for the overweight group. Class III obese individuals had the least number of life years lost associated with diabetes, possibly because people with the highest degree of obesity have increased risk of other obesity-related comorbidities in addition to diabetes, like coronary heart disease, hypertension, and stroke, which lowers the life expectancy for class III obese individuals without diabetes (35,36). This leads to smaller life years lost between patients with diabetes and those without diabetes for class III obese individuals. However, on average, class III obese individuals had fewer life years (77.1 years) than those of other BMI groups (80.1 years for the normal weight, 84.9 years for the overweight, and 83.8 and 81.5 years for the class I and II obese).

It should be noted that our conclusions are applicable to the U.S. general population in 1997–2000. This population was chosen because the NHIS Linked Mortality Public-use Files provide the most up-to-date mortality follow-up data from the NHIS interview through 31 December 2006, allowing us to have 6–10 years of mortality follow-up data to estimate the probability of death for patients with diabetes and those without diabetes (23). In addition, all risk and cost estimates were estimated from the same source of nationally representative data and were used to populate a Markov model to predict life years lost and total lifetime health care expenditures by age, race, sex, and BMI. None of these estimates were adapted from other existing studies. Therefore, no additional assumptions were made for the use of published data in populating our model.

The prevalence of diabetes has increased over the last few decades and has shown signs of leveling off in the past few years. As reported by Geiss et al. (4), the prevalence per 100 persons was 3.5 in 1990, 7.9 in 2008, and 8.3 in 2012. It has also been documented that the mortality rate of diabetes has been decreasing over time. Using NHIS 1997–2004, Gregg et al.

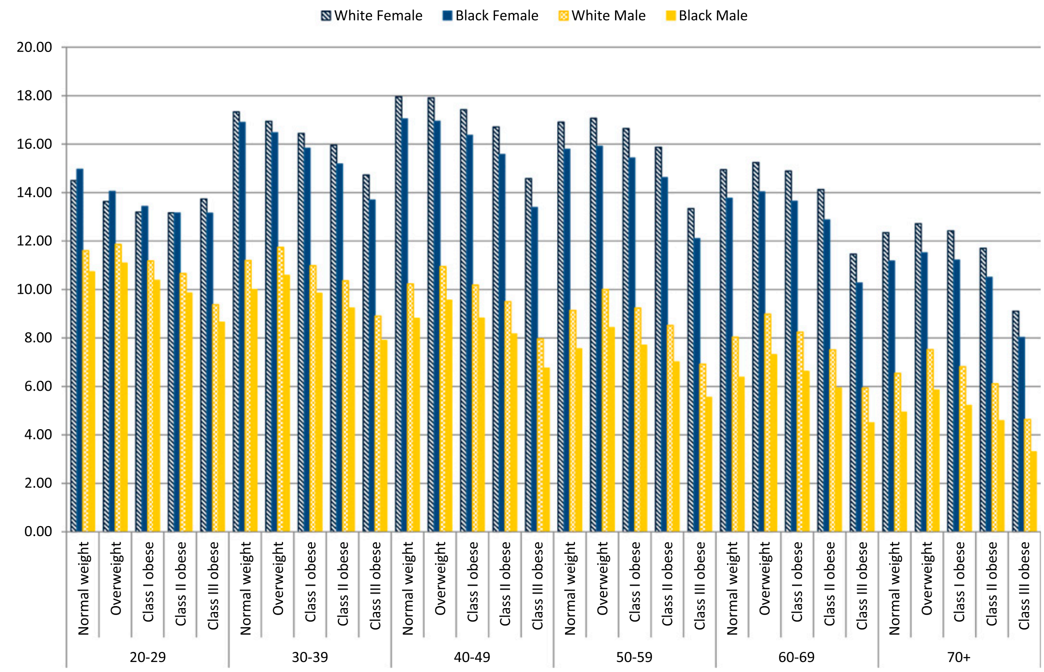

Figure 1—Life years lost associated with diabetes for insured population.

(34) showed that the excess all-cause 3-year mortality rate associated with diabetes declined by 44% (from 10.8 to 6.1 deaths per 1,000). These trends have led to ambiguous effects on both life years lost associated with diabetes and lifetime health care expenditure differentials. Further investigation using more recent data are needed to analyze the impact of the change in time trends of the risk and probability of death of diabetes on the lifetime cost of diabetes.

Our analysis has several strengths. First, our study focused on the estimation of life years lost and total lifetime medical expenditures associated with diabetes by age, race, sex, and BMI. Our results can inform policy makers on which demographic groups in the population are subject to the greatest impact of life years lost and lifetime health care expenditures associated with diabetes. Second, lifetime burden is provided in our study rather than risk or cost estimates at one point in time. Third, the use of Markov model allowed us to infer the life expectancy and the

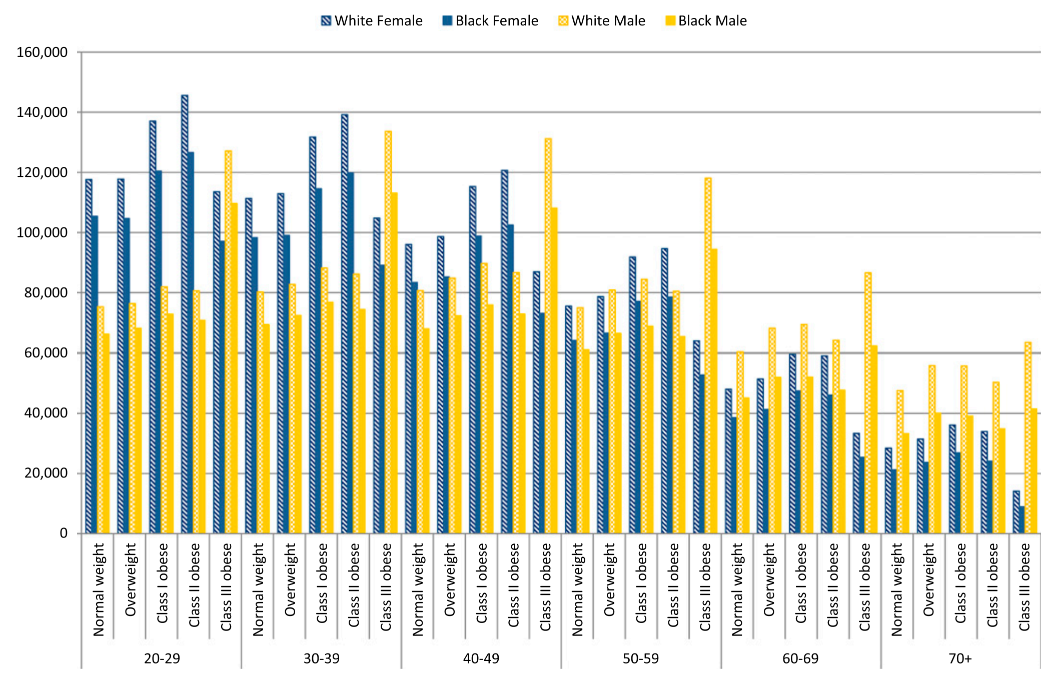

Figure 2—Lifetime health care expenditure differentials for insured population.

lifetime health care expenditures over cohorts of different age-race-sex-BMI classification groups, which had not been reported before. Last, instead of adapting estimates from existing studies, which requires stringent assumptions, our model was populated by probabilities that were consistently estimated from the same sources of nationally representative data. Our analysis has several limitations. First, the data from NHIS are self-reported, which may be subject to reporting errors, particularly with respect to BMI, diabetes status, and age of diagnosis. In our study, we used BMI category rather than BMI level, which may mitigate the reporting error in the BMI, although self-reported and measured BMI have been found to be highly correlated (0.9–0.95) and sufficient for epidemiological studies (37). Moreover, there is evidence demonstrating that the accuracy of self-reporting data for diabetes is reasonably high in population surveys (38). Second, literature suggests that average BMI among U.S. adults increases with age, but our analysis could not capture BMI change throughout an individual's lifetime (39). This might lead to an underestimation of the life years lost and cost differentials of diabetes as the weight of individuals in younger cohorts is likely to increase over time. Third, we did not separately consider type 1 and 2 diabetes, because the data did not differentiate between them. However, previous studies have shown that the majority (95%) of diabetes in the U.S. is type 2 (40). Finally, given changes in secular trends of risk and mortality rates of diabetes, our results cannot be extended to the current period.

CONCLUSIONS

We predicted the life years lost and the total health care expenditures associated with diabetes over the life course of individuals by age, race, sex, and BMI in the U.S. general population, 1997–2000. Our results showed that diabetes is associated with large decreases in life expectancy and large increases in lifetime health care expenditures. Diabetes decreased life expectancy by 3.3–18.7 years and increased lifetime health expenditures by $8,946 to $159,380, depending on age-race-sex-BMI classification groups. Life years lost associated with diabetes was greater for females than for males and whites than blacks. For a given age, race, and sex, overweight individuals with diabetes had, on average, lost the most life years, and the class II obese individuals had the largest increase in lifetime health care expenditures.

Our results provide evidence that the health and economic burden of diabetes is substantial over the life span. We find that certain population groups are most susceptible to the health and economic consequences of diabetes over the life course. Policy makers can implement diabetes prevention and intervention policies that target these populations to decrease life years lost and reduce the economic burden of diabetes more effectively.

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