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Lifetime Risk for Diabetes Mellitus in the United States

K. M. Venkat Narayan, MD
James P. Boyle, PhD
Theodore J. Thompson, MS
Stephen W. Sorensen, PhD
David F. Williamson, PhD

Context Although diabetes mellitus is one of the most prevalent and costly chronic diseases in the United States, no estimates have been published of individuals' average lifetime risk of developing diabetes.

Objective To estimate age-, sex-, and race/ethnicity-specific lifetime risk of diabetes in the cohort born in 2000 in the United States.

Design, Setting, and Participants Data from the National Health Interview Survey (1984-2000) were used to estimate age-, sex-, and race/ethnicity-specific prevalence and incidence in 2000. US Census Bureau data and data from a previous study of diabetes as a cause of death were used to estimate age-, sex-, and race/ethnicity-specific mortality rates for diabetic and nondiabetic populations.

Main Outcome Measures Residual (remaining) lifetime risk of diabetes (from birth to 80 years in 1-year intervals), duration with diabetes, and life-years and quality-adjusted life-years lost from diabetes.

Results The estimated lifetime risk of developing diabetes for individuals born in 2000 is 32.8% for males and 38.5% for females. Females have higher residual lifetime risks at all ages. The highest estimated lifetime risk for diabetes is among Hispanics (males, 45.4% and females, 52.5%). Individuals diagnosed as having diabetes have large reductions in life expectancy. For example, we estimate that if an individual is diagnosed at age 40 years, men will lose 11.6 life-years and 18.6 quality-adjusted life-years and women will lose 14.3 life-years and 22.0 quality-adjusted life-years.

Conclusions For individuals born in the United States in 2000, the lifetime probability of being diagnosed with diabetes mellitus is substantial. Primary prevention of diabetes and its complications are important public health priorities.

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DIABETES IS A SERIOUS AND costly disease.[1,2] The prevalence of diagnosed diabetes among US adults has increased by 40% in 10 years from 4.9% in 1990 to 6.9% in 1999.[3,4] It is estimated that the number of individuals in the United States with diagnosed diabetes will increase by 165% between 2000 and 2050, with the fastest increases occurring in older and minority subpopulations.[5]

While the prevalence of diabetes can provide information about the burden of disease in the community, prevalence rates do not capture individuals' risks of developing diabetes during a defined period. Prevalence rates contain no information about the impact of a disease on length and quality of life. Although mortality rates and disease incidence are also useful for assessing the impact of a disease at the community level, they say little about how they affect individuals. Lifetime risk, as well as estimates of length and quality of life with disease, are informative and easily understood measures of the effect of disease in individuals.[6,7]

Although estimates of lifetime risk are available for several chronic conditions (hypertension, breast cancer, dementia, fractures, and coronary heart disease) and have been used effectively in public education campaigns,[8-12] the lifetime risk of diabetes has not been previously reported.

We used data from the National Health Interview Surveys (NHIS; 1984-2000) to estimate prevalence and incidence of diabetes in 2000 specific to age (birth through ≥100 years), sex, and race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, other). Data from the US Census Bureau and from a previous study of diabetes as a cause of death were used to estimate mortality rates specific to age, sex, and race/ethnicity for the individuals with and without diabetes. These estimates were then entered into a Markov model to estimate residual (remaining) lifetime risk of diabetes specific to sex and race/ethnicity from birth to 80 years for the US population born in 2000. We also estimated age at diagnosis, duration with diabetes, and life-years lost from diabetes as well as quality-adjusted life-years (QALYs) lost.

METHODS

Diabetes prevalence and incidence rates, as well as mortality rates, were based on estimates for 2000. We calculated prevalence and incidence rates from the nationally representative NHIS.[13-16] Prevalence was assessed from the answer to the question "Have you ever

Author Affiliations: Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Division of Diabetes Translation, Atlanta, Ga.
Corresponding Author and Reprints: K. M. Venkat Narayan, MD, Division of Diabetes Translation, 4770 Buford Hwy, NE, MS K-10, Atlanta, GA 30341 (e-mail: kav4@cdc.gov).

been told by a doctor or health professional (other than during pregnancy, if female) that you have diabetes or sugar diabetes?" Incidence was assessed by cross-tabulating age at the time of the survey and the question "How old were you when a doctor first told you that you had diabetes or sugar diabetes?"

The NHIS is an ongoing continuous nationwide cross-sectional survey of the health status and behaviors of the US noninstitutionalized population conducted by the National Center for Health Statistics and by the US Bureau of Census. The NHIS uses a multistage, probability sampling strategy to select households and individuals each year; in 2000, there were approximately 45 000 households and 120 000 individuals selected. The overall response rate varies annually, but is approximately 90%. We jointly modeled NHIS data for 1984-2000 to improve the precision of the estimates for 2000.

There were 14 325 prevalent cases of diagnosed diabetes among the 356 787 respondents in the NHIS for 1984-2000. We used logistic regression to estimate diabetes prevalence as a function of age (birth through ≥100 years in 1-year intervals), race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, other), and sex, and used indicator variables to represent each calendar year. We used the Bayesian information criterion[17] to select the best fitting model. The Bayesian information criterion selects a model from a collection of possibly nonnested models by maximizing the likelihood but with a penalty for larger dimensional models. The final model included a cubic spline for age (knots at 20, 40, 60, 80 years), race/ethnicity, sex, calendar year, age by race/ethnicity interaction, and race/ethnicity by sex interaction. Cubic splines[18] are a flexible class of curves that can be used to model nonlinear responses in regression models. Our model appeared to fit the observed data well. The Hosmer-Lemeshow[19] goodness-of-fit test for the final model yielded a χ^2_8 of 8.99 ($P = .34$) and we calculated R^2 to be 0.70.[20]

There were 1349 incident cases of diagnosed diabetes among the 343 856 nondiabetic NHIS respondents for 1984-2000. The estimated incidence standardized to the 2000 US population ranged from 3.0/1000 during 1984-1990 to 4.2/1000 during 1997-2000. To improve precision, we used logistic regression to model incidence as a function of age, race/ethnicity, sex, and calendar year. The final model included a cubic spline for age (knots at 25, 50, 75 years), 4 racial/ethnic groups (non-Hispanic white, non-Hispanic black, Hispanic, other), sex, an age by sex interaction, and indicator variables for 3 calendar year groups (1984-1990, 1991-1996, 1997-2000). We used this calendar year grouping because the NHIS changed diabetes incidence reporting in 1997. This required that 1997-2000 be treated differently from previous years. The Hosmer-Lemeshow goodness-of-fit test for this final model yielded a χ^2_8 of 10.85 ($P = .21$) and we calculated R^2 to be 0.24.

We used estimates of the US mortality rate by age, race/ethnicity, and sex for 2000 that are provided in the US Census Bureau's projected components of change in the US resident population.[21] Because our Markov models require separate mortality rates for individuals diagnosed as having diabetes and those without the disease, we applied mortality relative risks (RRs) for diabetes to the mortality rates corresponding with age, sex, and race/ethnicity for persons without diabetes. In a recent study of death certificate data, Tierney et al[22] developed sex-specific estimates of the RR for death attributable to diabetes for adults (aged ≥18 years) in 4 age categories. They found that the RR for death from diabetes was highest in the youngest age group and declined progressively in older age groups. The age- and sex-specific estimates of RR used herein are also consistent with recent estimates from a National Health and Nutrition Examination Survey (NHANES) II mortality study[23] and other previously published estimates.[24]

Markov Chain Model

Markov chain models are frequently used to simulate the progression of individuals through mutually exclusive disease states. Transitions between states in a Markov model take place at discrete intervals, such as 1 month or 1 year, and the number of individuals who move from one state of the model to another during each cycle is determined by transition probabilities. For each race/ethnicity-sex combination, we estimated the age-specific 1-year probability of (1) remaining nondiabetic, (2) becoming diabetic, and (3) dying without diabetes. We estimated the probability of (1) remaining diabetic (for this analysis we assumed that once diagnosed, diabetes was not reversible) and (2) dying with diabetes for individuals who have developed diabetes.

Using these probabilities in a Markov chain model,[25] we estimated the (1) "residual" or remaining lifetime risk for diabetes among persons not diabetic at a specific "baseline" age, (2) average length of time or duration that a person is expected to live after diabetes diagnosis (assumes diabetes is not reversible), (3) life-years lost, which is the diabetes-related reduction in remaining life expectancy after a specific age at diagnosis, (4) QALYs lost, which we calculated by weighting each year with diabetes by 0.75 of a year without diabetes,[26] and (5) distributions of age at diagnosis by sex and race/ethnicity.

The Markov chain model used (available from the corresponding author on request) here can be considered an extension of the lifetable technique, a commonly used statistical method for demographic projections and clinical trial analysis. It begins with age-specific transition rates for a given period and then assumes that this schedule of rates is in operation for the lifetime of a hypothetical birth cohort. This cohort is "aged" year by year to produce residual lifetime risks at birth and at each age thereafter. Hence the residual lifetime risks for diabetes are those that would be realized if the age-specific transition rates do not change.

We estimated 8 sets of parameters and the associated Markov chains corresponding to the 8 race/ethnicity-sex combinations: non-Hispanic white male

and female, non-Hispanic black male and female, Hispanic male and female, and males and females of other races/ethnicities. We calculated all race/ethnicity estimates by weighting the race/ethnicity-specific values by the proportions of nondiabetic individuals in the 2000 US population. We calculated total population estimates by weighting the race/ethnicity-specific values by the proportions of newly incident cases in the 2000 US population.

Sensitivity Analyses

We conducted sensitivity analyses for several of our assumptions. In a probabilistic sensitivity analysis,[27] we simultaneously varied prevalence and incidence rates and RRs of mortality from diabetes. This approach generates confidence intervals for residual lifetime risks from distributions reflecting the uncertainty in the parameter estimates.

Because contemporary population-based data on the RR for death among children and adolescents (aged <18 years) with diabetes are not available, we assumed that their RR was the same as the RR for 18- to 44-year-olds with diabetes; 6.5 for males and 8.8 for females. In addition, we performed a sensitivity analysis by setting the RR for males and females (aged ≤18 years) equal to 1.0. This implies that death rates were not elevated for adolescents with diabetes. The resulting lifetime risks were almost identical, differing only in the fifth decimal place.

For the base-case analysis of QALYs lost, we weighted each year with diabetes by 0.75 of a year without diabetes.[26] A study, using the self-administered Quality of Well-Being Index[28] instead of the Euroqol[26] found that the health utility associated with diabetes may be as low as 0.65. However, individuals may adapt to diabetes with time and may not perceive their quality of life as poor as these data suggest. In a sensitivity analysis, we varied the weighting factor by 0.05 units in calculating QALYs lost from 0.65 to 0.90. For example, for a man diagnosed as having diabetes at age 40 years, the estimate of QALYs lost was 21.4 years for a weighting factor of 0.65; 20.0 for 0.70; 18.6 for 0.75; 17.2 for 0.80; 15.8 for 0.85; and 14.4 for 0.90. For a woman diagnosed at the same age, the respective QALYs lost were 25.1, 23.5, 22.0, 20.5, 18.9, and 17.4 years.

Table 1. Residual Lifetime Risk for Diagnosis of Diabetes Among Males

	Lifetime Risk (95% Confidence Interval), %*				
	Non-Hispanic				
Baseline Age, y	White	Black	Hispanic	Other	Total†
Birth	26.7 (24.4-29.5)	40.2 (36.1-44.7)	45.4 (40.5-51.0)	36.9 (29.6-46.0)	32.8 (30.3-35.8)
10	26.7 (24.4-29.5)	40.6 (36.4-45.1)	45.5 (40.7-51.3)	37.0 (29.6-46.1)	32.1 (29.7-35.0)
20	26.6 (24.3-29.3)	40.5 (36.4-45.1)	45.4 (40.5-51.2)	37.0 (29.5-46.1)	31.9 (29.5-34.8)
30	26.3 (24.0-29.1)	40.6 (36.4-45.3)	45.4 (40.4-51.2)	37.0 (29.5-46.2)	31.3 (28.9-34.3)
40	25.3 (23.0-28.1)	39.7 (35.5-44.4)	44.3 (39.3-50.2)	36.1 (28.6-45.3)	29.5 (27.1-32.4)
50	22.4 (20.2-25.0)	36.1 (31.9-40.7)	40.3 (35.4-46.2)	32.7 (25.7-41.6)	25.5 (23.2-28.4)
60	16.6 (14.6-19.2)	28.1 (24.2-32.5)	31.7 (27.0-37.7)	25.7 (19.7-33.8)	18.9 (16.8-21.7)
70	9.9 (8.0-12.5)	17.7 (14.1-22.6)	20.4 (15.8-27.2)	16.8 (11.7-24.5)	11.2 (9.1-14.4)
80	4.6 (2.8-7.7)	9.3 (5.5-15.8)	10.5 (6.0-18.5)	8.8 (4.7-16.9)	5.2 (3.2-8.9)

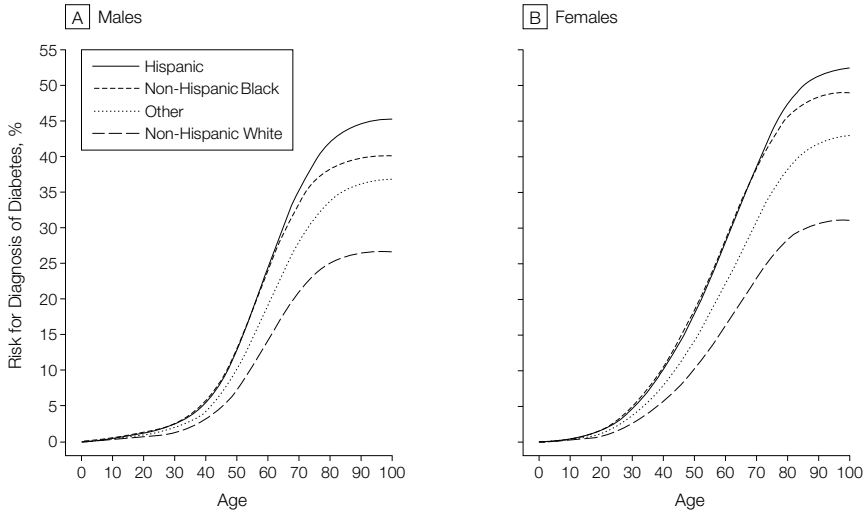
*Values obtained through a probabilistic sensitivity analysis.
†We estimated risks for all races/ethnicities combined by weighting the race/ethnicity-specific values by the proportions of nondiabetic individuals in the 2000 US population.

Table 2. Residual Lifetime Risk for Diagnosis of Diabetes Among Females

	Lifetime Risk (95% Confidence Interval), %*				
	Non-Hispanic				
Baseline Age, y	White	Black	Hispanic	Other	Total†
Birth	31.2 (28.8-33.9)	49.0 (44.6-53.7)	52.5 (47.4-58.3)	43.3 (35.1-53.2)	38.5 (36.0-41.5)
10	31.2 (28.8-33.9)	49.6 (45.1-54.3)	52.8 (47.6-58.5)	43.5 (35.2-53.4)	37.9 (35.4-40.7)
20	30.9 (28.4-33.5)	49.1 (44.6-53.8)	52.3 (47.1-58.0)	43.1 (34.9-53.1)	37.3 (34.8-40.1)
30	29.8 (27.4-32.5)	47.8 (43.3-52.6)	50.9 (45.8-56.7)	42.0 (33.9-52.0)	35.7 (33.2-38.5)
40	27.7 (25.4-30.4)	45.2 (40.7-50.0)	48.2 (43.0-54.0)	39.8 (31.8-49.6)	32.6 (30.2-35.4)
50	24.4 (22.2-27.0)	40.8 (36.4-45.6)	43.6 (38.5-49.5)	35.9 (28.4-45.4)	28.2 (25.9-31.0)
60	19.5 (17.4-21.9)	33.6 (29.4-38.4)	36.2 (31.3-42.1)	29.9 (23.2-38.8)	22.4 (20.1-25.1)
70	12.8 (10.8-15.4)	23.2 (19.2-28.3)	25.2 (20.6-31.6)	21.3 (15.5-29.7)	14.6 (12.4-17.6)
80	6.1 (4.3-9.0)	12.3 (8.4-18.3)	13.2 (8.9-20.0)	11.7 (7.2-19.8)	6.9 (4.9-10.2)

*Values obtained through a probabilistic sensitivity analysis.
†We estimated risks for all races/ethnicities combined by weighting the race/ethnicity-specific values by the proportions of nondiabetic individuals in the 2000 US population.

Figure. Cumulative Lifetime Risk for Diagnosis of Diabetes



We also performed 2 procedures to check the accuracy of the model. First, we compared life expectancies specific to sex and race/ethnicity from the Markov model with US Census Bureau life expectancies for 2000.[21] In all cases, the life expectancies from the Markov model were within 1 year of the US Census Bureau life expectancies. Second, we compared our estimates of the prevalence of diabetes, assuming the Markov model was at steady state, with previously published projections for 2050.[5,29] The Markov model produced a prevalence estimate of 8.9% vs previous projections of 7.2% by Boyle et al[5] and 9.7% by Honeycutt et al.[29] Boyle et al[5] used different data and a different modeling strategy from our analysis while Honeycutt et al[29] used NHIS data and Markov chains.

RESULTS

Residual Lifetime Risk

TABLE 1 and TABLE 2 list the residual lifetime risks for diabetes for males and females by baseline age and race/ethnicity. For individuals born in 2000, the lifetime risk for diabetes was higher for females than males (38.5% vs 32.8%). The residual lifetime risk for diabetes remained higher among females than males at all ages, declining to 22.4% for females and 18.9% for males at age 60 years, and to 6.9% and 5.2%, respectively, at age 80 years. The lifetime risk for diabetes was higher among minority groups at birth and at all ages. Among males, the lifetime risk at birth ranged from 45.4% for Hispanics to 26.7% for non-Hispanic whites. Among females, the lifetime risk ranged from 52.5% for Hispanics to 31.2% for non-Hispanic whites. The residual risk for diabetes remained high for minority groups even at older ages, ranging from 31.7% for Hispanic men to 16.6% for non-Hispanic white men at age 60 years and from 36.2% for Hispanic women to 19.5% for non-Hispanic white women.

In the cohort of individuals born in 2000, we estimated that 0.88% of males and 1.11% of females will develop diabetes by age 20 years; by age 40 years, 4.05% and 7.19%; by age 60 years, 18.09% and 20.38%; and by age 80 years, 30.77% and 35.08%, respectively. The estimated proportion of individuals who will develop diabetes before various ages is higher among minority groups (FIGURE).

Life-Years and QALYs Lost

Among children diagnosed as having diabetes at age 10 years, we project that on average boys will lose 18.7 life-years and 31.0 QALYs (TABLE 3) and girls will lose 19.0 life-years and 32.8 QALYs (TABLE 4). We project loss of life-years and QALYs to be higher in minority groups and highest for non-Hispanic blacks. Black males diagnosed as having diabetes at age 10 years lose 22.2 life-years and 32.6 QALYs; black females diagnosed at the same age lose 23.1 life-years and 35.3 QALYs. The projected loss of life-years and QALYs is substantial even among in-

Table 3. Duration of Diabetes, Life-Years Lost, and Quality-Adjusted Life-Years Lost Among Males

Age at Diagnosis, y	Duration	Life-Years Lost	QALYs Lost
Non-Hispanic White			
10	51.0	16.6	29.3
20	42.6	15.3	26.0
30	35.3	13.2	22.0
40	28.2	10.9	18.0
50	21.2	8.8	14.1
60	14.5	7.1	10.8
70	9.3	5.2	7.5
80	5.3	3.6	4.9
Non-Hispanic Black			
10	41.4	22.2	32.6
20	33.6	20.5	28.9
30	28.2	17.1	24.2
40	23.1	13.4	19.1
50	18.1	10.1	14.7
60	12.9	7.9	11.1
70	8.7	5.7	7.9
80	5.6	4.2	5.6
Hispanic			
10	51.9	19.3	32.3
20	43.8	17.8	28.8
30	37.7	14.8	24.2
40	31.8	11.5	19.5
50	25.0	9.3	15.5
60	18.0	7.7	12.2
70	12.2	5.8	8.9
80	7.3	4.3	6.1
Other			
10	49.4	21.5	33.8
20	41.6	19.7	30.1
30	35.9	16.4	25.4
40	30.3	13.0	20.6
50	24.3	10.3	16.3
60	18.0	8.4	12.9
70	12.8	6.2	9.4
80	7.9	4.7	6.7
Total*			
10	49.0	18.7	31.0
20	40.9	17.2	27.4
30	34.4	14.5	23.1
40	28.0	11.6	18.6
50	21.4	9.2	14.5
60	14.9	7.3	11.1
70	9.6	5.3	7.7
80	5.6	3.8	5.1

Abbreviation: QALY, quality-adjusted life-year.
*Estimates were obtained by weighting the race-specific values by the proportions of newly incident cases in the 2000 US population.

Table 4. Duration of Diabetes, Life-Years Lost, and Quality-Adjusted Life-Years Lost Among Females

Age at Diagnosis, y	Duration	Life-Years Lost	QALYs Lost
Non-Hispanic White			
10	55.4	17.9	31.8
20	46.6	16.9	28.5
30	38.2	15.6	25.1
40	30.2	13.8	21.4
50	22.9	11.8	17.5
60	16.4	9.3	13.4
70	11.3	6.2	9.1
80	6.8	3.9	5.6
Non-Hispanic Black			
10	49.0	23.1	35.3
20	40.3	22.0	32.0
30	32.8	19.9	28.1
40	26.7	16.8	23.4
50	20.9	13.6	18.8
60	15.3	10.5	14.3
70	11.0	7.1	9.9
80	7.3	4.7	6.5
Hispanic			
10	62.1	16.1	31.7
20	53.2	15.2	28.5
30	44.7	13.9	25.1
40	36.5	12.4	21.5
50	28.6	10.8	17.9
60	21.1	8.9	14.2
70	14.6	6.6	10.3
80	9.0	4.7	6.9
Other			
10	56.1	22.9	37.0
20	47.9	21.4	33.4
30	40.3	19.4	29.5
40	34.0	16.3	24.9
50	27.3	13.8	20.6
60	21.2	11.0	16.3
70	16.0	8.0	12.0
80	10.7	6.0	8.7
Total*			
10	55.5	19.0	32.8
20	46.7	17.9	29.6
30	38.4	16.5	26.1
40	30.8	14.3	22.0
50	23.5	12.1	18.0
60	17.0	9.5	13.8
70	11.8	6.5	9.4
80	7.1	4.1	5.9

Abbreviation: QALY, quality-adjusted life-year.
*Estimates were obtained by weighting the race-specific values by the proportions of newly incident cases in the 2000 US population.

dividuals diagnosed as having diabetes at older ages. If diagnosed as having diabetes at 60 years, men are projected to lose 7.3 life-years and 11.1 QALYs; women, 9.5 years and 13.8 QALYs, respectively.

Age at Diagnosis of Diabetes

In 2000, the mean age at diagnosis of diabetes was 55.7 years for non-Hispanic black males and females; 57.9 years for Hispanic males and 57.4 years for Hispanic females; 58.1 years for non-Hispanic white males and 57.9 for non-Hispanic white females; and 58.8 years for males and females of other races/ethnicities. The distribution of age at diagnosis displayed a sigmoid shape: relatively few cases occurred among those aged 20 years or younger and the numbers increased rapidly from age 40 years before plateauing among those aged 80 years or older. Among eventual diabetes patients, about 3% of cases were diagnosed by age 20 years; about 13% of male and 19% of female cases, respectively, by age 40 years; about 55% by age 60 years; and about 90% by age 80 years.

COMMENT

For individuals born in the United States in 2000, we estimate the lifetime risk of diagnosed diabetes mellitus to be roughly 1 in 3 for males and 2 in 5 for females. The estimated lifetime risk is even higher among minority populations, with Hispanic females having roughly 1 in 2 risk at birth and 1 in 3 residual risk at age 60 years. The lifetime risk of diabetes is comparable with or higher than that for many diseases and conditions that are perceived as common.[6-12] For example, the lifetime risk of diabetes is considerably higher than the widely publicized 1 in 8 risk for breast cancer among US women.[9] At age 40 years, the residual lifetime risk of diabetes is roughly 1 in 3 for men and women, and is nearly as high as that for coronary heart disease (1 in 2 for men and 1 in 3 for women).[12] At age 50 years, the residual lifetime risk of diabetes for women is a little less than 3 in 10, which is close to the residual risk for hip fracture (about 1 in 3).[11] The residual lifetime risk of diabetes remains high even at older ages. For example, at age 70 years the residual lifetime risk of diabetes for men is about 1 in 10, the same as dementia.[10]

These estimates of lifetime risk for diabetes must be carefully interpreted. The lifetime risk estimates are for an average person in the population. The estimates, thus, incorporate the effects of diabetes risk factors on an average person. The level of diabetes risk factors, especially obesity, lifestyle, and socioeconomic factors, may raise or lower the lifetime risks away from the average for an individual. Our estimates of the lifetime risk for diabetes are likely to be lower than the true risk for a number of reasons. First, we only used data on diagnosed diabetes. A third or more of individuals may have diabetes but the disease has not been diagnosed.[30] Therefore, our estimates only apply to the risk of diagnosed diabetes. However, there are no data on the effect of undiagnosed diabetes on mortality. Thus, it was not feasible to include rates of undiagnosed diabetes in our estimates. Second, our data on diagnosed diabetes was based on self-report, but a report[31] indicates that the accuracy of self-reporting for diabetes is reasonably high in population surveys. Third, we modeled for constant diabetes incidence rates even though obesity incidence is increasing rapidly in the United States.[32] Thus, the incidence of diabetes is likely to increase and the results of several studies suggest that this increase may already be occurring,[33-35] especially among younger people.[36] A fourth factor limiting the accuracy of our projections is the projected increase in life expectancy in the United States, particularly for ethnic minority groups at greatest risk for diabetes.[37] Longer life expectancies will also increase the average lifetime risk for diabetes in the total US population. Our estimates, however, are based on diabetes incidence and mortality rates specific to age, sex, and race/ethnicity.

The data used for our estimates did not differentiate between type 1 and type 2 diabetes. However, the major form of diabetes in the population is type 2 diabetes, which accounts for up to 95% of diabetes cases in the United States.[38] Among children, however, type 1 diabetes poses a greater risk, although this may change in the future as the rate of type 2 diabetes in children and adolescents increases.[36] Although the accuracy of our estimates

depends on the accuracy of the RRs for death from diabetes that we used, we believe that the age-specific RR estimates we used closely reflect those of the population of people with diabetes in the United States, and the age- and sex-specific estimates of RR we used herein are consistent with recent estimates from an NHANES II mortality study and with those from previous studies.[23,24] However, if the true RR is different than our estimate, then the lifetime risks of diabetes we report may be affected. If the true age-specific RRs of death from diabetes are higher than the values we used, life-years lost due to diagnosed diabetes will be higher than our estimates, and the duration of diabetes will be lower, but the precise impact on lifetime risk of diabetes is not clear. Our estimation of life-years lost do not imply causality to diabetes per se, but rather take into account all the aspects of morbidity (eg, obesity, cardiovascular disease) an average person with diabetes may experience. We also estimated QALYs lost due to diabetes to describe in a composite manner the combined impact of life-years lost and quality of life lost due to diabetes. Published data on quality of life lost due to diabetes are scant, and it was not possible to estimate from the available data the utility associated with diabetes after accounting for other comorbidities. Our estimates of QALYs lost due to diabetes are far less precise than those of life-years lost.

Our estimates of lifetime risk for diabetes are from a carefully constructed dynamic model that uses nationally representative data, including incidence and mortality rates specific to age, sex, and race/ethnicity. The use of a dynamic model to estimate lifetime risk is an extension of the well-established tradition of projecting life expectancy with life tables. Indeed, life expectancies estimated from our Markov model were within 1 year of the US Census Bureau life expectancies. Also, our model's steady-state prevalence is close to previous projections of prevalence in 2050. Our estimate of life-years lost when diabetes was diagnosed at age 60 years is also quite similar to that estimated directly from the NHANES I for individuals aged 55 to 64 years,[39] and fairly close to a recently published report from England.[40]

Lifetime risk estimates have been published for several diseases and conditions,[6-12] but there has been no previous estimates for diabetes. To our knowledge, all previous lifetime risk estimates for these other diseases and conditions have been based on epidemiological cohort studies of disease incidence. Cohort studies are subject to several biases, including volunteer bias for healthy participants. In addition, cohort studies are rarely nationally representative in terms of demographics, disease risk, or mortality. Temporal trends within a cohort may also confound the estimation of lifetime risks. Therefore, we believe that our method of estimation of lifetime risk allows more accurate inference to the general population than methods based on the experience of individuals followed up in cohort studies.

The population burden of diabetes complications is large in terms of mortality, morbidity, and loss of quality of life.[2,40] We have quantified this burden in a way that is easily communicated to both policy makers and individuals. For example, we project that, on average, a US male diagnosed as having diabetes at age 40 years will lose almost 12 life-years and 19 QALYs compared with a person of the same age without diabetes. A US female diagnosed as having diabetes at age 40 years will lose about 14 life-years and 22 QALYs. Estimates of lifetime risk and life-years and QALYs lost will also be useful tools for communicating the risk of diabetes and its affect on health to the general public, to individuals at high risk for developing diabetes, to clinicians, to policy makers, and to the media. These estimates can also serve as baseline data to monitor secular trends in the burden of diabetes. Implementation of available treatments to prevent diabetes complications is suboptimal.[41] Furthermore, results of recent clinical trials show promise that diabetes itself may be prevented or at least delayed with lifestyle interventions that produce modest weight loss or with the use of drugs.[42-44] Our estimates of lifetime risk of diabetes and life-years and QALYs lost due to diabetes further support concerted action to prevent diabetes and its complications.

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Acquisition of data: Sorensen,
Analysis and interpretation of data: Narayan, Boyle, Thompson, Williamson.
Drafting of the manuscript: Narayan, Boyle, Williamson.
Critical revision of the manuscript for important intellectual content: Narayan, Boyle, Thompson, Sorensen, Williamson.
Statistical expertise: Narayan, Boyle, Thompson, Sorensen, Williamson.

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