Disability-Free Life-Years Lost Among Adults Aged ≥50 Years With and Without Diabetes

Barbara H. Bardenheier,[1,2] Ji Lin,[1] Xiaohui Zhuo,[1,3] Mohammed K. Ali,[4] Theodore J. Thompson,[1] Yiling J. Cheng,[1] and Edward W. Gregg[1]

Diabetes Care 2016;39:1222–1229 | DOI: 10.2337/dc15-1095

OBJECTIVE

To quantify the impact of diabetes status on healthy and disabled years of life for older adults in the U.S. and provide a baseline from which to evaluate ongoing national public health efforts to prevent and control diabetes and disability.

RESEARCH DESIGN AND METHODS

Adults (*n* = 20,008) aged 50 years and older were followed from 1998 to 2012 in the Health and Retirement Study, a prospective biannual survey of a nationally representative sample of adults. Diabetes and disability status (defined by mobility loss, difficulty with instrumental activities of daily living [IADL], and/or difficulty with activities of daily living [ADL]) were self-reported. We estimated incidence of disability, remission to nondisability, and mortality. We developed a discrete-time Markov simulation model with a 1-year transition cycle to predict and compare lifetime disability-related outcomes between people with and without diabetes. Data represent the U.S. population in 1998.

RESULTS

From age 50 years, adults with diabetes died 4.6 years earlier, developed disability 6–7 years earlier, and spent about 1–2 more years in a disabled state than adults without diabetes. With increasing baseline age, diabetes was associated with significant ($P < 0.05$) reductions in the number of total and disability-free life-years, but the absolute difference in years between those with and without diabetes was less than at younger baseline age. Men with diabetes spent about twice as many of their remaining years disabled (20–24% of remaining life across the three disability definitions) as men without diabetes (12–16% of remaining life across the three disability definitions). Similar associations between diabetes status and disability-free and disabled years were observed among women.

CONCLUSIONS

Diabetes is associated with a substantial reduction in nondisabled years, to a greater extent than the reduction of longevity.

Diabetes is one of the most common public health threats in the U.S., affecting 12% of adults and carrying an estimated lifetime probability of 40% (1,2). Furthermore, increases in life expectancy of the diabetes population have led to a large increase in the number of years spent with diabetes for the average person (1). This, combined with increased prevalence since 1985, has led to a 156% and 70% increase in the number of years that a typical community of men and women, respectively, will spend with diabetes (1).

[1]Division of Diabetes Translation, Centers for Disease Control and Prevention, Atlanta, GA
[2]Immunization Safety Office, Centers for Disease Control and Prevention, Atlanta, GA
[3]Merck & Co., North Wales, PA
[4]Hubert Department of Global Health, Rollins School of Public Health, Emory University, Atlanta, GA

Corresponding author: Barbara H. Bardenheier, bfb7@cdc.gov.

Received 22 May 2015 and accepted 2 November 2015.

This article contains Supplementary Data online at http://care.diabetesjournals.org/lookup/suppl/doi:10.2337/dc15-1095/-/DC1.

B.H.B. is currently affiliated with the Immunization Safety Office, National Center for Emerging and Zoonotic Infectious Diseases, Centers for Disease Control and Prevention, Atlanta, GA.

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

Diabetes is known for its diverse vascular and neuropathic complications and for the associated excess risk of disability. Disability experienced among people with diabetes includes loss of mobility and the ability to carry out instrumental and basic activities of daily living (3–6). The increased risk of disability erodes quality of life, increases morbidity, and increases the need for health services and social security resources, relative to peers without diabetes (7). Disability-free life-years is a measure of population health that quantifies the impact of health conditions on nondisabled and disabled years (8). As such, it provides an important metric to gauge the impact of chronic conditions, as well as attempts of public health interventions to compress morbidity in the population alongside reductions in mortality.

Despite the well-documented impact of diabetes on diverse forms of macrovascular morbidity (9) and mortality (10), there have been no national estimates of the years of disability-free versus disabled life-years lost to the disease among U.S. adults. In these analyses, we assembled prospective cohort data on incidence of disability and mortality among a diverse, population-based sample of U.S. adults aged ≥50 years to quantify the impact of diabetes on disability-free and disabled years of life and to provide a baseline from which to evaluate the impact of national public health efforts to control and prevent diabetes.

RESEARCH DESIGN AND METHODS

Population and Data Sources

Our analyses are based on 20,008 adults aged 50 years and older enrolled in the Health and Retirement Study (HRS), a population-based longitudinal cohort study (11). Respondents entered in 1998 with biennial visits in 2000, 2002, 2004, 2006, 2008, 2010, and 2012. Initial response rates ranged from 69% to 81%, and follow-up response rates were 87% to 89% (12). Reports from the eight visits, described below, were used to estimate prevalence and incidence of diabetes, incidence of disability, mortality, and incidence transitions from diabetes and nondiabetes status to disability and mortality, as well as remission from disability to nondisabled states and mortality. The HRS is sponsored by the National Institute on Aging and performed by the Institute for Social Research at the University of Michigan. The Health Sciences Institutional Review Board at the University of Michigan approved the HRS study design. The data used for this analysis were stripped of unique personal identifiers and are publicly available. The data used for our analyses are nationally representative.

Definitions

Prevalent diabetes was defined by the survey question of whether the individual had been diagnosed by a physician with diabetes or high blood glucose. Incident diabetes was defined as the first self-report by a respondent to HRS of a diabetes diagnosis (i.e., being told by a doctor that he or she has diabetes or high blood glucose) during the study period (13). Incident diabetes cases were incorporated into analyses such that an individual who was diagnosed with diabetes after baseline was included in the diabetes group only if they did not become disabled prior to a diabetes diagnosis. If they became disabled after they were diagnosed with diabetes, they were considered an incident case of disability in the diabetes group.

Mobility disability was defined as self-report of difficulty with any of the following: walking one block; climbing one flight of stairs; stooping, crouching, or kneeling; and pushing or pulling a large object (14). Modifying a previously developed four-state model for defining mobility disability among people with diabetes (14), we classified a respondent's mobility disability as severe if they reported four or five of the previously mentioned mobility measures. Similarly, instrumental activities of daily living (IADL) were defined as self-report of difficulty doing any of the following: using the telephone, taking medication, handling money, shopping, and preparing meals. Activities of daily living (ADL) were defined as self-report of difficulty doing any of the following: walking across a room, getting in and out of bed, dressing, bathing, and eating. Death was determined during exit interviews with the respondent's proxy, family, or friend and confirmed as valid by the National Center for Health Statistics via linkage to the National Death Index (12). The year of death reported during the exit interview was used for censoring at time of death. If year was unknown, year of exit interview was used (n = 126, 7%).

Estimation of Incidence

Age-specific incidence of mobility, ADL, and IADL was modeled using generalized estimating equations with a binary outcome, wherein people with prevalent disability at baseline were excluded. All the regression models were stratified by sex and included age, piecewise age function, race/ethnicity, and diabetes status. Data were modeled with STATA version 13 (StataCorp, College Station, TX), which accounts for the longitudinal complex survey design. Estimates were weighted to the U.S. population in 1998, followed through 2012. Regression estimates were used to determine the probability of incident disability among those with and without diabetes by age. We were unable to further stratify on race/ethnicity due to the small sample size. Therefore we adjusted for race/ethnicity by centering individual responses around the grand mean. Thus, our primary findings are adjusted for the proportion of respondents by race/ethnicity. We conducted additional analyses adjusting for the prevalence of cardiovascular disease (CVD) to determine its effects on the primary outcomes (incidence, remission, and mortality) affecting healthy life-years. These probabilities were used as inputs to the Markov models. Similarly, probability of remission from disability was calculated on a yearly basis as the people with incident disability (for mobility, IADL, and/or ADL, respectively) who return to a state of nondisablement.

Modeling Approach

We developed a discrete-time Markov cohort simulation model with annual transition to predict and compare lifetime disability-related outcomes between people with and without diabetes from age 50 through 100 years (Fig. 1) (15). The model has five states: not disabled, short-term disability, not disabled but with previous disability, permanent disability, and death. Each year, the specific proportion that moves between states (i.e., transition probabilities) was determined by the regression models.

We created states of short-term disability and not being disabled but with

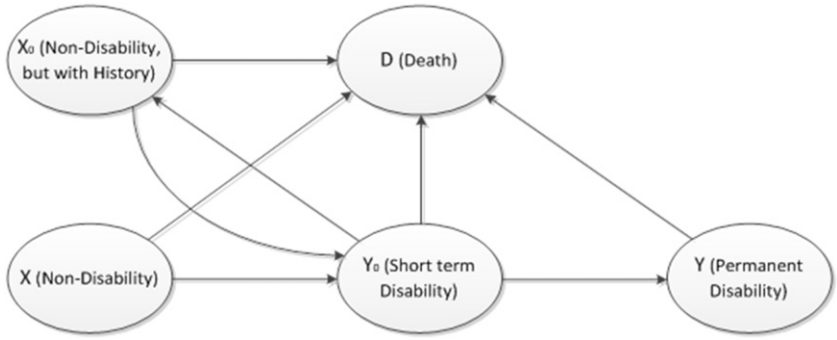

Figure 1—The five-state Markov model.

disability history (i.e., recovered from disability) as two bridge states (i.e., connections between states) because of the high remission rates (returning to nondisabled states) observed in the data. Moreover, to simplify the model, the state of short-term disability is defined as being disabled and having no remission by the end of the 1st year of disability onset. Therefore, in the model, a person with disability onset will either recover or move to the state of permanent disability in the next year. The assumption is supported by the fact that few remissions occurred later in the study. Further, like those in the study population, individuals may have multiple episodes of short-term disability over their lifetime in the model.

On the basis of the model, we predicted three disability-related outcomes, including the remaining lifetime risk of becoming disabled, average age of disability onset, and remaining life-years living with and without disability, among adults who reported having and not having diabetes at ages 50, 60, 70, and 80 years. Remaining lifetime risk was calculated as the cumulative risk of experiencing short-term or permanent disability over a lifetime. Because of the high frequency of multiple episodes of short-term disability, the average age of onset was defined as the difference between the life expectancy and mean disability-free life-years. For example, from a baseline age of 50 years, it is possible to become disabled at age 56 years, recover at 58 years, and then become disabled again at age 64 years. Therefore the average age of onset was defined by taking the difference between life expectancy from age 50 years and the average number of disability-free life-years remaining instead of choosing the age of onset of one of the disabled episodes. The CIs and *P* values of the lifetime estimates were estimated using a Monte Carlo simulation of the Markov model with transition probabilities sampled from the previously described regression models. Five thousand runs were performed for each group with or without diabetes.

RESULTS

Study Population Characteristics

Among the 20,008 respondents in the analytic sample, age ranged from 50 to 105 years, and baseline diabetes prevalence was 14.1% among men and 12.2% among women. Among both sexes, ~15–17% of the population was nonwhite and 22–23% was obese. (Table 1) Among those with a diabetes diagnosis at baseline, 8.7% were taking insulin and oral medication, 52.4% were taking oral medication only, 17.1% were taking insulin only, and 21.7% were not taking antidiabetic medications. The vast majority of all respondents who reported they had high blood pressure at baseline reported they were taking medication for high blood pressure (those with diabetes, 87%; those without diabetes, 81%).

Incidence of Diabetes, Disability, and Mortality

Estimated incidence of diabetes was 1.5% per year among men and 1.3% per year among women. Annual incidence of severe mobility disability increased with age from absolute levels of 0.4% in men and 0.6% in women at age 50 years, roughly doubling in incidence by age 60 years, and quadrupling by age 68 years and then increased 20 times by age 87 years (data not shown). Compared with severe mobility disability, incidence of IADL and ADL disability increased similarly from age 50 to 68 years and increased 26 times for women and 27 times for men by age 87 years. Among both men and women, disability rates (mobility, IADL, and ADL) were one and a half to two times higher among people with diabetes. Disability rates were 27–35% higher among women with diabetes than men with diabetes; sex-related differences in disability were smaller among those without diabetes.

Incidence of remission from disability was >20% per year for most strata (Table 2), was greater for those without diabetes than for those with diabetes, and declined substantially with age in all groups (data not shown, $P < 0.001$). Mortality rates among those with diabetes were about twice as high as their counterparts without diabetes, but the relative risk of mortality associated with diabetes decreased with increasing age (data not shown). Additional analyses adjusting for prevalent CVD at baseline resulted in a <0.3 percentage point difference from the estimates unadjusted for prevalent CVD (Supplementary Table 1).

Disability-Free and Disabled Life-Years

Across all ages and disability definitions, having diabetes was significantly associated with reduced years of total life and reduced disability-free life-years compared with people without diabetes (Tables 3 and 4). However, there was a greater impact of diabetes on disability-free life-years than on total life-years, and those with diabetes spent a greater proportion of their remaining years in a disabled state, particularly among those incident at younger ages. This is illustrated in Fig. 2*A* and *B* for mobility loss disability; results were similar for ADL and IADL disability (data not shown). From age 50 years, men with diabetes died 4.6 years earlier, developed disability 6 years earlier, and spent 1–1.5 more years in a disabled state than men without diabetes. This means that men with diabetes spent about twice as many of their remaining years disabled (20–24% of remaining life across the three disability definitions) compared with men without diabetes (12–16% of remaining life across the three disability definitions).

Table 1—General characteristics of study population according to diabetes status at baseline

	Men			Women		
	Diabetes, *n* (%)	No diabetes, *n* (%)	*n* total deaths*	Diabetes, *n* (%)	No diabetes, *n* (%)	*n* total deaths*
Age (years)						
50–59	318 (31.8)	2,225 (41.9)	515	371 (26.5)	3,036 (37.3)	482
60–69	504 (31.9)	2,562 (28.0)	1,098	537 (30.8)	3,081 (26.6)	944
70–79	390 (27.2)	1,803 (21.9)	1,490	428 (30.0)	2,293 (23.7)	1,555
80+	138 (9.1)	745 (8.2)	847	208 (12.7)	1,369 (12.3)	1,401
Mean ± SE age	65.8 ± 0.4	63.9 ± 0.2	—	67.5 ± 0.3	65.5 ± 0.2	—
Race/ethnicity						
Non-Hispanic white	950 (79.0)	5,848 (86.6)	3,056	903 (70.3)	7,652 (85.6)	3,322
Hispanic	137 (9.1)	509 (5.6)	273	188 (9.9)	650 (5.8)	274
Non-Hispanic black	232 (11.9)	830 (7.8)	545	417 (19.8)	1,298 (8.6)	721
Education						
<HS	473 (30.2)	1,970 (22.7)	1,475	686 (40.7)	2,588 (23.5)	1,739
HS	626 (48.0)	3,480 (48.5)	1,776	696 (47.5)	5,451 (56.9)	2,148
>HS	251 (21.8)	1,885 (28.8)	699	162 (11.8)	1,740 (19.6)	495
BMI (kg/m^2)						
<25	308 (22.1)	2,407 (31.8)	1,517	373 (25.2)	4,395 (46.6)	2,099
25 to <30	585 (42.7)	3,485 (47.7)	1,718	496 (32.2)	3,197 (32.9)	1,298
≥30	455 (35.2)	1,427 (20.5)	708	641 (42.6)	1,993 (20.5)	900
Prevalent ADL	277 (20.6)	909 (11.1)	842	475 (29.0)	1,555 (14.9)	1,341
Prevalent IADL	245 (17.5)	779 (9.6)	770	417 (25.5)	1,326 (12.6)	1,262
Prevalent mobility loss	204 (15.2)	537 (6.4)	572	404 (25.5)	1,165 (11.2)	1,059
Cardiovascular disease						
High blood pressure	814 (59.7)	2,853 (36.9)	1,911	1,080 (68.4)	4,030 (38.6)	2,476
Heart disease	485 (34.6)	1,618 (20.1)	1,405	485 (31.7)	1,512 (14.6)	1,312
Stroke	168 (12.6)	471 (5.7)	494	181 (11.3)	546 (5.4)	547
Arthritis	743 (53.3)	3,283 (41.4)	2,077	1,084 (69.0)	5,594 (54.6)	2,920
Lung disease	105 (8.2)	549 (6.6)	505	140 (9.2)	623 (6.0)	523
Entered nursing home after baseline	24 (1.8)	92 (1.2)	—	52 (3.2)	281 (2.9)	—

All data are self-reported, except death, which is reported by proxy, friend, or family and confirmed with the National Death Index. Dashes indicate cell size too small to report for confidentiality. HS, high school. *Died prior to end of the study.

With increasing baseline age, diabetes was still associated with significant reductions in the number of total and disability-free life-years, but the absolute difference in years lost between those with and without diabetes was less than at younger baseline age; the exceptions to this were that by ages 60, 70, and 80 years, IADL disabled years were no longer significantly different between groups, and by ages 70 and 80 years, the difference in ADL disabled years between people with and without diabetes was no longer significant.

Similar associations between diabetes status and disability-free and disabled years were observed among women. From age 50 years, women with diabetes had an average disability onset 6–7 years earlier than women without diabetes and lived 1–2 years longer in a disabled state. The largest difference was observed for mobility disability, where women with diabetes from age

Table 2—Incidence (annual % and 95% CI) of major sources of morbidity affecting disability-free life-years among U.S. men and women with and without diabetes

	Men		Women	
	Diabetes	No diabetes	Diabetes	No diabetes
Disability incidence				
Severe mobility loss	3.3** (3.0, 3.6)	1.7 (1.6, 1.8)	5.0** (4.6, 5.4)	2.6 (2.4, 2.7)
IADL	3.5** (3.2, 3.8)	2.2 (2.1, 2.4)	4.9** (4.6, 5.3)	2.7 (2.5, 2.8)
ADL	3.8** (3.5, 4.1)	2.3 (2.2, 2.4)	5.1** (4.8, 5.5)	2.9 (2.8, 3.0)
Mortality rate	4.1** (3.8, 4.4)	2.8 (2.7, 2.9)	4.0** (3.8, 4.3)	2.4 (2.3, 2.5)
Disability remission*				
Severe mobility loss	19.7** (17.6, 21.9)	23.4 (21.7, 25.1)	19.2 (17.3, 20.8)	20.9 (19.8, 22.0)
IADL	22.1 (20.2, 24.0)	23.5 (22.3, 24.8)	16.7** (15.1, 18.2)	18.3 (17.0, 19.5)
ADL	22.0** (20.3, 23.7)	25.3 (23.9, 26.6)	18.6** (17.3, 19.9)	22.4 (21.3, 23.5)

All models were adjusted for age, race/ethnicity, and sex. *Estimated among people with incident disability. **P value <0.001 between those with and without diabetes within sex.

Table 3—Number of disability-free and disabled years by disability type among U.S. men with and without diabetes

	Diabetes				No diabetes			
Disability type†	Disability onset (age [years])	Disability-free years (*n*)	Disabled years (*n*)	Total years (*n*)	Disability onset (age [years])	Disability-free years (*n*)	Disabled years (*n*)	Total years (*n*)
Mobility								
50	72.4*	22.4*	5.6*	28.0*	78.6	28.6	4.0	32.6
60	75.9*	15.9*	3.7*	19.6*	80.8	20.8	2.9	23.6
70	80.2*	10.2*	2.5*	12.8*	83.9	13.9	2.1	16.0
80	85.9*	5.9*	1.5*	7.4*	88.2	8.2	1.2	9.6
IADL								
50	72.2*	22.2*	5.8*	28.0*	77.5	27.5	5.0	32.6
60	75.7*	15.7*	3.9	19.6*	80.0	20.0	3.7	23.6
70	79.9*	9.9*	2.9	12.8*	83.1	13.1	2.9	16.0
80	85.4*	5.4*	2.0	7.4*	87.5	7.5	2.1	9.6
ADL								
50	71.4*	21.4*	6.6*	28.0*	77.3	27.3	5.3	32.6
60	75.4*	15.4*	4.2*	19.6*	80.0	19.7	3.7	23.6
70	79.8*	9.8*	3.0	12.8*	83.2	13.0	2.7	16.0
80	85.5*	5.5*	1.9	7.4*	87.7	7.5	1.9	9.6

*Indicates statistically significantly different between those with and without diabetes at $P < 0.05$. †From baseline age (years).

50 years lost 7 disability-free years and had 2.5 more disabled years compared with women without diabetes. Also similar to men, women with diabetes spent about one and a half times as many of their remaining years disabled (27–32% across the three disability definitions) as women without diabetes (20–22% across the three disability definitions). Similar to men, the diabetes versus nondiabetes differences in disability among women were significant and decreased with increasing age; the exceptions to this were that by ages 70 and 80 years, differences in IADL disabled years between all adults with and without diabetes were no longer significant, and by ages 70 and 80 years, the difference in ADL disabled years was no longer significant.

CONCLUSIONS

Using a large, nationally representative cohort of Americans aged 50 years and older, we found that diabetes is associated with a substantial deterioration of nondisabled years and that this is a greater number of years than the loss of longevity associated with diabetes. On average, a middle-aged adult with diabetes has an onset of disability 6–7 years earlier than one without diabetes, spends 1–2 more years with disability, and loses 7 years of disability-free life to the condition. Although other nationally representative studies have reported large reductions in complications (9) and mortality among the population with diabetes in recent decades (1), these studies, akin to our results, suggest that diabetes continues to have a substantial impact on morbidity and quality of remaining years of life.

The differences in disability-free and disabled life-years between people with

Table 4—Number of disability-free and disabled years by disability type among U.S. women with and without diabetes

	Diabetes				No diabetes			
Disability type†	Disability onset (age [years])	Disability-free years (*n*)	Disabled years (*n*)	Total years (*n*)	Disability onset (age [years])	Disability-free years (*n*)	Disabled years (*n*)	Total years (*n*)
Mobility								
50	71.6*	21.6*	9.6*	31.2*	78.6	28.6	7.1	35.7
60	75.8*	15.8*	6.7*	22.4*	81.2	21.2	5.3	26.5
70	80.4*	10.4*	4.6*	15.0*	84.5	14.5	3.9	18.3
80	86.1*	6.1*	2.8*	8.9*	88.7	8.7	2.5	11.2
IADL								
50	72.7*	22.7*	8.5*	31.2*	78.3	28.3	7.3	35.7
60	76.5*	16.5*	6.0*	22.4*	80.9	20.9	5.6	26.5
70	80.5*	10.5*	4.5	15.0*	83.9	13.9	4.4	18.3
80	85.8*	5.8*	3.0	8.9*	88.0	8.0	3.2	11.2
ADL								
50	71.3*	21.3*	9.9*	31.2*	77.6	27.6	8.0	35.7
60	75.8*	15.8*	6.6*	22.4*	80.7	20.7	5.8	26.5
70	80.3*	10.3*	4.7	15.0*	83.9	13.9	4.4	18.3
80	85.8*	5.8*	3.0	8.9*	88.2	8.2	3.0	11.2

*Indicates statistically significantly different between those with and without diabetes at $P < 0.05$. †From baseline age (years).

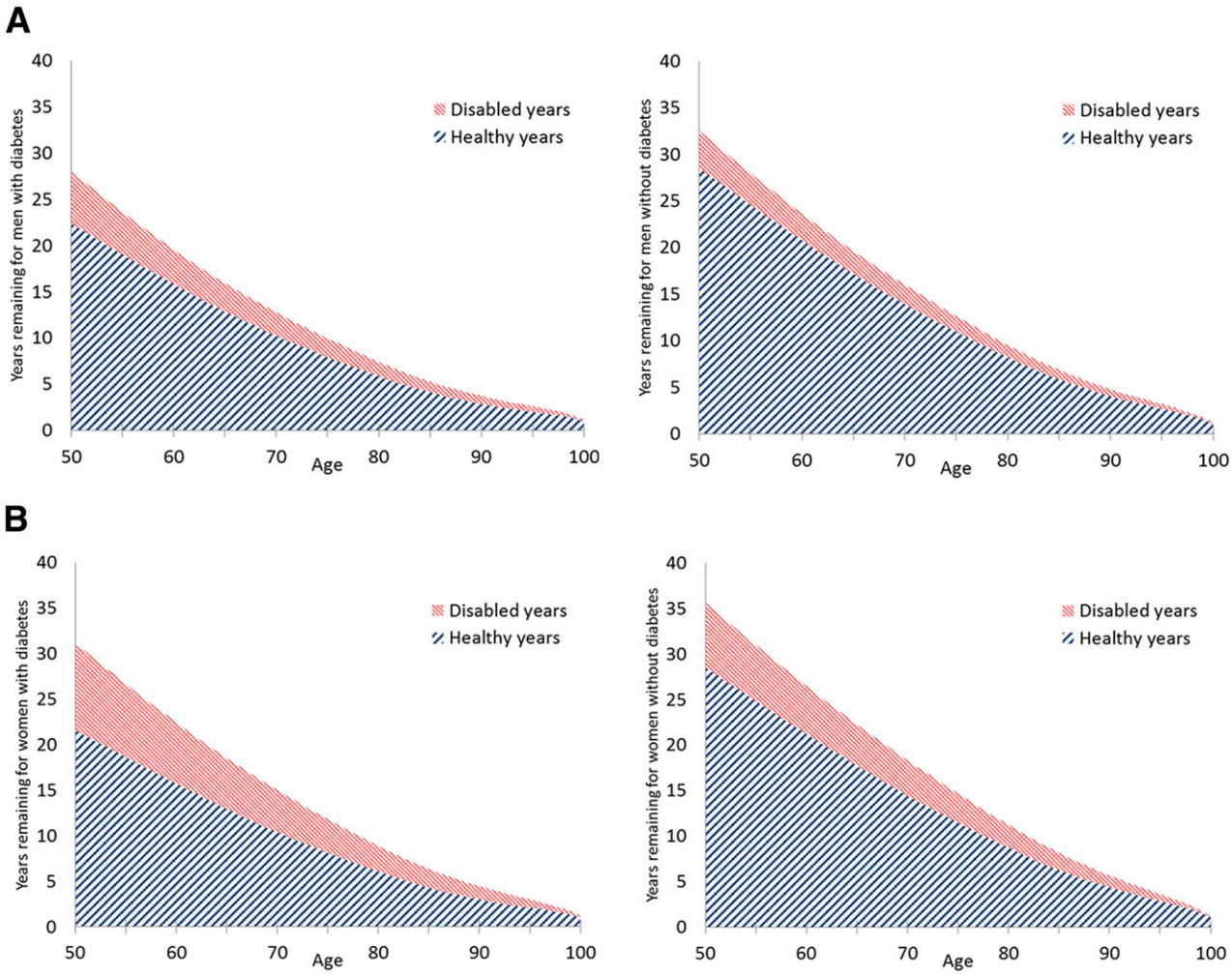

Figure 2—*A*: Disability-free and mobility loss disability life-years remaining by age for men with and without diabetes. *B*: Disability-free and mobility loss disability life-years remaining by age for women with and without diabetes.

and without diabetes were driven by several factors. First, people with diabetes had considerably higher disability incidence at all ages, leading to a younger age of disability onset and more years spent in a disabled state. Second, once a person with diabetes became disabled, they were less likely to revert to regular functioning, therein increasing the number of years with disability. Third, diabetes and disability were each associated with increased mortality, which has a modest contradictory effect on the first two factors (i.e., incidence and remission of disability), as the increased mortality reduces the number of years spent in both a healthy and unhealthy state. Given this combination of factors, improving the number of disability-free life-years over time will depend upon identification of interventions that can reduce disability and increase remission at least as much as mortality rates are being reduced.

The association of diabetes with disability has been found to be multifactorial (4,16,17). Previous studies have suggested that coronary heart disease (CHD), lower extremity arterial disease, and obesity explain a particularly large proportion of the difference in disability between people with and without diabetes (4,16,18). However, these factors are likely to vary by sex, and numerous other factors, including physical inactivity, inflammatory factors, insulin resistance, and diabetes-related complications (such as neuropathy, kidney disease, stroke, hyperglycemia, and hypoglycemia), may intervene. Our findings related to mortality are also consistent with national estimates that among older adults, diabetes is associated with 60–70% increases in mortality rates and 4.6–5.7 years of reduced life spans (1). We are not aware of previous estimates of the rate of remission from disability, and it is noteworthy that people with diabetes were less likely to recover from disability, which could also be an indication that their levels of disability were somewhat more severe (19). Several recent developments in the epidemiology of diabetes complications from intervention studies have made disability-free and disabled years increasingly important metrics for assessing the impact of diabetes. Although rates of complications have declined, the extra years of life spent with diabetes and cumulative morbidity that follows could erode the quality of those extra years of life. Also,

older adults are the fastest growing segment of the population with diabetes, raising the importance of physical disability and other geriatric syndromes that may result from or be associated with diabetes (20).

In addition, and perhaps most importantly, there is increasing evidence that disability is modifiable with lifestyle interventions (14,21). The Look AHEAD (Action for Health in Diabetes) Study found that intensive lifestyle intervention results in a 50% reduced incidence of physical disability among adults with diabetes (14). Similarly, the general effectiveness of similar interventions among older and overweight adults with osteoarthritis has found that structured exercise and moderate weight loss programs can improve functional status (22). In theory, many other aspects of risk factor modification initiated through primary care, including glycemic and blood pressure control, could also affect disability risk, but there has been little evaluation of the effects of such interventions on disability. We did not adjust for other risk factors for morbidity and mortality, such as hypertension, obesity, CHD, and stroke, which were largely unbalanced among people with and without diabetes at baseline, so that we could determine the overall differences in remaining disability life-years and disability-free life-years between those with and without diabetes. However, incidence of disability, remission from disability, and mortality changed only slightly when adjusting for prevalent CVD. Assessing the contribution of the specific related reason for the differences is warranted.

There are several limitations to this study. First, diabetes was based on self-report, which means that people with undiagnosed diabetes were classified as not having diabetes; if their disability risk is higher than adults truly without diabetes, the difference in disability-free life-years between adults with and without diabetes in our analyses would be underestimated. Our disability estimates are also based on subjective reports, for which interpretation and agreement with objective measurements could vary by diabetes status. Third, we could not distinguish between secondary diagnosis of diabetes and primary diagnosis due to the self-reporting of the diagnosis. Fourth, although the incident cases of diabetes were accounted for in the age-specific probabilities input into the Markov models, those models were designed to compare people with prevalent diabetes and those without prevalent diabetes who do not develop diabetes in their lifetime. Thus, the final estimates should be interpreted with the assumption that diabetes status did not change at the specified age. Although the majority of people without diabetes at age 70 years will not develop diabetes, this ignores a substantial minority of people who become incident diabetes cases after baseline. The group of people who go on to develop diabetes later are likely to have a number of disability-free and total years remaining that is intermediate between the groups with and without diabetes. Finally, our estimates did not adjust for potential intervening and confounding factors such as obesity, CHD, and lower extremity disease. However, the objective here was to quantify the basic differences in disability-free life-years by diabetes status occurring in the U.S. population.

Despite these limitations, these analyses are the first-ever quantification of disability-free and disabled years experienced after age 50 years for the U.S. population with diabetes, which incorporates information on disability incidence, disability remission, and mortality across older ages. As such, these findings are an important baseline from which to monitor the success of future clinical and public health efforts to reduce diabetes and its complications as well as interventions aimed directly at reducing disability.

Acknowledgments. The authors thank Tony Pearson-Clarke, Centers for Disease Control and Prevention, for help with editing.

Duality of Interest. X.Z. is currently working for Merck. No other potential conflicts of interest relevant to this article were reported.

Author Contributions. B.H.B. conducted the data analysis, researched data, contributed to discussion, and wrote, reviewed, and edited the manuscript. J.L., X.Z., and E.W.G. researched data, contributed to discussion, and wrote, reviewed, and edited the manuscript. M.K.A., T.J.T., and Y.J.C. researched data, contributed to discussion, and reviewed and edited the manuscript. B.H.B. is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Prior Presentation. Parts of this study were presented in abstract form at the 75th Scientific Sessions of the American Diabetes Association, Boston, MA, 5–9 June 2015.

References

1. Gregg EW, Zhuo X, Cheng YJ, Albright AL, Narayan KM, Thompson TJ. Trends in lifetime risk and years of life lost due to diabetes in the USA, 1985-2011: a modelling study. Lancet Diabetes Endocrinol 2014;2:867–874
2. Geiss LS, Wang J, Cheng YJ, et al. Prevalence and incidence trends for diagnosed diabetes among adults aged 20 to 79 years, United States, 1980-2012. JAMA 2014;312:1218–1226
3. Nathan DM. Long-term complications of diabetes mellitus. N Engl J Med 1993;328:1676–1685
4. Gregg EW, Beckles GL, Williamson DF, et al. Diabetes and physical disability among older U.S. adults. Diabetes Care 2000;23:1272–1277
5. Wong E, Backholer K, Gearon E, et al. Diabetes and risk of physical disability in adults: a systematic review and meta-analysis. Lancet Diabetes Endocrinol 2013;1:106–114
6. Lu FP, Lin KP, Kuo HK. Diabetes and the risk of multi-system aging phenotypes: a systematic review and meta-analysis. PLoS One 2009;4:e4144
7. Guralnik JM, Fried LP, Salive ME. Disability as a public health outcome in the aging population. Annu Rev Public Health 1996;17:25–46
8. World Health Organization. *Health Systems Performance Assessment: D*ebates*, Methods and Empricism*. Murray CJL, Evans DB, Eds. Geneva, Switzerland, World Health Organization, 2003
9. Gregg EW, Li Y, Wang J, et al. Changes in diabetes-related complications in the United States, 1990-2010. N Engl J Med 2014;370:1514–1523
10. Gregg EW, Cheng YJ, Saydah S, et al. Trends in death rates among U.S. adults with and without diabetes between 1997 and 2006: findings from the National Health Interview Survey. Diabetes Care 2012;35:1252–1257
11. Juster FT, Suzman R. An overview of the health and retirement study. J Hum Resour 1995;40:S7–S56
12. University of Michigan. Health and Retirement Study [Internet], 2011. Available from http://hrsonline.isr.umich.edu/sitedocs/sampleresponse.pdf. Accessed 20 November 2015
13. RAND. *RAND HRS Data, Version N.* Santa Monica, CA, RAND Corp., 2014
14. Rejeski WJ, Ip EH, Bertoni AG, et al.; Look AHEAD Research Group. Lifestyle change and mobility in obese adults with type 2 diabetes. N Engl J Med 2012;366:1209–1217
15. Ross S. *Introduction to Probability Models*. Oxford, U.K., Academic Press, 2014
16. Volpato S, Blaum C, Resnick H, Ferrucci L, Fried LP, Guralnik JM; Women's Health and Aging Study. Comorbidities and impairments explaining the association between diabetes and lower extremity disability: The Women's Health and Aging Study. Diabetes Care 2002;25:678–683
17. Kalyani RR, Saudek CD, Brancati FL, Selvin E. Association of diabetes, comorbidities, and A1C with functional disability in older adults: results from the National Health and Nutrition Examination Survey (NHANES), 1999-2006. Diabetes Care 2010;33:1055–1060
18. Gregg EW, Mangione CM, Cauley JA, et al.; Study of Osteoporotic Fractures Research

Group. Diabetes and incidence of functional disability in older women. Diabetes Care 2002;25:61–67
19. Hardy SE, Gill TM. Recovery from disability among community-dwelling older persons. JAMA 2004;291:1596–1602
20. Cheng YJ, Imperatore G, Geiss LS, et al. Secular changes in the age-specific prevalence of diabetes among U.S. adults: 1988-2010. Diabetes Care 2013;36:2690–2696
21. Pahor M, Guralnik JM, Ambrosius WT, et al.; LIFE study investigators. Effect of structured physical activity on prevention of major mobility disability in older adults: the LIFE study randomized clinical trial. JAMA 2014;311:2387–2396
22. Messier SP. Physical activity and weight loss interventions in older adults with knee osteoarthritis. N C Med J 2007;68:436–438