Compression of disability between two birth cohorts of US adults with diabetes, 1992-2012: a prospective longitudinal analysis

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Summary

Background The life expectancy of the average American with diabetes has increased, but the quality of health and functioning during those extra years are unknown. We aimed to investigate the net effect of recent trends in diabetes incidence, disability, and mortality on the average age of disability onset and the number of healthy and disabled years lived by adults with and without diabetes in the USA. We assessed whether disability expanded or was compressed in the population with diabetes and compared the findings with those for the population without diabetes in two consecutive US birth cohorts aged 50–70 years.

Methods In this prospective longitudinal analysis, we analysed data for two cohorts of US adults aged 50–70 years from the Health and Retirement Study, including 1367 people with diabetes and 11 414 without diabetes. We assessed incident disability, remission from disability, and mortality between population-based cohort 1 (born 1931–41, follow-up 1992–2002) and cohort 2 (born 1942–47, follow up 2002–12). Disability was defined by mobility loss, difficulty with one or more instrumental activities of daily living, and difficulty with one or more activities of daily living. We entered age-specific probabilities representing the two birth cohorts into a five-state Markov model to estimate the number of years of disabled and disability-free life and life-years lost by age 70 years.

Findings In people with diabetes, compared with cohort 1 (n=1067), cohort 2 (n=300) had more disability-free and total years of life, later onset of disability, and fewer disabled years. Simulations of the Markov models suggest that in men with diabetes aged 50 years, this difference between cohorts amounted to a 0·8–2·3 year delay in disability across the three metrics (mobility, 63·0 [95% CI 62·3–63·6] to 64·8 [63·6–65·7], p=0·01; instrumental activities of daily living, 63·5 [63·0–64·0] to 64·3 [63·0–65·3], p=0·24; activities of daily living, 62·7 [62·1–63·3] to 65·0 [63·5–65·9], p<0·0001) and 1·3 fewer life-years lost (ie, fewer remaining life-years up to age 70 years; from 2·8 [2·5–3·2] to 1·5 [1·3–1·9]; p<0·0001 for all three measures of disability). Among women with diabetes aged 50 years, this difference between cohorts amounted to a 1·1–2·3 year delay in disability across the three metrics (mobility, 61·3 [95% CI 60·5–62·1] to 63·2 [61·5–64·5], p=0·0416; instrumental activities of daily living, 63·0 [62·4–63·7] to 64·1 [62·7–65·2], p=0·16; activities of daily living, 62·3 [61·6–63·0] to 64·6 [63·1–65·6], p=0·0001) and 0·8 fewer life-years lost by age 70 years [1·0 [0·7–2·2] to 1·1 [0·9–1·5]; p<0·0001 for all three measures of disability]. Parallel improvements were gained between cohorts of adults without diabetes (cohort 1, n=8687; cohort 2, n=2727); within both cohorts, those without diabetes had significantly more disability-free years than those with diabetes (p<0·0001 for all comparisons).

Interpretation Irrespective of diabetes status, US adults saw a compression of disability and gains in disability-free life-years. The decrease in disability onset due to primary prevention of diabetes could play an important part in achieving longer disability-free life-years.

Funding US Department of Health & Human Services and the US Centers for Disease Control and Prevention.

Introduction

Incidence and prevalence of both types of diabetes have more than doubled in the past 20 years in almost all demographic subgroups of the US population.1 These trends have been accompanied by large reductions in mortality that have increased the number of years spent with diabetes for the average person and for the population overall.7 As a result, the lifetime probability of diabetes has also increased substantially, and is now about 40% for both men and women in the USA.1 Although yearly rates of several diabetes-related complications decreased during this period,7 the effect of living more years of life with diabetes on the quality of those extra years of life remains unclear.

People with diabetes have double the incidence of physical disability, and the few estimates of trends in disability prevalence from surveys in the population with diabetes suggest that there has been no change in the past 20 years.7 Thus, whether recent clinical and public health efforts have been successful in compressing disability (ie, reducing the number of years with disability) while increasing lifespans remains unclear. Compression of disability occurs if the delay in onset of disability is greater than the increase in life expectancy. As a result, the average time spent in an active state (ie, disability free) will increase, both in absolute terms and as a proportion of total life expectancy.7 Alternatively, expansion of disability...
occurs if the gain in total life expectancy is associated with longer periods of disability, implying that medical advances have extended life for those suffering from disabling diseases, without changing the age of disability onset or the number of healthy years of life.

Because diabetes is one of the most common disorders associated with increasing rather than decreasing prevalence, we assessed whether disability expanded or was compressed in the population with diabetes and compared the findings with those for the population without diabetes in two consecutive US birth cohorts aged 50–70 years.

Methods
We analysed data from the Health and Retirement Study (HRS), a population-based, prospective health interview survey of a cohort of adults aged 50 years and older in the USA. These survey data were collected every 2 years from 1992 to 2012. We used birth cohorts to assess the net effect of recent trends in diabetes incidence, disability, and mortality. The first cohort (cohort 1) included 9754 respondents (8687 without diabetes and 1067 with diabetes) born between 1942 and 1947, followed up until 2002. The second cohort (cohort 2) included 3027 respondents (2727 without diabetes and 300 with diabetes) born between 1931 and 1941 and surveyed in 1992 (baseline) and every 2 years until 2002. The second cohort (cohort 2) included 3027 respondents (2727 without diabetes and 300 with diabetes) born between 1942 and 1947 and surveyed in 2002 (baseline) and every 2 years up to 2012. Baseline response rates during the study ranged from 70% for cohort 2 to 81% for cohort 1, and the follow-up response rates ranged from 84% to 89% for cohort 1 and from 87% to 91% for cohort 2. The HRS is sponsored by the National Institute on Aging and conducted 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.

Added value of this study
We are not aware of previous studies examining trends in healthy and disabled life-years from birth cohorts within a national sample. In this comparison of disability and mortality between US adults born in the 1940s versus the 1930s, individuals with diabetes are generally becoming disabled later and living more disability-free years by the age of 70 years. These improvements in health status (which suggest a compression of morbidity), affected adults both with and without diabetes, both sexes, and were seen across different disability definitions.

Implications of all the available evidence
Available evidence related to compression of disability in adults with diabetes suggests that healthy lifestyles that help to maintain a healthy weight and lean-to-fat ratios are effective in reducing disability in adults with diabetes. Similarly, evidence-based approaches to prevent diabetes and cardiovascular disease through both lifestyle modification and preventive care are also important for continued reduction in diabetes-related morbidity and disability.
Articles

Figure: Markov model for disease progression for a specific sex and diabetes status cohort

explanation of how these variables were constructed has been published elsewhere. Activities of daily living-related disability was defined as having difficulty in performing at least one of the following tasks: walking across a room, getting in and out of bed, dressing, bathing, and eating.

Deaths were confirmed from the National Death Index and the Social Security Death Index. To obtain data for the health condition of deceased respondents before their death, proxies for the respondents were interviewed. Next of kin were interviewed if a respondent had died, and if no next of kin were contactable, a friend was contacted. If the participant’s financial estate was not settled at the time of the exit interview, a post-exit contact was made. If the participant died within 1 year of disability onset. Based on data from HRS, individuals can have several episodes of short-term disability over a lifetime.

To understand the effect of diabetes on 20 year disability outcomes, we estimated and compared outcomes with those of individuals of the same ages without diabetes who remained without diabetes until death. The CIs of the 20 year estimates were estimated from Monte Carlo simulation, with 10 000 random draws of age-specific and sex-specific estimates for each sex from the underlying parametric distributions derived from HRS data.

Role of the funding source
This study was funded by the US Department of Health & Human Services and the US Centers for Disease Control and Prevention. The funder of the study was involved in the study design, data collection, data analysis, data interpretation, and writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results
Cohort 1 included 9754 respondents, 1067 of whom had a diagnosis of diabetes, and 8687 of whom did not; cohort 2 included 3027 respondents, 300 of whom had a diabetes diagnosis and 2727 of whom did not. Age-adjusted diabetes prevalence did not differ between respondents born in the 1940s and those born in the 1930s (9·9%, 95% CI 9·3–10·4 vs 9·2%, 8·1–10·4). However, BMI, educational attainment, and age each differed by cohort (table 1). In participants with and without diabetes, the baseline prevalence of history of stroke and self-reported high blood pressure increased significantly between the first and second cohorts (p<0·05). In participants without diabetes, the prevalence of current smokers declined significantly from 27·2% (95% CI 25·8–28·7) to 21·2% (18·8–23·8).

The proportions of respondents with prevalent difficulty with activities of daily living and mobility loss at baseline were significantly higher in those with diabetes than in those without. However, the prevalence of mobility loss and difficulty with activities of daily living decreased significantly among those in cohort 2 compared with cohort 1, for participants with and without diabetes. Differences in difficulty with instrumental activities of daily living are not reported at baseline. 

Statistical analysis
We compared baseline characteristics between cohort 1 and cohort 2, in respondents with diabetes and in those without diabetes, using $\chi^2$ statistics with 95% CIs and a significance cutoff value of less than 0·05. We did logistic regression using generalised estimating equations to obtain annual cutoff value of less than 0·05. We did logistic regression status by age group and also to determine the age-specific incidence of disability and mortality according to diabetes wave or previous waves. In this method, logistic regression loss of follow-up or non-reporting by the respondent in that to reduce bias related to missing data, whether it was due to remission estimates. We used inverse probability weighting prevalent disability were excluded from the incidence and remission estimates. We used inverse probability weighting to reduce bias related to missing data, whether it was due to loss of follow-up or non-reporting by the respondent in that wave or previous waves. In this method, logistic regression is used to determine the predicted value of having complete data; weights are the inverse of the probability of having complete data. To obtain these estimates, data were modelled with Stata (version 13).

Markov model with a 20 year time horizon
We developed a discrete-time Markov simulation model with annual transition. The model was applied to two populations, one for those with diabetes and the other for those who remained diabetes free. The models predict disability-related outcomes from ages 50–70 years, using probability estimates of disability, mortality, and remission (figure). During each 1 year interval, individuals can move from and to one of the five states: not disabled, short-term disability, not disabled but with previous disability, long-term disability, and death. Because of the high recovery rates recorded in the data, we created two bridge states of short-term disability and not being disabled but had disability history. Short-term disability is defined as being disabled for less than 1 year, by contrast with long-term disability defined as remaining disabled for more than 1 year. In the model, individuals with short-term disability revert to not being disabled, die, or continue to be disabled after 1 year of disability onset. Based on data from HRS, individuals can have several episodes of short-term disability over a lifetime.
because of the differences in measurements in 1992 from the rest of the interview years.

We noted some significant differences between cohorts within both age groups (ie, 50–60 years and 61–70 years) for incidence of disability, recovery from disability, and mortality by disability status, although it varied by diabetes status (p<0·05; table 2). In cohort 2 compared with cohort 1, incidence of mobility loss, instrumental activities of daily living-related disability, and activities of daily living-related disability decreased in those aged 50–60 years and 61–70 years in participants with and without diabetes. Recovery from incident disability increased significantly among both age groups for all disability types, with the exception of mobility loss among those with diabetes aged 50–60 years.

In men with diabetes aged 50–60 years, we noted a significant decrease in life-years lost (ie, decrease in total remaining life-years up to age 70 years) between the two cohorts (–1·3 years, 95% CI –1·7 to –0·8; from 2·8 to 1·5 for men aged 50 years; and –0·3 years, –0·6 to 0·0; from 1·6 to 1·3 for men aged 60 years), with a delay in the age of onset of disability from age 60 years for all disability types and from age 50 years for mobility loss and activities of daily living-related disability (table 3; appendix). From age 60 years, men with diabetes in cohort 2 had later age of disability onset for all three disability types and from age 50 years for mobility loss and activities of daily living-related disability (table 3; appendix). From age 60 years, men with diabetes in cohort 2 had later age of disability onset for all three disability types and from age 50 years for mobility loss and activities of daily living-related disability (table 3; appendix). 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From age 60 years, men with diabetes in cohort 2 had later age of disability onset for all three disability types and from age 50 years for mobility loss and activities of daily living-related disability (table 3; appendix).

Similar to men with diabetes, in cohort 2 compared with cohort 1, women without diabetes had a postponement of disability onset, along with equivalent increases in disability-free years of life and a reduction in years of disabled life from age 60 to age 70 years. Comparing cohort 2 with cohort 1, women with diabetes from age 50 years had significantly fewer life-years lost (across disability types), a delay in onset of disability age for mobility loss and activities of daily living-related disability, and no significant change in disabled years for any of the disability types. Women with diabetes from age 60 in cohort 2 had later age of disability onset for all three disability types (1·2–1·6 years later), more disability-free years (1·2–1·6 more years), and fewer life-years lost (across disability types) compared with cohort 1.
### Annual incidence of disability and mortality, by diabetes status

#### Table 2: Annual incidence of disability and mortality, by diabetes status

<table>
<thead>
<tr>
<th>Diabetes group</th>
<th>Cohort 1</th>
<th>Cohort 2</th>
<th>p value 50–60 years</th>
<th>p value 61–70 years</th>
<th>p value Total</th>
<th>p value Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50–60 years</td>
<td>61–70 years</td>
<td>Total</td>
<td>50–60 years</td>
<td>61–70 years</td>
<td>Total</td>
</tr>
<tr>
<td><strong>Incidence of disability, stratified by age group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mobility loss</td>
<td>6.7 (5.8–7.7)</td>
<td>7.0 (6.2–7.8)</td>
<td>6.7 (6.0–7.4)</td>
<td>4.7 (3.5–5.9)</td>
<td>0.0035</td>
<td>3.5 (2.9–4.1)</td>
</tr>
<tr>
<td>Instrumental activities</td>
<td>5.7 (4.8–6.6)</td>
<td>6.3 (5.6–7.7)</td>
<td>5.9 (5.3–6.5)</td>
<td>4.3 (3.3–5.3)</td>
<td>0.0522</td>
<td>2.9 (2.3–3.6)</td>
</tr>
<tr>
<td>Activities of daily living</td>
<td>6.8 (5.9–7.7)</td>
<td>7.9 (7.3–8.7)</td>
<td>7.0 (6.3–7.8)</td>
<td>4.4 (3.4–5.3)</td>
<td>0.0005</td>
<td>3.2 (2.6–3.8)</td>
</tr>
<tr>
<td><strong>Incidence of recovery from disability, stratified by age group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mobility loss</td>
<td>18.4 (11.8–24.9)</td>
<td>15.6 (13.1–18.1)</td>
<td>15.9 (13.6–18.2)</td>
<td>23.9 (18.7–29.2)</td>
<td>0.17</td>
<td>23.5 (20.0–26.9)</td>
</tr>
<tr>
<td>Instrumental activities</td>
<td>15.3 (9.9–20.6)</td>
<td>17.3 (14.4–20.2)</td>
<td>17.3 (14.7–20.1)</td>
<td>26.3 (22.4–30.3)</td>
<td>0.0025</td>
<td>26.7 (22.6–30.8)</td>
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<tr>
<td>Activities of daily living</td>
<td>12.4 (6.6–18.3)</td>
<td>15.8 (13.5–18.2)</td>
<td>15.7 (13.5–18.0)</td>
<td>24.4 (19.1–29.8)</td>
<td>0.0036</td>
<td>26.1 (23.5–28.7)</td>
</tr>
<tr>
<td><strong>Mortality by incident disability</strong></td>
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</tr>
<tr>
<td>Mobility loss</td>
<td>2.9 (2.0–3.8)</td>
<td>5.8 (4.6–7.1)</td>
<td>4.5 (3.8–5.3)</td>
<td>1.4 (0.2–2.7)</td>
<td>0.07</td>
<td>5.3 (3.8–7.0)</td>
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<tr>
<td>Instrumental activities</td>
<td>3.0 (1.4–4.6)</td>
<td>5.4 (4.3–6.5)</td>
<td>4.4 (3.6–5.2)</td>
<td>1.9 (0.0–4.2)</td>
<td>0.41</td>
<td>4.3 (2.6–6.0)</td>
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<tr>
<td>Activities of daily living</td>
<td>2.4 (1.4–3.4)</td>
<td>5.7 (4.6–6.8)</td>
<td>4.3 (3.6–5.0)</td>
<td>1.1 (0.0–2.5)</td>
<td>0.0545</td>
<td>5.3 (3.6–7.0)</td>
</tr>
</tbody>
</table>

Data are estimates of the annual incidence per 100 person-years, adjusted for sex (95% CI), unless otherwise indicated. p values are for comparison between cohort 1 and cohort 2, within age group and disability status. Estimates are the annual incidence per 100 person-years, adjusted for sex.

Disability years (1–1.4 fewer years) than those in cohort 1 (table 4). We noted similarly encouraging findings in women without diabetes, who also had significant increases in non-disabled years and decreases in disabled years.

All differences between those with diabetes and without diabetes within each cohort by sex, age, and disability type were significantly different (p<0.0001).

### Discussion

In this comparison of disability and mortality between US adults born in the 1940s versus the 1930s, people with diabetes are generally becoming disabled later and living more disability-free years by age 70 years. These improvements in health status, which suggest a compression of morbidity, affected adults both with and without diabetes, both sexes, and were seen across different disability definitions. We noted some differences by sex—men had a decrease in life-years lost from ages 50 and 60 years, whereas women only had a decrease in life-years lost from age 50 years.

The difference in healthy years over time was driven by three factors in our model: mortality, incident disability, and remission from disability. With the exception of disability defined by instrumental activities of daily livings, disability-free life-years increased in all groups because mortality risk and disability risk decreased simultaneously, along with an increase in remission from disability. However, the population without diabetes in the first cohort had a greater number of healthy years and later disability onset than the population with diabetes. Even though they had less scope for improvement than those with diabetes, those without diabetes in cohort 2 improved significantly compared with cohort 1 in terms of life-years lost for all disability types and disability-free years for all disability types (with...
the exception of instrumental activities of daily living-related disability from age 50 years) for men and women. Although our analyses could not assess the factors that might account for the compression of disability in the US population with diabetes, our findings are consistent with the concurrent improvements in the management and control of cardiovascular disease risk factors and glycaemic control, as well as improved processes of care and reductions in diabetes-related complications and other chronic disorders, such as cardiovascular disease.13–15 Decreases in mortality in people with diabetes has been reported previously in the USA1 and elsewhere,9 but such decreases can sometimes have the effect of suppressing reductions in the prevalence of chronic diseases, as was shown by the increase rather than decrease in prevalence of stroke and heart disease over time in the population with diabetes.

According to findings reported by Martin and colleagues,7 from 1997 to 2007, diabetes increasingly contributed to disability in people aged 50–64 years. However, that study assessed the prevalence of disability, unlike our study, which excluded prevalent disability cases and assessed incidence of disability and remission, which are different metrics. Other reported causes of difficulty with a physical function included depression, heart problems, hypertension, and weight problems. Although our analyses did not assess factors modifying the changes in disability, morbidity, and healthy life-years, our analysis of baseline characteristics suggests that increases in BMI, prevalent hypertension, and history of stroke are all plausible factors for the gap between those with diabetes and those without. Compared with non-diabetic adults, in adults with diabetes, class II and class III obesity increased more between the two cohorts; these categories of obesity

<table>
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<tr>
<td><strong>Disability-free years</strong></td>
<td><strong>Disability years</strong></td>
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<tr>
<td>Mobility loss</td>
<td></td>
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<tr>
<td>50 years</td>
<td>13·0 (12·3–13·6)</td>
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<tr>
<td>60 years</td>
<td>6·8 (6·5–7·0)</td>
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<tr>
<td>Instrumental activities of daily living-related disability</td>
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<tr>
<td>50 years</td>
<td>13·5 (13·0–14·0)</td>
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<tr>
<td>60 years</td>
<td>6·9 (6·7–7·1)</td>
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<tr>
<td>Activities of daily living-related disability</td>
<td></td>
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<tr>
<td>50 years</td>
<td>12·7 (12·1–13·3)</td>
</tr>
<tr>
<td>60 years</td>
<td>6·4 (6·2–6·6)</td>
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<tr>
<td>No diabetes</td>
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<td>Mobility loss</td>
<td></td>
</tr>
<tr>
<td>50 years</td>
<td>17·0 (16·7–17·3)</td>
</tr>
<tr>
<td>60 years</td>
<td>8·6 (8·5–8·7)</td>
</tr>
<tr>
<td>Instrumental activities of daily living-related disability</td>
<td></td>
</tr>
<tr>
<td>50 years</td>
<td>16·9 (16·6–17·2)</td>
</tr>
<tr>
<td>60 years</td>
<td>8·5 (8·4–8·6)</td>
</tr>
<tr>
<td>Activities of daily living-related disability</td>
<td></td>
</tr>
<tr>
<td>50 years</td>
<td>16·4 (16·1–16·7)</td>
</tr>
<tr>
<td>60 years</td>
<td>8·3 (8·2–8·4)</td>
</tr>
</tbody>
</table>

Data are n (95% CI).

Table 3: Estimated healthy and disabled years in US men with and without diabetes, from baseline age to 70 years
Table 4: Estimated healthy and disabled years among US women with and without diabetes, from baseline age to 70 years

<table>
<thead>
<tr>
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<tr>
<td></td>
<td>Disability-free</td>
<td>Disabled years</td>
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<td>Mobility loss</td>
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<tr>
<td>50 years</td>
<td>11.3 (10.5–11.3)</td>
<td>6.8 (6.0–7.6)</td>
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<tr>
<td>60 years</td>
<td>6.2 (6.0–6.5)</td>
<td>2.7 (2.5–3.0)</td>
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<tr>
<td>Instrumental activities of daily living-related disability</td>
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<tr>
<td>50 years</td>
<td>13.0 (12.4–13.7)</td>
<td>5.1 (4.4–5.8)</td>
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<tr>
<td>60 years</td>
<td>6.8 (6.5–7.0)</td>
<td>2.2 (1.9–2.4)</td>
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<td>Activities of daily living-related disability</td>
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<tr>
<td>50 years</td>
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<td>60 years</td>
<td>6.3 (6.0–6.6)</td>
<td>2.6 (2.4–2.9)</td>
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Diabetes

Estimated healthy and disabled years among US women with and without diabetes, from baseline age to 70 years.

No diabetes

Estimated healthy and disabled years among US women with and without diabetes, from baseline age to 70 years.

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carry, respectively, 1-4 and 1-8 times the prevalence of disability compared with normal weight people older than 65 years. Stroke prevalence, which increased 4-7 percentage points over time in the population with diabetes, has been associated with a 50% increased risk of disability. Although rates of diabetes-related complications have fallen substantially in the past two decades, the absolute numbers of adults with diabetes who have complications persists because of the continued increase in the prevalence of diabetes.

Our findings show that in people with diabetes, by age 70 years, an increase in years of total life remaining combined with postponement or recovery from disability results in a greater number of healthy life-years in the later birth cohort. This finding could be related to increases in the number of people following a healthy lifestyle, which prolongs life expectancy and postpones disability. However, the increase in healthy life-years might have been due to increased health-care utilisation, and in some cases, expensive procedures. For example, from 1999 to 2008, the rate of knee replacements increased substantially (tripling for people aged 45–64 years and doubling for those ≥65 years) in the USA, which substantially reduces pain and improves function in people with severe knee problems. Future studies should focus on how other components of health care, whether efficient, low-expense primary care, or advanced treatments for other chronic disorders such as cardiovascular diseases, cancers, and musculoskeletal disorders, are affecting disability rates.

Our study has several limitations. First, our discrete-time Markov model assumed that participants without diabetes would remain diabetes free until death. However, the age-specific probabilities used as input into the model included incident cases of diabetes. By using 1 year transition cycle simulations, the age-specific probabilities might have been due to increased health-care utilisation, and in some cases, expensive procedures. For example, from 1999 to 2008, the rate of knee replacements increased substantially (tripling for people aged 45–64 years and doubling for those ≥65 years) in the USA, which substantially reduces pain and improves function in people with severe knee problems. Future studies should focus on how other components of health care, whether efficient, low-expense primary care, or advanced treatments for other chronic disorders such as cardiovascular diseases, cancers, and musculoskeletal disorders, are affecting disability rates.

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Data are n (95% CI).
probabilities by diabetes accounted for the incident diabetes cases (ie, those who were not disabled before diabetes diagnosis, because those who were previously disabled would have been censored after disability onset). Second, our Markov model does not allow for stratification of the transitions by multiple factors, such as obesity, physical activity, high blood pressure, cardiovascular disease, education, and depression, which could account for many of the reported differences between populations with and without diabetes. Findings of a separate study of HRS data showed that lower wealth and education were associated with higher levels of disability and earlier onset of disability.21 Thus, the greater educational attainment achieved in cohort 2 might be associated with the compression of disability and later onset of disability. Third, our study was limited by an absence of data beyond age 70 years in cohort 2, which led us to restrict analyses of both cohorts to the 50–70 years age range to permit a valid comparison of the two cohorts. Thus, our analyses should be regarded as examination of fairly early disability, as opposed to more common age-related disability that occurs between age 70 years and death. Fourth, data at diabetes diagnosis were not available for cohort 2 at baseline. Because cohort 2 was on average 1 year older than cohort 1 and the prevalence of diabetes was greater in cohort 2, patients in cohort 2 probably had a longer duration of diabetes, which might have affected the onset of disability. Fifth, disability measures were self-reported difficulty with performing tasks, which might not be regarded as a strict definition of disability, but we used four or five tasks to define severe mobility loss to lessen potential bias. Although our measurement of instrumental activities of daily living differed at baseline for cohort 1, there was consistency across the remaining interview years; therefore, this difference should pose minimum bias in assessing incidence and remission of instrumental activities of daily living-related disability. Finally, our study design does not allow the effects of period differences to be separated from cohort differences; there could be changes attributable to the year or period (eg, changes in technology that would lessen disability or changes in the environment that might affect disability) but we could not tease out factors from actual cohort differences. However, to our knowledge, our study is the first to quantify whether later cohorts with diabetes experience a compression of morbidity relative to earlier cohorts.

Few studies have quantified healthy and disabled life-years in adults with diabetes.22–24 Results of a previous analysis of HRS data showed that people with diabetes become disabled 6–7 years earlier than people without diabetes. Estimates from the 2013 Global Burden of Disease Study (GBD) suggest that diabetes is the seventh leading cause of increased years with disability.25 However, the GBD estimate of disabled life-years is based on a combination of prevalence and standard disability weights, which is driven by prevalence and therefore does not lend itself to direct comparison with our estimates, which incorporated individual-level disability incidence estimates that are independent of prevalence. Our analyses are also not directly comparable with studies of trends in disability prevalence because our estimates incorporate incidence of and remission from disability, as well as mortality.27 We are not aware of previous studies examining trends in healthy and disabled life-years from birth cohorts within a national sample. In addition to having important implications for patients with diabetes and the families and health systems that care for them, trends in healthy years of life serve as an indication of whether clinical and public health goals to compress disability are being achieved. It is unknown whether the compression of disability among people with and without diabetes will continue. Our analyses only included people born up to 1947; investigators of one study examining the so-called baby boomer generation (ie, people born between 1947 and 1964) noted that difficulty with activities of daily living increased significantly for this generation.25

If reduction in mortality occurs because of longer survival with diabetes and disability, then length of life with both will increase. Findings from one intervention study in obese adults with type 2 diabetes showed that a mean weight loss of 7% or more and increasing duration of physical activity to more than 175 min per week led to a reduction of 48% in the severity of mobility-related disability.28 Additionally, in a systematic review on interventions to prevent disability in frail community-dwelling adults,29 Daniels and colleagues reported that relatively long-lasting and multi-component, several-times-weekly physical activity programmes for moderately physically frail older people can be protective against disability.26 Healthy lifestyle programmes including physical activity also reduce the risk of developing clinically significant symptoms of depression and preserve physical quality of life in overweight adults with diabetes.27 Because of the possible burden of new cases of mobility loss in people with and without diabetes aged 50–64 years, physical activity programmes might be helpful in reducing the risk of disability in this age group. Additionally, factors leading to disability, such as weight and physical and mental functioning, might be addressed so that the benefits of better health care are optimised. Ultimately, the decrease in disability onset due to primary prevention of diabetes might play an important part in achieving longer disability-free life-years.

**Contributors**

BHB, EWG, XZ, JL, and MKA conceived and designed the study. BHB obtained the data. All authors revised the report for important intellectual content and contributed to the literature search. BHB, JL, XZ, TJT, and YJC did the statistical analyses. EWG and MKA provided administrative, technical, and material support.
Declaration of interests

XZ is an employee of a pharmaceutical company that produces diabetes-related products. All other authors declare no competing interests.

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References