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The Effect of Diabetes on Disability in Middle-Aged and Older Adults

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Background. Physical disability is increasingly recognized as an adverse health consequence of type 2 diabetes in older adults. We studied the effect of diabetes on disability in middle-aged and older adults to: 1) characterize the association of diabetes with physical disability in middle-aged adults, and 2) determine the extent to which the effect of diabetes is explained by related covariates in either or both age groups.

Methods. We used data from two parallel national panel studies of middle-aged and older adults to study the effect of self-reported diabetes at baseline on disability 2 years later, adjusting for baseline covariates.

Results. Diabetes was strongly associated with subsequent physical disability (measured by a composite variable combining activities of daily living, mobility, and strength tasks) in middle-aged and older adults. Controlling for socioeconomic characteristics and common diabetes-related and unrelated comorbidities and conditions reduced the diabetes effect substantially, but it remained a significant predictor of disability in both groups.

Conclusions. Our analyses demonstrated that disability is an important diabetes-related health outcome in middle-aged and older adults that should be prevented or mitigated through appropriate diabetes management.

TYPE 2 diabetes is a prevalent chronic disease of middle-aged and older adults associated with excess atherosclerotic diseases, microvascular complications, disability, and mortality (1–14). Cross-sectional and longitudinal studies in older people document that diabetes is strongly linked to most types of disability, including higher order mobility and strength, personal care, household management, falls, and recovery from disability (9–11,15–20). Factors mediating this disability in older adults are not yet understood. Although vascular disease explains a portion of diabetes-related disability, unmeasured clinical and physiological effects of diabetes as well as social factors are also likely involved (17,21).

Less is known about the diabetes–disability link in midlife (13,20,22,23) where the impact of vascular complications and other comorbid diseases on diabetes-related disability is not known. Although much research concerning diabetes in middle age focuses on preventing vascular complications (24,25), current information on older adults suggests that preventing vascular complications of diabetes (e.g., coronary artery disease, stroke, impaired vision) decreases but does not eliminate diabetes-related disability. Hence, it is important to understand how complications and comorbidities affect diabetes-related disability in midlife and older age (26,27).

This study's goal was to answer two primary questions: 1) Is self-reported diabetes associated with subsequent disability in middle-aged and older adults? and 2) Is the diabetes effect on disability mediated by other social and health factors? To address these questions, we used data from two nationally representative panel studies of middle-aged and older adults and a conceptual model linking diabetes to a composite measure of mobility, strength, and activities of daily living disability, and adjusted for a broad range of covariates that were identical (or nearly so) in both surveys.

Methods

Data

Data were analyzed from baseline and 2-year follow-up waves of the Health and Retirement Study (HRS) and the Study of Assets and Health Dynamics Among the Oldest Old (AHEAD), complementary health interview surveys with complex stratified multistage designs and nationally representative data on samples of community-dwelling middle-aged and older U.S. adults. Response rates were 80% or higher at baseline and 92% or higher at follow-up; details are described elsewhere (28,29). Our analytic samples included 8001 HRS self-respondents (for whom we had matching data in 1992 and at first follow-up in 1994) and 5478 age-eligible AHEAD self-respondents (for whom we had matching data in 1993 and 1995).

Disability Measures

Physical disability is measured as the sum of respondent reports of any (versus no) difficulty on 10 physical activity tasks: 1) five activities of daily living (e.g., transferring, dressing, bathing, toileting, eating); 2) three mobility (or lower body) activities (e.g., walking across a room, walking several blocks, climbing a flight of stairs); and 3) two strength (or upper body) activities (e.g., pushing a piece of furniture, lifting 10 pounds). This composite measure captures known effects of diabetes on higher order mobility and strength tasks in older adults and a broad range of physical disability from early or ‘‘preclinical’’ disability to later personal care disability (30–33).

Covariates

The study’s independent variables included our measure of analytic interest—reported diabetes—and measures of comorbid health conditions, health and social risks documented as associated with diabetes or disability.

Diabetes is measured by self-report of having diabetes at baseline (1992 HRS, 1993 AHEAD), based on the question ‘‘Do you have diabetes now?’’ Chronic diseases and conditions potentially related to diabetes (mediators) include: cardiopulmonary conditions (history of heart problems or lung disease), history of stroke, high blood pressure, and impaired vision (fair/poor/blind). Chronic diseases and conditions not related to diabetes (confounders) include: musculoskeletal conditions (current arthritis or history of fractures/broken bones), history of cancer, impaired hearing (fair/poor), chronic pain (troubles with pain most or all of the time), cognitive impairment (total scores from immediate and delayed word recall performance tests in lowest HRS or AHEAD quartiles), and depressive symptoms (total score from the eight-item Center for Epidemiologic Studies Depression Scale (CES-D) in highest HRS or AHEAD quartiles) (29,34). The measures of cognitive impairment (10 items AHEAD, 20 items HRS) and depressive symptoms (frequency response scale HRS, yes/no response scale AHEAD) (hip fracture in AHEAD, all fractures since age 45 in HRS) differed somewhat between the two surveys.

Similarly, HRS and AHEAD respondents were not always asked the same battery of questions for all diseases and conditions. For this study, however, we used identical or nearly identical questions in the two surveys to construct chronic condition categories—cardiopulmonary, musculoskeletal, history of stroke, and other (cancer, high blood pressure)—that we expected would impact different capacities (e.g., cardiopulmonary conditions and aerobic capacity, musculoskeletal conditions, and strength) and, in turn, different domains of physical functioning. For example, both groups of respondents were asked about physician diagnosis of heart problems, lung disease, stroke, cancer, and high blood pressure, so the measures that include these individual conditions reflect history of diagnosis for those conditions. In contrast, our measure of musculoskeletal conditions is based on assessments of whether respondents had seen a physician within the past year about their arthritis and whether they had fractured or broken any bones since age 45 (HRS) or ever broken a hip (AHEAD).

Disability-related health risks other than diabetes include: smoking status (current cigarette smoker); heavy drinking ($\geq$3 alcoholic drinks per day) and moderate drinking (1–2 alcoholic drinkers per day) versus no drinking; and body mass index (BMI), calculated from self-reported height and weight and categorized as underweight (BMI < 19 kg/m^2), overweight (BMI > 25 and < 30 kg/m^2), or obese (BMI $\geq$ 30 kg/m^2) versus normal weight.

Socioeconomic and social risks include: education (years of schooling); insurance status (employer health insurance, other private nongovernmental health insurance); net worth (housing and nonhousing assets); age (years); being female; being African American or Hispanic; and being married/partnered.

Data Analysis

Respondent characteristics were compared between samples using means, standard deviations, and *t* tests (for continuous variables), and frequencies and Pearson chi-square tests (for categorical variables). Ordinary least squares regression models tested relative contributions of diabetes and covariates on physical disability after 2 years of follow-up in both age groups. The base model for each age group regressed disability on diabetes to test the unadjusted contribution of reported diabetes to disability. To evaluate mediation effects (35), successive models estimated the effects of four independently entered blocks of variables on functional difficulties to evaluate if these covariates accounted for the diabetes effect: 1) health characteristics; 2) other health risks; 3) socioeconomic factors; 4) other social risks; 5) all covariates simultaneously; and 6) all covariates plus baseline functioning difficulties. Results are presented as standardized coefficients to facilitate comparing effects across variables within models as well as between the two age groups.

Analyses were conducted separately for middle-aged and older adults. Due to slight measurement differences between HRS and AHEAD, we were unable to conduct formal tests of differences between the age groups. All analyses were weighted for differential probability of selection and nonresponse, and standard errors were adjusted to account for complex sample designs. We used SAS 6.1 (36) for data management and STATA V. 7.0 (37) for analysis, weighting, and sample design adjustments.

Results

Characteristics of HRS and AHEAD respondents are presented in Table 1 by age group and by diabetes status within each age group. Middle-aged adults with diabetes were 1 year older on average, whereas older adults with diabetes were about 1 year younger than those without. In both age groups, African Americans, Hispanic Americans, and adults with comorbid conditions were overrepresented among those reporting diabetes, compared to those without. Adults with diabetes were disproportionately obese and reported lower socioeconomic status (e.g., schooling, net worth, health insurance). Older adults reported a higher prevalence of chronic conditions, impairments, and functional limitations at baseline and in subsequent interviews than did middle-aged adults. Proportionately fewer older adults smoked, used alcohol, or were obese compared to middle-aged adults.

Table 2 presents results of analyses to assess the impact of self-reported diabetes on disability in midlife. Although reported diabetes alone explained only 4% of the variance in physical disability, the effect was highly significant. Comorbid conditions and impairments (Model 1) explained more of the variance and decreased the effect of diabetes on disability by more than 35%. Nonetheless, the diabetes effect remained large and highly significant, and its independent effect was as strong as those of cardiopulmonary conditions or vision impairments. As noted previously, models

Table 1. Percentagess and Means on Selected Characteristics of Middle-Aged and Older Adults in the United States

Characteristics	HRS (Age 51–61) Total	HRS Without Diabetes	HRS With Diabetes	AHEAD (Age 70+) Total	AHEAD Without Diabetes	AHEAD With Diabetes
Reported diabetes	7.3	—	—	11.6	—	—
Age (mean)	55.6	55.5	56.3*	76.8	76.9	76.0*
Female	53.7	53.7	52.5	63.5	63.7	61.6
African American	9.4	8.7	18.6*	9.1	8.0	17.4*
Hispanic	5.5	5.1	9.6*	3.3	3.0	5.8
Married/partnered	75.1	75.6	68.8*	50.3	50.4	49.7
Cardiopulmonary conditions	18.7	17.6	32.6*	36.1	34.8	45.9*
Musculoskeletal conditions	24.3	23.7	31.3*	27.7	27.1	32.2
History of stroke	2.4	2.1	5.8*	6.5	6.0	10.2*
Other chronic conditions	41.0	39.0	65.9*	56.8	54.8	72.8*
Functional difficulties (mean, 0–10)	1.1	1.0	2.2*	1.7	1.6	2.4*
Impaired vision	10.6	9.7	21.9*	22.3	20.9	33.2*
Impaired hearing	13.2	12.8	18.2*	23.2	22.8	26.2
Light drinker (1–2 drinks/day)	59.2	60.7	39.9*	46.5	48.7	29.3*
Heavy drinker (3+ drinks/day)	5.0	5.2	1.9*	2.0	2.1	1.4
Current smoker	26.8	27.2	21.9*	9.4	9.7	6.9*
Underweight (BMI $\leq$ 19.0)	1.7	1.8	0.6*	4.2	4.5	2.0*
Overweight (BMI $>$ 25 and $<$ 30)	40.6	40.7	38.4	37.4	36.8	42.3
Obese (BMI $\geq$ 30.0)	22.2	20.3	46.4*	13.3	11.9	24.0*
Total word recall (mean)[a]	13.1	13.2	11.7*	7.7	7.8	7.3*
CES-D symptoms (mean, 0–8)	0.8	0.7	1.2*	1.5	1.5	1.8*
Chronic pain	23.8	22.8	37.3*	31.3	30.6	36.5*
Education (mean, 0–17)	12.5	12.5	11.5*	11.3	11.4	10.6*
Net worth (median)	$65,250	$68,250	$36,250*	$69,000	$71,500	$52,027*
Employer health insurance	73.1	73.9	63.5*	—	—	—
Other health insurance	28.9	28.4	35.6*	—	—	—
Private/non-govt. health insurance	—	—	—	79.6	80.5	72.8*
Outcome (Wave 2)						
Functional difficulties (mean, 0–10)	0.8	0.7	1.9*	2.2	2.1	3.1*
Sample *N*	8,001	7,340	661	5,478	4,808	670

Notes: *Source*: Health and Retirement Study (HRS): 1992, 1994, and Study of Assets and Health Dynamics Among the Oldest Old (AHEAD): 1993, 1995. BMI = body mass index; CES-D = Center for Epidemiologic Studies Depression Scale.

[a]Possible range is 0–40 for HRS and 0–20 for AHEAD.

*$p < .05$ for differences between those without and with diabetes in each sample.

including health controls may underestimate the true effect of diabetes on disability. Thus, some of the heart disease and impaired vision effects are likely due to diabetes complications; in turn, some disability associated with them is potentially attributable to diabetes.

Although the effect of diabetes was less attenuated by health risks (Model 2) than by other health conditions (Model 1), the explained variance doubled from that of diabetes alone. Socioeconomic status (Model 3) nearly quadrupled the accounted variance compared to diabetes alone, and further attenuated the effects of diabetes. The addition of demographic factors (Model 4) also explained more disability, but the diabetes effect was largely unchanged. When all covariates were tested simultaneously (Model 5), the proportion of explained variance in disability increased to .35, and the effect of diabetes was halved but remained strongly significant. Finally, adding baseline functional difficulties in Model 6 increased the overall explained variance to .51 and reduced the diabetes effect by about one-third.

Table 3 presents results of parallel models to assess the impact of diabetes on physical disability in older adults. Although the unadjusted effect of diabetes on physical disability was strong and significant in older adults (as in middle-aged adults), the effect was smaller than in the middle-aged group. Similarly, all but one of the added variable blocks (comorbid conditions and impairments) attenuated the diabetes effect. Adjusting for demographic factors (Model 4), we found that the diabetes effect strengthened somewhat (presumably due to the inverse association with age for older adults noted in Table 1). In contrast to the results for middle-aged adults, the diabetes effect was smaller than the effects of other conditions and impairments for older adults.

Otherwise, results for the age groups were strikingly similar: The full set of covariates (Model 5) explained the same amount of variance in disability ($R^2 = .35$), and the diabetes effect was nearly identical (0.09 middle-aged adults, 0.08 older adults) and statistically significant in both age groups. Finally, including baseline disability (Model 6) increased the overall explained variance substantially (from .35 to .54) and reduced the diabetes effect by about one-half in both groups.

Discussion

Our analyses demonstrated that diabetes significantly and independently predicted disability 2 years later in both

Table 2. Standardized Regression Coefficients for the Effect of Diabetes on Physical Functioning in Middle-Aged Adults ($n = 8001$)

Characteristics	Base Model	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Reported diabetes	0.19***	0.11***	0.16***	0.15***	0.17***	0.09***	0.06***
Cardiopulmonary conditions		0.11***				0.11***	0.04***
Musculoskeletal conditions		0.08***				0.07***	0.03**
History of stroke		0.07***				0.06***	0.03**
Other chronic conditions		0.06***				0.05***	0.03**
Impaired vision		0.11***				0.08***	0.03*
Impaired hearing		0.02				0.03*	0.00
Cognitive impairment		−0.03**				−0.01	0.00
Affective impairment		0.21***				0.17***	0.06***
Chronic pain		0.27***				0.24***	0.08***
Light drinker			−0.13***			−0.02*	−0.01
Heavy drinker			−0.05***			−0.01	−0.01
Current smoker			0.11***			0.04***	0.03**
Underweight			0.04***			0.02*	0.01
Overweight			0.01			0.00	−0.01
Obese			0.10***			0.03	0.00
Education				−0.14***		−0.05***	−0.03**
Employer health insurance				−0.09***		−0.05***	−0.03**
Other health insurance				0.07***		0.03*	0.00
Net worth				−0.20***		−0.08***	−0.05***
Age					0.05***	0.03**	0.01
Female					0.11***	0.08***	0.02*
African American					0.08***	0.02	0.01
Hispanic					0.06***	−0.01	0.00
Married/partnered					−0.09***	0.00	−0.01
Baseline functional difficulties							0.54***
Model R^2	0.04	0.32	0.08	0.15	0.07	0.35	0.51

Note: *Source*: Health and Retirement Study (HRS): 1992, 1994, and Study of Assets and Health Dynamics Among the Oldest Old (AHEAD): 1993, 1995.

middle-aged and older adults. Prior to adjusting for covariates, the diabetes effect was slightly stronger for middle-aged than for older adults. Although the covariates reduced the diabetes effect, it remained a significant predictor of disability in both age groups. In fully adjusted models, the magnitude of the diabetes effect and the explained variance were nearly identical in both groups.

Although social risks decreased the diabetes effect in middle-aged adults but increased it slightly in older adults, other covariate groups affected the diabetes coefficient similarly in both age groups. Models including baseline functioning further decreased the diabetes effect in both groups (more so for the older group, perhaps due to greater disability at baseline from multiple competing comorbidities in older adults).

This research represents one of few evaluations of diabetes and disability demonstrating independent effects of diabetes on disability in both midlife and older age. The diabetes effect on disability has been found in older adults by other researchers using different covariates and methodologies, some using objective measures of diseases (clinical adjudication), BMI (measured weight and height), or performance-based functioning measures (1,7,17) and by others using self-reported diseases and limitations as we did (14,21). However, none of these previous studies accounted for health and economic covariates as fully as we did using nationally representative data.

Our finding of an independent effect of diabetes on disability in midlife suggests that similar unmeasured variables or incomplete covariate adjustments may be implicated in both age groups. Behavioral and psychological factors, diabetes management interventions, and potential diabetes complications (e.g., worsening or severe coronary artery disease, peripheral vascular disease, renal disease, peripheral neuropathy, chronic catabolism, or hyperglycemia) that were unmeasured in our study may explain the diabetes effect that we found. For example, in studies of older adults with diabetes, peripheral vascular disease and peripheral neuropathy (PN) were associated with diabetes-related disability (38) and PN was linked to mobility performance impairment (39,40), although PN did not explain all prevalent or incident mobility disability or severe walking limitations in older women (1,7). Although we expect that PN may be partially responsible for some of our detected ‘‘independent’’ effect of diabetes on physical disability, other unmeasured variables (e.g., peripheral vascular disease, level of hyperglycemia, inflammation, deconditioning, renal insufficiency) are also potentially involved.

The characteristics of excluded respondents may also have limited our results. For example, respondents excluded because of missing data at reinterview generally represented adults who were disadvantaged in both health and socioeconomic status compared to respondents with complete matched data in both waves. Furthermore, a lower proportion of baseline respondents were reinterviewed for AHEAD than for HRS because of greater attrition due to death in the older sample. For both of these reasons, our study is likely to underestimate the effects of reported diabetes on disability, perhaps more so in older adults.

The study may also be limited by the fact that diabetes status, other diseases, weight, and disability were self-reported; however, there is no reason to believe that

Table 3. Standardized Regression Coefficients for the Effect of Diabetes on Physical Functioning in Older Adults ($n = 5478$)

Characteristics	Base Model	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Reported diabetes	0.13***	0.07***	0.10***	0.10***	0.14***	0.08***	0.04***
Cardiopulmonary conditions		0.08***				0.10***	0.04***
Musculoskeletal conditions		0.16***				0.13***	0.03*
History of stroke		0.12***				0.11***	0.03***
Other chronic conditions		0.05***				0.03**	0.02*
Impaired vision		0.11***				0.07***	0.03**
Impaired hearing		0.03*				0.03**	0.01
Cognitive impairment		−0.14***				−0.07***	−0.05***
Affective impairment		0.20***				0.16***	0.04***
Chronic pain		0.14***				0.15***	0.02
Light drinker			−0.17***			−0.05***	−0.02*
Heavy drinker			−0.08***			−0.02	−0.01
Current smoker			0.04**			0.04***	0.02*
Underweight			0.08***			0.04***	0.03**
Overweight			−0.04**			0.00	−0.01
Obese			0.08***			0.07***	0.03**
Education				−0.11***		0.01	0.00
Private/non-govt. health insurance				−0.06***		−0.04***	−0.04***
Net worth				−0.16***		−0.06***	−0.02
Age					0.28***	0.20***	0.11***
Female					0.15***	0.13***	0.05***
African American					0.07***	0.00	0.00
Hispanic					0.03*	−0.03**	−0.03**
Married/partnered					−0.04**	0.02	0.02
Baseline functional difficulties							0.58***
Model R^2	0.02	0.27	0.07	0.08	0.14	0.35	0.54

Note: *Source*: Health and Retirement Study (HRS): 1992, 1994, and Study of Assets and Health Dynamics Among the Oldest Old (AHEAD): 1993, 1995.

inaccuracies in reporting would vary systematically by age group. Similarly, although the proportion of people with undiagnosed diabetes and the duration of diabetes may also differ between age groups, there is no reason to suspect that the effect of unmeasured variables on the diabetes–disability link would differ between age groups. For example, a direct relationship can be hypothesized between increasing diabetes duration and increasing disability in midlife and older age. If more older adults have longer diabetes duration, more disability would be expected in older age (supported by our data). Furthermore, although undiagnosed diabetes may be more prominent in middle-aged people, there is no reason to expect the effect of undiagnosed diabetes on disability to differ by age group. Finally, although the HRS and AHEAD were fully integrated in 1998, they were conducted as separate surveys of each age group for the first two waves of data collection, and measures were not identical. Therefore, we were unable to conduct a formal test for an interaction of age group on the effect of diabetes on disability.

Despite these limitations, this study had several important strengths. First, the data are nationally representative of both age groups, so in-depth age group comparisons of diabetes and disability could be made. Second, both surveys included detailed measures of covariates of diabetes and disability (e.g., depressive symptoms, cognitive performance, net worth, health insurance coverage) that are rarely measured in population-based surveys. In addition, nearly all of the covariates included in this study were measured identically in the HRS and AHEAD.

Our research focused on the independent association of diabetes with disability to emphasize that neither obesity nor the most prevalent cardiovascular complications of diabetes fully explained diabetes-associated disability. To address the problem of disability in diabetes and to design interventions to decrease disability, we need to better understand the role of these factors. Furthermore, because diabetes leads to vascular complications and may also be associated with increased depression, pain, and cognitive impairment, the total effect of diabetes on disability may be substantially larger than just the independent effect our research has identified. Finally, our study evaluated two population groups most affected by the current epidemic of type 2 diabetes—middle-aged adults increasingly diagnosed with diabetes and older adults with the highest prevalence of diabetes. In both groups, diabetes was a significant independent predictor of disability even after accounting for health-related covariates and other risks. Regardless of age, diabetes strongly predicted disability at 2-year follow-up, an outcome that diabetes management should seek to prevent or mitigate.

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