Diabetes and Incidence of Functional Disability in Older Women

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OBJECTIVE — To examine the relationship between diabetes and the incidence of functional disability and to determine the predictors of functional disability among older women with diabetes.

RESEARCH DESIGN AND METHODS — We analyzed data from 8,344 women enrolled in the Study of Osteoporotic Fractures, a prospective cohort of women aged ≥65 years. Diabetes (n = 527, 6.3% prevalence) and comorbidities (coronary heart disease, stroke, arthritis, depression, and visual impairment) were assessed by questionnaire and physical examination. Incident disability, defined as onset of inability to do one or more major functional tasks (walking 0.25 mile, climbing 10 steps, performing household chores, shopping, and cooking meals), was assessed by questionnaire over 12 years.

RESULTS — The yearly incidence of any functional disability was 9.8% among women with diabetes and 4.8% among women without diabetes. The age-adjusted hazard rate ratio (HRR) of disability for specific tasks associated with diabetes ranged from 2.12 (1.82–2.48) for doing housework to 2.50 (2.05–3.04) for walking two to three blocks. After adjustment for potential confounders at baseline (BMI, physical activity, estrogen use, baseline functional status, visual impairment, and marital status) and comorbidities (heart disease, stroke, depression, and arthritis), diabetes remained associated with a 42% increased risk of any incident disability and a 53–98% increased risk of disability for specific tasks. Among women with diabetes, older age, higher BMI, coronary heart disease, arthritis, physical inactivity, and severe visual impairment at baseline were each independently associated with disability.

CONCLUSIONS — Diabetes is associated with an increased incidence of functional disability, which is likely to further erode health status and quality of life.

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Diabetes prevalence increases sharply with age, and it is projected that by the year 2025, the majority of persons with diabetes will be aged 65 years or older (1,2). Although diabetes is often accompanied by vascular and neuropathic comorbidities (3), the threats of physical disability, loss of independence, and diminished quality of life may ultimately be the greatest concern for many with the disease. Cross-sectional data from nationally representative surveys show that >50% of older people with diabetes report difficulty performing daily physical tasks, such as climbing stairs, but few prospective studies have examined the specific impact of diabetes on incident disability or how it may act through its comorbidities (4–6). Additionally, no prospective studies have assessed the predictors of disability among women with diabetes. Therefore, we used data from the Study of Osteoporotic Fractures, a prospective cohort study of >9,000 women followed for 12 years, to examine the incidence and predictors of functional disability among older women with diabetes.

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Abbreviations: CHD, coronary heart disease; HRR, hazard rate ratio.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

RESEARCH DESIGN AND METHODS

Study design and population

The Study of Osteoporotic Fractures is a prospective, observational cohort study that initially enrolled 9,704 community-dwelled white women aged 65–99 years (mean 71.7, SD 5.3) (7). Participants were recruited between 1986 and 1988 from population-based lists in Baltimore, MD (drivers' license and identification card lists); Monongahela Valley, PA (voter registration lists); Portland, OR (large health maintenance organizations); and Minneapolis, MN (large health maintenance organization, jury selection list, hypertension detection, and follow-up study). Each woman received a letter and brochure inviting her to participate in the study. Women were excluded before the baseline visit if they were institutionalized or unable to walk without assistance from another person. African-American women were not included in the original Study of Osteoporotic Fractures cohort because of the low incidence of hip fractures in this population. Questionnaires, interviews, and physical examinations were conducted at baseline and at five follow-up visits at approximate 2-year intervals. Median studywide follow-up (to last visit or onset of disability) was 8.8 years (maximum 12.3 years).

Diabetes and risk factor measurements

At the baseline visit, diabetes status and age at diagnosis, current insulin use, hormone replacement therapy, benzodiazepine use, stroke, arthritis, and marital status were assessed by questionnaire. Height and weight were measured without shoes and used to calculate BMI (kg/m^2). Frequency and duration of walking and other leisure-time physical activities, smoking, and years of education were assessed by interview. Poor cognitive function was defined by a score of ≤23 of 26 points on a modified mini-mental state examination (8). Binocular visual acuity while wearing current correction was assessed using Bailey-Lovie letter charts and log-transformed for statistical analyses (9). We defined visual impairment as vision worse than 20/40 and severe visual impairment as worse than 20/80. Assessment of coronary heart disease (CHD; self-reported history of myocardial infarction, congestive heart failure, or angina) and depression were initiated at the second study visit. Depression was defined as a score of ≥6 on a shortened (15-point) Geriatric Depression Scale (10).

Disability assessment

To assess disability, women were asked how much difficulty (none, some, much, or unable) they had walking two to three blocks on level ground, walking up or down 10 steps, and doing housework, shopping, and cooking meals (11,12). These questions served as the basis for our primary outcome of incident disability, which we defined as a new report of being unable to conduct one or more tasks. We also examined separately the incidence of inability to do each specific task mentioned above.

Exclusions and loss to follow-up

Of the 9,704 women who participated in the baseline visit, 27 did not provide information on both diabetes and physical disability and were excluded. An additional 899 women (17% of those with diabetes and 9% without diabetes) were excluded from these prospective analyses because they reported being unable to perform at least one of the functional tasks at baseline. (Women who reported having some or much difficulty performing the tasks were included in the analyses, but we controlled for baseline level of difficulty performing tasks in our multivariate analyses.) Additionally, 222 women (4 and 2% of diabetic and nondiabetic women, respectively) died before the second visit, and no follow-up data were available on 212 women (1% of diabetic and nondiabetic women) due to nonattendance, refusal, and missing data. Therefore, incidence of disability was evaluated in 8,344 women. Additionally, data on at least one of the covariates of interest were missing in 1,373 women; therefore, the regression models evaluating the relative contribution of diabetes-related comorbidities to the relationship of diabetes and disability were conducted among a subgroup of 6,971 women (400 with diabetes and 6,571 without diabetes). Women for whom data were missing data were somewhat older (mean age 72.7 years) and had more comorbidities (e.g., arthritis 67.8%, depression 6.9%, CHD 20.3%, and poor vision 17.0%) than those in the multivariate analyses (arthritis 59.8%, depression 3.6%, CHD 13.7%, and poor vision 11.5%), but the absolute differences between those with and without diabetes were similar to the differences observed in the entire cohort. Because of the high cumulative mortality (18.0% of the eligible cohort died before their sixth visit [34% of those with diabetes and 16% of those without diabetes]), we conducted additional analyses of those who survived and had disability data at the final study visit ($n = 5,819$).

Statistical analyses

To compare baseline characteristics by diabetes status, χ^2 and Student's t tests were used. Primary analyses examined the association of diabetes status at baseline to incidence of functional disability, defining disability as reported inability to do one or more major functional tasks (walking two to three blocks, climbing steps, performing household chores, shopping, and cooking meals). We used life-table analyses to compare disability incidence between women with and without diabetes with the date of disability, defined as the midpoint between the visit at which a woman last reported being not disabled and the visit at which she first reported being disabled.

Cox proportional hazards regression analyses were used to estimate the association between diabetes status at baseline and hazard rate ratios (HRRs) for functional disability, controlling for potential confounders and explanatory factors. Primary models controlled for age, potential behavioral and demographic confounders (BMI, education, physical activity level, estrogen use, and marital status), and baseline functional status (level of reported difficulty doing tasks). We also controlled for visual impairment and several comorbidities, including CHD, stroke, depression, arthritis, and cognitive impairment. Because two of these covariates (CHD and depression) were assessed at the second visit but not at the baseline visit, we entered them as time-dependent covariates. We also tested for several biologically plausible interactions with diabetes, including age, BMI, CHD, and arthritis.

As secondary analyses, we used Cox proportional hazards regression to evaluate the age- and multivariate-controlled associations of demographic, behavioral, and medical comorbidity variables with risk of incident disability specifically among women with diabetes. In these analyses, we conducted backward stepwise regression analyses to identify primary predictors of disability.

RESULTS — In the eligible cohort, 527 women (6.3%) reported diabetes at baseline, 77 (14.6%) of them were insulin users, and mean duration of disease was 9.8 ± 9.5 years. Women with diabetes had fewer years of school, had higher BMI, were more likely to be widowed, to have symptoms of depression and to use benzodiazepines and were less likely to take estrogen and to walk for exercise (Table 1). Women with diabetes were also more likely to report hypertension, CHD, stroke, and arthritis and to have cognitive impairment and visual impairment. Diabetes was not associated with age or smoking.

Incidence of disability

The incidence of disability, as defined by each of the individual tasks (walking, climbing 10 steps, doing housework, shopping, and cooking meals) or defined as the inability to perform any of the above tasks, was approximately twice as high for women with diabetes as those without diabetes (Fig. 1). For example, average yearly incidence of inability to walk two to three blocks was 4.3% among women with diabetes and 1.9% among those without diabetes. Average yearly incidence of other disabilities among women with diabetes ranged from 1.5%

Table 1—*Baseline characteristics of Study of Osteopathic Fractures cohort evaluated for disability outcomes by diabetes status*

Variable	Nondiabetic subjects (n = 7,817)	Diabetic subjects (n = 527)	P
Disease duration			
≤5 years	—	200 (38)	—
5–14 years	—	196 (37)	—
≥15 years	—	127 (24)	—
Insulin use	—	77 (15)	—
Age (years)	71.3 ± 5.0	71.4 ± 4.8	0.44
BMI (kg/m^2)	26.3 ± 4.4	28.7 ± 5.3	<0.001
Education less than high school	21.1	30.2	<0.001
Marital status			
Married	50.8	45.5	0.02
Widowed	36.7	43.5	0.002
Separated/divorced/unmarried	12.6	11.0	0.34
Smoking	9.7	8.9	0.56
Walking for exercise	53.6	45.4	<0.001
Current estrogen use	14.5	7.7	<0.001
Benzodiazepine use	13.7	19.4	<0.001
Hypertension	36.2	53.9	<0.001
CHD*	13.8	26.2	<0.001
Stroke	2.0	5.4	<0.001
Arthritis	60.5	67.6	0.002
Visual impairment	12.1	16.5	0.03
Depression score ≥6*	3.7	6.6	0.003
Cognitive impairment	16.6	21.0	<0.01

Data are n (%), means ± SD, or %. *Estimates are based on the second study visit for CHD (n = 6,907) and depression (n = 6,872).

for cooking meals (vs. 0.7% for nondiabetic women) to 8.5% for heavy housework (vs. 4% for nondiabetic women). Average yearly incidence of any disability was 9.8% for women with diabetes and 4.7% for women without diabetes. The corresponding age-adjusted HRR of disability for women with diabetes ranged from 2.05 to 2.50 (Fig. 1).

Controlling for age, education, marital status, physical activity, BMI, estrogen use, and baseline functional status attenuated the risk of disability associated with having diabetes (Fig. 1); HRRs ranged from 1.69 to 2.18 for specific tasks, and the HRR of any disability was 1.58 (95% CI 1.36–1.83). After additional control for comorbidities (CHD, stroke, depression, visual impairment, poor cognitive function, and arthritis), the HRR was further attenuated by as much as 0.29, with the HRR of any disability for women with diabetes dropping to 1.42 (1.23–1.65) and ranging from 1.53 to 1.98 for specific tasks. The risk of physical disability for women with diabetes was equivalent to the risk associated with an age increase of 7.4 years in age-adjusted analyses and 4.5 years after controlling for all measured comorbidities.

When we restricted analyses to women who survived and attended the last visit, absolute incidence rates of disability were lower, but the HRR of disability for those with diabetes was higher (data not shown) than in analyses conducted among the entire cohort. Incidence of any disability was 9.0% among women with diabetes and 3.8% among nondiabetic women, corresponding to an age-adjusted HRR of 2.34 (1.95–2.81). By task, the age-adjusted HRR of disability for women with diabetes ranged from 2.1 to 3.0.

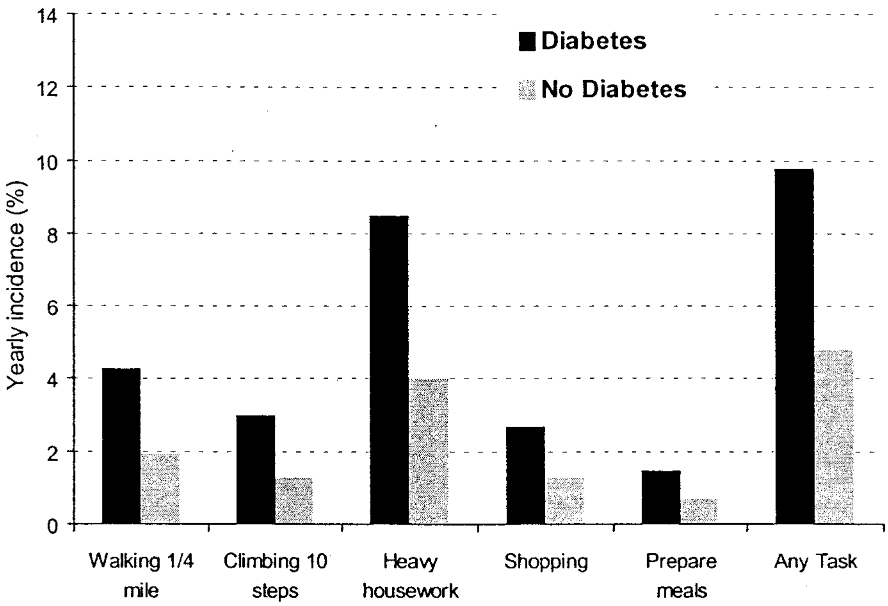
We found a significant age by diabetes interaction, wherein diabetes was strongly associated with disability among younger women (HRR 2.73 [95% CI 2.16–3.44] for those aged 65–69 years; 1.97 [1.61–2.41] for those aged 70–79 years) but not in the oldest women (0.95 [0.56–1.63] for those aged ≥80 years) (Fig. 2). After controlling for BMI, education, marital status, physical activity, estrogen replacement therapy, and baseline functional status, HRR estimates for the three age strata were 1.83 [1.44–2.32], 1.61 [1.31–1.97], and 0.87 [0.51–1.49], respectively.

Insulin-treated women with diabetes had a higher risk of disability (2.70 [1.90–3.83]) than those not on insulin (1.96 [1.68–2.30]), but after controlling for age, BMI, and baseline functional status, the HRRs were similar (1.63 [1.15–2.32] for insulin-treated women and 1.57 [1.34–1.84] for non–insulin-treated women) among this elderly cohort. No consistent relationship was found between duration of diabetes and overall risk of disability. The age-adjusted HRR of any disability for women with diabetes for <5 years, 5–14 years, and >14 years was 1.95 (1.54–2.47), 2.25 (1.80–2.80), and 1.90 (1.41–2.56), respectively. We also found no significant interactions between diagnosis of diabetes and BMI, heart disease, or arthritis and the incidence of physical disability. Additionally, excluding the first 3 years of follow-up did not appreciably alter the overall risk of disability associated with diabetes, suggesting that our associations are not explained by people with diabetes having higher undetected disability at baseline.

Predictors of disability

In multivariate analyses conducted specifically among women with diabetes, disability risk was associated with baseline functional difficulty, arthritis, obesity (≥30 kg/m^2), older age, CHD, and severe visual impairment. Additionally, physical activity and past use of estrogen were associated with a reduced disability risk. Depression was a significant predictor of disability in univariate analyses but not in the multivariate analyses. Insulin use, duration of disease, stroke, smoking, moderate visual impairment, and benzodiazepine use were not associated with disability among women with diabetes in multivariate analyses (Table 2).

DISCUSSION — In this 10-year prospective cohort study, older women with diabetes were twice as likely as their nondiabetic counterparts to become unable to perform physical and household tasks; the annual incidence of disability was ~10% among women with diabetes, compared with ~5% among those without diabetes. Disability, whether defined as an inability to perform gross tasks of



	Walking 1/4 mile	Climbing 10 steps	Heavy housework	Shopping	Prepare meals	Any Task
Age-adj HRR*	2.50 (2.05 – 3.04)	2.47 (1.94 – 3.14)	2.12 (1.82 – 2.48)	2.23 (1.74 – 2.84)	2.29 (1.64 – 3.21)	2.05 (1.77 – 2.37)
Multivariate HRR I	1.80 (1.47 – 2.21)	1.93 (1.51 – 2.47)	1.69 (1.44 – 1.98)	2.01 (1.57 – 2.58)	2.18 (1.55 – 3.06)	1.58 (1.36 – 1.83)
Multivariate HRR II	1.76 (1.43 – 2.15)	1.76 (1.37 – 2.25)	1.53 (1.31 – 1.80)	1.80 (1.40 – 2.30)	1.98 (1.40 – 2.79)	1.42 (1.23 – 1.65)

Figure 1—*Incidence of inability to perform physical and household tasks among women aged ≥65 years with and without diabetes. Multivariate analysis I controlled for age, marital status, education, baseline physical functioning, BMI, physical activity level, and estrogen use. Multivariate analysis II controlled for these variables as well as for CHD, stroke, depression, visual impairment, poor cognitive function, and arthritis. Regression models and corresponding estimates of HRRs were conducted excluding individuals with missing data on one or more covariates to allow for comparison of incremental models. Point estimates for age-adjusted models conducted on the entire cohort were HRR 2.32 (95% CI 1.97–2.74), 2.12 (1.75–2.58), 2.05 (1.81–2.33), 2.07 (1.69–2.53), 2.27 (1.74–2.97), 2.00 (1.77–2.26) for walking, climbing, housework, shopping, cooking, and any task, respectively.*

mobility such as walking or climbing steps or by more specific tasks of daily living such as cooking meals, leads to loss of independence and predicts future hospitalization, institutionalization, and death (13–15).

The relationship between diabetes and disability is likely due to multiple factors, because diabetes is related to numerous vascular and neuropathic complications that could conceivably affect functional status (16–21). We found that controlling for CHD, stroke, depression, cognitive impairment, visual impairment, and arthritis attenuated the association between diabetes and disability somewhat, but no single factor dominated this association, and the relationship remained statistically significant. Our finding that diabetes was still related to a 42% increased risk of disability after controlling for comorbidities could be due to several factors, including subclinical coronary and peripheral vascular disease (18,22), renal impairment, peripheral or autonomic neuropathy, or the direct effects of hyperglycemia, which has been associated with fatigue, blurred vision, and headaches (23). It is also possible that the association between diabetes and disability could be mediated by other social and psychological processes, such as financial resources and living arrangements, or by cognitive impairment not detected by our study.

The relationship between diabetes and disability was strongest among younger age strata (e.g., 65–69 years), and diabetes was not associated with disability among the oldest women (≥80 years of age). This could be because of the high absolute levels of disability among the oldest (10-year cumulative incidence >75%), making it difficult to detect relative differences. This may also reflect a survival bias, wherein diabetic women who survive to 80 years of age are otherwise relatively healthy. Finally, there may have been selective attrition, wherein older, disabled, diabetic women were less likely to attend follow-up visits than their nondiabetic counterparts. This would likely lead to an underestimation of the association between diabetes and disability. Of note, when we excluded women who died or did not attend follow-up visits, the relative risk of disability associated

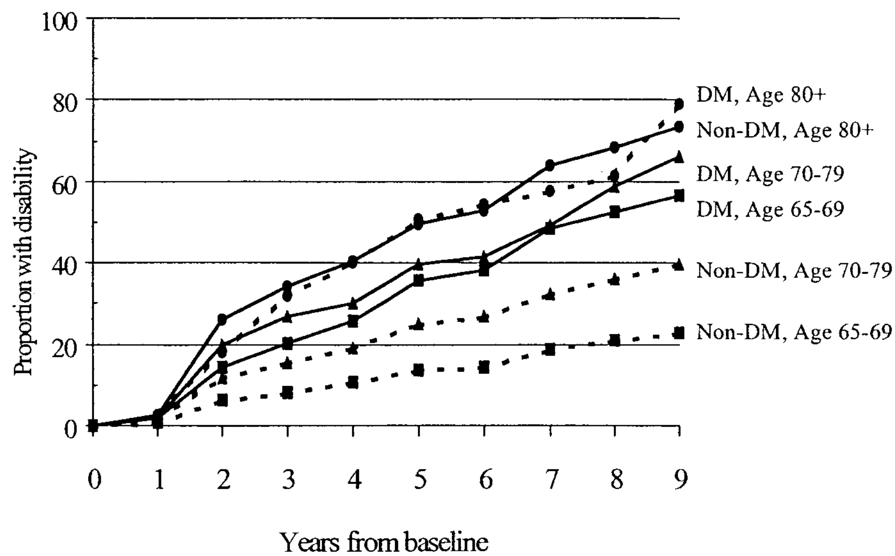


Figure 2—*Cumulative incidence of any inability to perform physical tasks according to diabetes status and age group.*

Table 2—*Predictors of any disability among women with diabetes*

Predictors	Age-adjusted HRR*	Multivariate HRR*
Baseline functional difficulty	2.16 (1.68–2.78)	1.59 (1.21–2.10)
BMI (kg/m^2)		
(< 25)	1.0	1.0
(25–29.9)	1.56 (1.09–2.23)	1.40 (0.97–2.01)
(≥ 30)	2.57 (1.82–3.63)	2.00 (1.39–2.89)
Age (years)		
(65–69)	1.0	1.0
(70–74)	1.20 (0.89–1.61)	1.15 (0.85–1.56)
(75–79)	1.52 (1.08–2.15)	1.61 (1.13–2.30)
(80–84)	1.57 (0.92–2.67)	1.42 (0.81–2.50)
(≥ 85)	1.84 (0.68–5.01)	2.84 (1.02–7.93)
CHD	1.93 (1.48–2.52)	1.72 (1.30–2.27)
Arthritis	1.75 (1.31–2.33)	1.38 (1.02–1.86)
Physical activity (highest versus lowest quartile)	0.49 (0.34–0.70)	0.61 (0.41–0.91)
Visual impairment		
Mild/moderate (20/42 to 20/76)	1.04 (0.73–1.49)	—
Severe (20/80 or worse)	2.11 (1.03–4.34)	2.18 (1.03–4.63)
Estrogen use		
Former (versus never)	0.68 (0.49–0.94)	0.68 (0.49–0.96)
Present (versus never)	1.05 (0.67–1.64)	—
Depression	1.89 (1.16–3.08)	—
Benzodiazepine use (%)	1.23 (0.90–1.68)	—
Education (group)	0.90 (0.78–1.02)	—
Stroke	1.46 (0.94–2.27)	—
Cognitive impairment	0.89 (0.65–1.23)	—
Insulin treatment	1.29 (0.92–1.82)	—
Disease duration (per 5 years)	0.97 (0.82–1.14)	—
Smoking		
Former (versus never)	0.92 (0.69–1.22)	—
Present (versus never)	1.01 (0.64–1.61)	—

*Data are HRR (95% CI). Third column includes only variables significant at the <0.05 level in multivariate analyses; data presented represent HRRs conducted only among those with diabetes who had all variables present in multivariate analyses (n = 472).

with diabetes was higher than in our primary analyses.

We found several potentially modifiable factors, including obesity, CHD, physical inactivity, and arthritis, to be associated with onset of disability among women with diabetes. Each of these factors has also been associated with disability in the general population (15–18,24), but to our knowledge, this is the first prospective longitudinal study to specifically examine the predictors of disability among people with diabetes. These findings raise the question of whether specific interventions may influence disability risk. Physical activity interventions, including strength and balance training and walking, have been associated with improved physical functioning among older persons without diabetes (25,26). Similarly, lifestyle-based weight loss interventions or clinical management of CHD and related risk factors could improve physical functioning, but these factors have not been tested in randomized controlled trials or specifically among older persons with diabetes. Our study contrasts with previous studies in that smoking, benzodiazepine use, stroke, and insulin use were not associated with disability, but the number of diabetic women reporting these risk factors (n = 101, 47, 28, and 77 for smoking, benzodiazepine use, stroke, and insulin use, respectively) indicates that we had limited power to evaluate these variables.

Our study has several limitations. The study population was limited to white, noninstitutionalized women who were probably healthier than those in the typical same-aged population. This is evident in the study's prevalence of diagnosed diabetes (6%), which was lower than the national prevalence at the time of the study for older white women (8–9%) (5). Additionally, our multivariate analyses were based on a subsample that was somewhat healthier than the overall cohort. However, we found little difference in the age-adjusted relative risk of disability associated with diabetes between the whole cohort and this subgroup.

Because we collected diabetes status by self-report, our findings may not be generalizable to women with undiagnosed diabetes. However, self-reported diabetes has been shown to have good specificity (27). Assuming that the disability prevalence of persons with undiagnosed diabetes is higher than that of nondiabetic individuals, then bias related to undiagnosed diabetes would lead to an underestimation of the association between diabetes and disability. We defined disability using subjective measurements rather than physical performance tests, because they ultimately have high face validity, in that reported inability has consequences for caregivers, health care resources, and future outcomes whether or not the person is actually capable of each task (14). Factor analyses have shown that the tasks we examined, including walking 0.25 mile, climbing 10 steps, and doing heavy housework are central measures of mobility disability, and meal preparation and shopping are central measures of complex disability (28). Finally, we lacked information about glycemic control and specific diabetes medications, which would have helped us assess their contribution to disability.

In summary, this study of older women shows that, in addition to well-documented effects on microvascular and macrovascular complications, diabetes leads to functional disability. Our findings, combined with studies conducted in other populations (6,14–21,25), suggest that this effect may be due to a combination of factors, including some intrinsic to diabetes (e.g., hyperglycemia, obesity), some due to commonly recognized complications (e.g., CHD, peripheral vascular disease), and some due to less commonly recognized factors that might be associated with diabetes (e.g., depression, arthritis). We identified several areas for potential research, including the effectiveness of physical activity and weight loss interventions and treatments for arthritis and heart disease for people with diabetes. The burden of disability is likely to be of increasing concern in future decades due to the aging of the population, indicating a need to respond by tracking levels of disability and implementing interventions for prevention.

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APPENDIX

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