Association Between Cognitive Function and Social Support with Glycemic Control in Adults with Diabetes Mellitus

Toru Okura, MD, MSc,† Michele Heisler, MD, MPA,‡§ and Kenneth M. Langa, MD, PhD‡§*

OBJECTIVES: To examine whether cognitive impairment in adults with diabetes mellitus is associated with worse glycemic control and to assess whether level of social support for diabetes mellitus care modifies this relationship.

DESIGN: Cross-sectional analysis.

SETTING: The 2003 Health and Retirement Study (HRS) Mail Survey on Diabetes and the 2004 wave of the HRS.

PARTICIPANTS: Adults aged 50 and older with diabetes mellitus in the United States (N = 1,097, mean age 69.2).

MEASUREMENTS: Glycosylated hemoglobin (HbA1c) level; cognitive function, measured with the 35-point HRS cognitive scale (HRS-cog); sociodemographic variables; duration of diabetes mellitus; depressed mood; social support for diabetes mellitus care; self-reported knowledge of diabetes mellitus; treatments for diabetes mellitus; components of the Total Illness Burden Index related to diabetes mellitus; and functional limitations.

RESULTS: In an ordered logistic regression model for the three ordinal levels of HbA1c (<7.0, 7.0–7.9, ≥ 8.0 mg/dL), respondents with HRS-cog scores in the lowest quartile had significantly higher HbA1c levels than those in the highest cognitive quartile (adjusted odds ratio = 1.80, 95% confidence interval = 1.11–2.92). A high level of social support for diabetes mellitus care modified this association; for respondents in the lowest cognitive quartile, those with high levels of support had significantly lower odds of having higher HbA1c than those with low levels of support (1.11 vs 2.87, $P = .02$).

CONCLUSION: Although cognitive impairment was associated with worse glycemic control, higher levels of social support for diabetes mellitus care ameliorated this negative relationship. Identifying the level of social support available to cognitively impaired adults with diabetes mellitus may help to target interventions for better glycemic control. **J Am Geriatr Soc 57:1816–1824, 2009.**

From the Divisions of *Geriatric Medicine and ‡General Medicine, Department of Internal Medicine, University of Michigan at Ann Arbor, Michigan Department of Veterans Affairs, Ann Arbor, Michigan; †Geriatric Research, Education and Clinical Center, Ann Arbor, Michigan; and §Health Services Research and Development Center of Excellence, Ann Arbor, Michigan.

Address correspondence to Toru Okura, 300 North Ingalls, Room 932, Ann Arbor, MI 48109. E-mail: toruo@med.umich.edu

DOI: 10.1111/j.1532-5415.2009.02431.x

Key words: cognitive impairment; glycemic control; diabetes mellitus; social support

Diabetes mellitus is highly prevalent and increasing in the elderly population of the United States. The Centers for Disease Control and Prevention estimated that 18.4% of people aged 65 to 74 and 16.6% of those aged 75 and older had diagnosed diabetes mellitus in 2006, up from 12.5% and 11.1% in 1996, respectively.[1] These estimates are conservative, because they do not include the institutionalized population and undiagnosed diabetes mellitus. Diabetes mellitus in older adults is associated with higher mortality,[2] worse functional status, and higher prevalence of geriatric syndromes, such as depression and cognitive impairment.[3] Diabetes mellitus in the elderly population also imposes significant costs on the U.S. healthcare economy; $47 billion was spent for diabetes mellitus care of older adults in 2002.[4]

For successful management of diabetes mellitus, individuals must commit to lifelong daily self-care tasks such as adhering to dietary, exercise, and medication regimens; checking blood glucose; and keeping provider appointments. The coordination of these tasks often requires complex cognitive functioning. Several studies have examined the association between cognitive function and management of diabetes mellitus. One small study of 60 adults with diabetes mellitus failed to detect an association between global cognitive function, measured using the Mini-Mental State Examination (MMSE), and glycemic control,[5] perhaps because of low statistical power. Another study found that lower MMSE scores were associated with poorer diabetes mellitus self-care and greater dependency.[6] Other studies have shown that impaired executive function—the ability to plan and organize activities—is associated with worse glycemic control.[5,7] Inadequate health literacy and numeracy have been shown to be associated with worse glycemic control and poorer self-management behaviors, respectively.[8,9] Finally, social support for diabetes mellitus care from family and friends was not associated with

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glycemic control,[8] and no prior studies of which the authors are aware have assessed the value of social support for diabetes mellitus care in those with cognitive impairment.

To address these deficiencies of knowledge about the roles of cognitive function and social support in diabetes mellitus care, whether cognitive impairment was associated with worse glycemic control in adults with diabetes mellitus was examined using a large nationally representative sample of older Americans with diabetes mellitus. Whether social support for diabetes mellitus care from family and friends modified the relationship between cognitive function and glycemic control was also assessed.

METHODS

Conceptual Model of Glycemic Control in Adults with Diabetes Mellitus with Cognitive Impairment

The conceptual model underlying the analysis of glycemic control in adults with diabetes mellitus with cognitive impairment is shown in Figure 1. It was assumed that medical comorbidities (e.g., stroke, congestive heart failure) and sociodemographic factors (e.g., age, education, race) are associated with impairment of memory and the other cognitive domains. Individuals with diabetes mellitus with cognitive impairment may have difficulties performing daily tasks of diabetes mellitus self-care effectively, which may result in worse glycemic control than in those without cognitive impairment. Depressed mood may be associated with cognitive impairment and may interfere with effective self-management.[10–13] It was hypothesized that adults with cognitive impairment who received help for diabetes mellitus self-care from family and friends would achieve better glycemic control.[14] Very frail elderly individuals, especially those with limited life expectancy, advanced cognitive impairment, or multiple comorbidities, may have higher glycemic levels because they have less-intensive treatment goals.[15]

Data

Data from the 2003 Health and Retirement Study (HRS) Mail Survey on Diabetes and the 2002 and 2004 waves of the HRS were used. The HRS is a biennial longitudinal survey of a nationally representative cohort of more than 20,000 U.S. adults. It is sponsored by the National Institute on Aging and performed by the Institute for Social Research at the University of Michigan. The Mail Survey on Diabetes is a supplemental survey that collected self-reported questionnaire data on treatment and self-management of diabetes mellitus and collected a clinical biomarker of glycemic control: glycosylated hemoglobin (HbA1c). The survey questions were drawn from several sources, including validated instruments from the Michigan Diabetes Research and Training Center. Flexsite Diagnostics, Inc. performed the blood spot assays for HbA1c. The diabetes mellitus survey was sent out to 2,350 HRS respondents who reported having diabetes mellitus in the 2002 wave of the HRS; 1,901 completed the survey (80.9% response rate), and 1,285 completed the at-home HbA1c kits, of which 1,233 yielded valid samples (52.5% response rate).[16,17]

The Behavioral Sciences Committee institutional review board at the University of Michigan approved the HRS. The data used for this study are publicly available without unique identifiers to ensure respondent anonymity.

Variables and Their Measurement

Cognitive Function

The HRS assesses cognitive function using the 35-point HRS cognitive scale (HRS-cog) for self-respondents in each biennial wave. This is a modified version of the Telephone Interview for Cognitive Status, which is a cognitive screen-

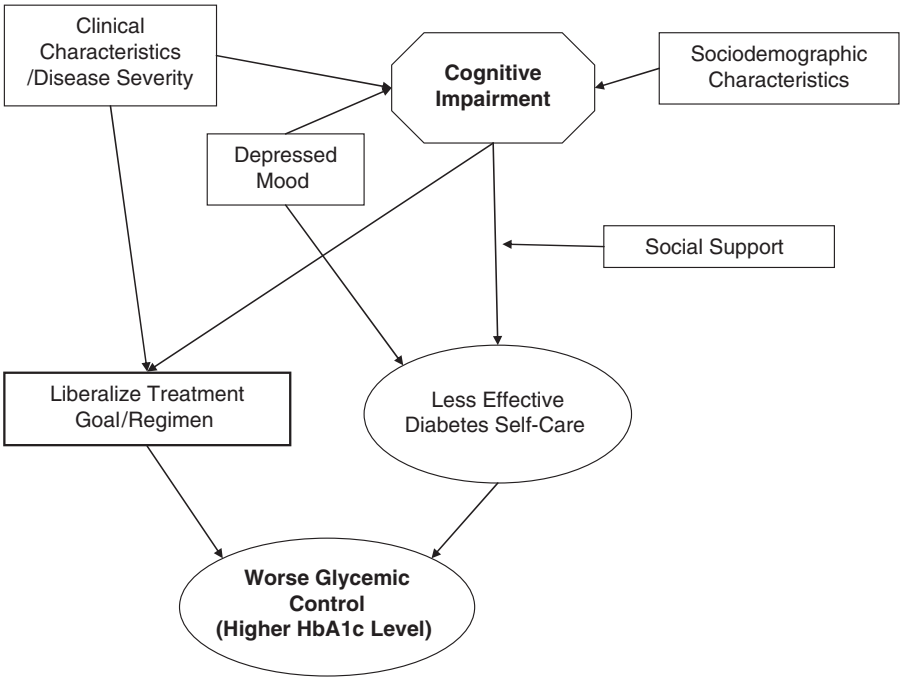

Figure 1. Conceptual model of glycemic control in adults with diabetes mellitus with cognitive impairment. HbA1c = glycosylated hemoglobin.

ing instrument specifically designed for population-based studies.[18] It includes an immediate and delayed 10-noun free-recall test to measure memory; a serial-sevens subtraction test to measure working memory; a counting backward test to measure speed of mental processing; an object naming test to measure knowledge and language; and recall of the date, the president, and the vice president to measure orientation. Detailed information on the measures included in the HRS-cog, including their derivation, reliability, and validity, is available at the HRS Web site.[19] Prior research using the HRS-cog has shown that it is related to limitations in activities of daily living (ADLs) and instrumental activities of daily living (IADLs),[20] level of informal caregiving,[21] likelihood of nursing home admission,[22] and mortality.[23]

Because the time from the survey date of the 2003 Mail Survey on Diabetes to the interview of the 2004 HRS wave was much shorter than from the 2002 wave (mean duration: 7.5 months (range 0–15 months) to the 2004 wave vs 15.5 months (range 8–24 months) to the 2002 wave), the cognitive data from the 2004 wave were used for the main analysis. The analyses were repeated using cognitive data from the 2002 wave as a sensitivity analysis. Level of cognitive impairment was characterized according to quartile of HRS-cog score (quartile 1, 0–18; quartile 2, 19–22; quartile 3, 23–25; quartile 4, 25–35).

Glycemic Control

The 2003 Mail Survey on Diabetes collected HbA1c data using the Flexsite Diagnostics A1c at Home Test Kit (Flexsite Diagnostics, Inc., Palm Beach, FL), which the U.S. Food and Drug Administration approved for home use and over-the-counter sale in 1997.[24] The A1c at Home Test Kit has been evaluated against Diabetes Control and Complications Trial reference technology and tested extensively in the laboratory and in company-sponsored supplements to clinical trials. Glycemic control, as measured according to HbA1c (higher values indicating worse glycemic control) was the dependent variable for the analysis. HbA1c was categorized into three ordinal levels (<7.0, 7.0–7.9, and ≥ 8.0 mg/dL).

Sociodemographic Characteristics

Sociodemographic covariates included age (<65, 65–74, ≥ 75), sex, race (white, black, other), years of formal education (<12, 12, >12), annual household income (categorized according to quartile, $<$\$17,500, \$17,500–35,000, \$35,001–70,000, $\geq$\$70,001), and health insurance (insured vs uninsured).

Clinical Characteristics

Clinical characteristic variables included duration of diabetes mellitus (≤ 10, 11–20, >20 years) and diabetes mellitus treatment (no treatment, oral medications, insulin). The HRS diabetes study assessed severity and number of diabetes mellitus comorbidities using diabetes mellitus–related components of the Total Illness Burden Index (TIBI), a validated scale that ranges from 0 to 100.[25,26] Diabetes mellitus comorbidities were characterized according to quartile of TIBI score. In the HRS 2002 and 2004 waves, depressive symptoms were assessed using eight items adopted from the Center for Epidemiologic Studies Depression Scale (CES-D).[27] CES-D score was categorized into three levels of depressed mood (0 = no depressed mood, 1–3 = mildly depressed mood, 4–8 = moderately to severely depressed mood). Data on functional disability (reported difficulties performing ADLs and IADLs) were obtained from the HRS core survey. The ADLs assessed were dressing, bathing, eating, transferring, and toileting. The IADLs assessed were preparing meals, grocery shopping, making telephone calls, taking medications, and handling finances.

Social Support for Diabetes Mellitus Care

In the diabetes mellitus study, each respondent was asked eight questions regarding diabetes mellitus–related social support drawn from the Diabetes Care Profile:[28] "How much would you agree that you can count on your family or friends to help and support you a lot with each particular diabetic care (following meal plan, taking medicine, taking care of feet, getting enough physical activity, testing sugar, going to the doctor or nurse, keeping weight under control, and handling feeling about diabetes)?" The possible responses to each question were strongly agree, agree, neither disagree nor agree, disagree, and strongly disagree. Because 70% to 80% of the respondents responded agree or strongly agree for each question, the number of diabetic care practices for which the respondent reported strongly agree (10–30% of the respondents) were counted to characterize significant social support, and the responses were categorized into three levels of social support (0 = low level, 1–5 = intermediate level, 6–8 = high level).

Understanding of Diabetes Mellitus

In the diabetes study, respondents were asked 10 survey questions drawn from the Diabetes Care Profile:[28] "How well do you understand each of the following areas of diabetes care?" The areas were "how to take your insulin or other medications," "what each of your prescribed medications do," "how to choose the food you should eat," "how to read nutrition labels on food," "how to exercise," "how and when to test your blood sugar," "how to care for your feet," "what the complications of diabetes are," "what to do for symptoms of low blood sugar," and "what your target blood sugar values should be." The possible responses to each question were understand completely, understand pretty well, it's still a little confusing, or I don't understand at all. The number of questions for which a respondent answered understand completely or understand pretty well (70–90% of the respondents) were counted to characterize good understanding, and these responses were categorized into three levels of understanding (0–5 = low level, 6–8 = intermediate level, 9–10 = high level).

Statistical Analysis

All sample characteristics were compared according to the quartile level of cognitive function using data obtained from the 2004 wave of the HRS and the 2003 Mail Survey on Diabetes. Bivariate ordered logistic regression models were then constructed with ordinal groups of HbA1c level as the dependent variable to examine the unadjusted association between each characteristic and glycemic control. To assess confounding or mediating effects on the association between cognitive function and glycemic control, different sets of independent variables (e.g., sociodemographic vari-

Table 1. Respondent Characteristics According to Quartile of Performance on the Health and Retirement Study (HRS) Cognitive Scale

Characterstic	All Respondents n (%)	HRS Cognitive Scale, n (Weighted %)				*P*-Value*
		Quartile 4 (Best)	Quartile 3	Quartile 2	Quartile 1 (Worst)	
Sample	1,097 (100.0)	229 (19.6)	275 (22.8)	310 (29.0)	283 (28.6)	
Age						<.001
≤64	342 (37.6)	88 (46.6)	71 (39.8)	96 (38.5)	87 (36.3)	
65–74	450 (33.7)	103 (36.4)	143 (46.9)	120 (31.5)	84 (23.6)	
≥75	305 (28.7)	38 (17.0)	61 (23.3)	94 (30.0)	112 (40.1)	
Sex						.61
Male	523 (48.1)	109 (47.9)	132 (49.5)	162 (50.3)	120 (44.9)	
Female	574 (51.9)	120 (52.1)	143 (50.5)	148 (49.7)	163 (55.1)	
Race						<.001
White	879 (80.4)	202 (87.1)	246 (88.9)	246 (81.8)	185 (67.5)	
Black	164 (14.2)	18 (6.8)	23 (8.4)	44 (12.4)	79 (25.7)	
Other	54 (5.4)	9 (6.1)	6 (2.7)	20 (5.8)	19 (6.8)	
Education, years						<.001
<12	316 (30.2)	19 (9.3)	46 (15.3)	98 (32.0)	153 (54.4)	
12	375 (33.4)	69 (32.6)	109 (38.2)	108 (33.5)	89 (30.0)	
>12	406 (36.4)	141 (58.1)	120 (46.5)	104 (34.5)	41 (15.6)	
Annual household income, $						<.001
<17,500	275 (28.2)	31 (15.1)	46 (16.6)	77 (29.2)	121 (45.4)	
17,500–35,000	325 (27.8)	49 (19.7)	96 (33.3)	86 (26.2)	94 (30.4)	
35,001–70,000	336 (30.0)	93 (41.4)	86 (33.5)	100 (29.0)	57 (20.3)	
>70,000	161 (14.0)	56 (23.8)	47 (16.6)	47 (15.6)	11 (3.9)	
Uninsured	32 (3.3)	4 (0.9)	3 (0.3)	10 (4.4)	15 (6.3)	<.001
Duration of diabetes mellitus, years						<.001
≤10	528 (56.4)	139 (69.5)	142 (61.0)	138 (52.7)	109 (45.8)	
11–20	226 (24.7)	42 (18.0)	62 (26.9)	68 (28.0)	54 (24.5)	
≥21	163 (18.9)	25 (12.5)	27 (12.1)	51 (19.3)	60 (29.7)	
Diabetes treatment						
No medication	151 (15.5)	43 (22.4)	53 (23.4)	36 (11.2)	19 (8.5)	<.001
Oral medications	719 (72.1)	164 (70.4)	194 (68.1)	227 (73.9)	206 (74.8)	.42
Insulin	256 (25.2)	45 (19.3)	44 (16.3)	72 (27.3)	95 (34.3)	<.001
Diabetes mellitus comorbidities (Total Illness Burden Index score)						<.001
Quartile 1	238 (19.4)	69 (27.6)	68 (22.0)	61 (18.7)	40 (12.3)	
Quartile 2	297 (27.5)	55 (21.6)	75 (29.6)	94 (32.1)	73 (25.2)	
Quartile 3	273 (23.7)	57 (29.7)	73 (24.1)	72 (21.1)	71 (21.8)	
Quartile 4	289 (39.4)	48 (21.1)	59 (24.3)	83 (28.1)	99 (40.8)	
Number of activity of daily living limitations						<.001
0	847 (73.9)	196 (81.2)	217 (76.4)	242 (77.2)	192 (63.5)	
1–2	192 (19.5)	28 (15.5)	52 (21.2)	56 (17.9)	56 (22.5)	
3–5	58 (6.6)	5 (3.3)	6 (2.4)	12 (4.9)	35 (14.0)	
Number of instrumental activity of daily living limitations						<.001
0	903 (79.9)	215 (92.7)	236 (84.3)	257 (81.3)	195 (66.1)	
1–2	163 (16.4)	13 (6.9)	33 (13.9)	49 (16.1)	68 (25.1)	
3–5	31 (3.7)	1 (0.4)	6 (1.8)	4 (2.6)	20 (8.8)	
Depressed mood (Center for Epidemiologic Studies Depression Scale score (range 0–8))						<.001
No (0)	432 (36.0)	110 (42.7)	137 (47.3)	119 (38.0)	66 (20.2)	
Mild (1–3)	475 (45.3)	95 (45.0)	107 (41.9)	141 (48.0)	132 (45.5)	
Moderate to severe (4–8)	190 (18.7)	24 (12.3)	31 (10.8)	50 (14.0)	85 (34.3)	
Social support (diabetes mellitus–related social support score (range 0–8))						.05

(*Continued*)

Table 1. (Contd.)

Characterstic	All Respondents n (%)	HRS Cognitive Scale, n (Weighted %)				*P*-Value*
		Quartile 4 (Best)	Quartile 3	Quartile 2	Quartile 1 (Worst)	
Low (0)	664 (63.8)	145 (66.4)	168 (68.9)	189 (63.5)	162 (58.9)	
Intermediate (1–5)	245 (22.1)	47 (22.7)	59 (20.1)	77 (24.8)	62 (21.4)	
High (6–8)	143 (14.1)	25 (10.9)	30 (11.0)	36 (11.7)	52 (19.7)	
Self-reported understanding of diabetes mellitus score (range 0–10))						.30
Low (0–5)	146 (13.5)	24 (8.7)	37 (15.1)	41 (13.2)	44 (15.9)	
Intermediate (6–8)	244 (24.8)	52 (25.9)	55 (24.1)	70 (22.3)	67 (27.3)	
High (9–10)	674 (61.7)	146 (65.4)	175 (60.8)	193 (64.5)	160 (56.8)	

Note: Data were obtained from the 2004 wave of the HRS and the 2003 HRS Mail Survey on Diabetes. Values in parentheses are weighted percentages derived using the study population weights to adjust for the complex sampling design of the HRS survey.

* *P*-values were derived from the chi-square test for association between the indicated variable and cognitive quartile levels.

ables, social support for diabetes mellitus care, depressed mood, knowledge of diabetes mellitus, functional disability, and diabetes mellitus comorbidities) were added to the bivariate model. The change in the odds ratio (OR) for higher HbA1c from the unadjusted model was assessed. To assess the extent to which level of social support for diabetes mellitus care modifies the risk of worse glycemic control in people with cognitive impairment, associations between the 12 mutually exclusive groups categorized based on the level of cognitive function and social support with glycemic control were examined in the fully adjusted model. Adjusted ORs were used to compare the relative strength of the association between each variable and glycemic control. In model checking, that the proportional odds assumption was not violated was verified by checking for the same OR from two logistic regression models with dichotomized dependent variables indicating whether HbA1c level was lower than 7.0 versus 7.0 or higher or was lower than 8.0 versus 8.0 or higher. The proportional odds assumption was statistically verified using the Score test.[29]

To assess the robustness of the results, the same analysis was repeated using data from the 2002 wave of the HRS, and the results were compared with those from the analysis using 2004 data. Independent variables that were missing for more than 10% of observations were imputed using proxy rating score of respondent memory for cognitive data and using the conditional mean imputation procedure and missing-value regressions in STATA for the other variables (StataCorp, College Station, TX). Then the results were compared with those from the complete case analysis. Imputation of respondent cognitive data according to proxy rating score has been used in previous studies using the HRS.[3,20] All analyses were weighted and adjusted for the complex sampling design (stratification, clustering, and nonresponse) of the HRS. STATA version 10.1 was used for data analysis. All reported *P*-values are two-tailed, and a *P*-value $<.05$ was considered statistically significant.

RESULTS

Characteristics of the Study Population

Of the 1,233 individuals with valid HbA1c samples, the HRS-cog score was missing for 136 (11%), so the resulting sample size was 1,097. The characteristics of the study population according to quartile of cognitive function are shown in Table 1. These data were obtained from the 2004 wave of the HRS and the 2003 Mail Survey on Diabetes. Quartile 4 is individuals with the best cognitive function, and quartile 1 is those with the worst cognitive function. Individuals with worse cognitive function were older and more likely to be African American, less educated, uninsured, and lower income. Their diabetes mellitus history tended to be longer than those with better cognitive function. In addition, individuals with diabetes mellitus with worse cognitive function tended to have more comorbid medical problems, more-depressed mood, higher likelihood of receiving insulin therapy, and higher level of support for diabetes mellitus care from their family and friends.

Association with Glycemic Control

Bivariate ordered logistic regression analyses were performed to examine the unadjusted association between each characteristic and the three ordinal levels of HbA1c (<7.0, 7.0–7.9, ≥ 8.0 mg/dL) (Table 2, first column). The cognition variables in the first four rows of the table represent the odds of a higher HbA1c level in each lower cognitive quartile group (quartile 3, 2, and 1) compared with the highest HRS-cog quartile group (quartile 4). Individuals with HRS-cog scores in the lowest quartile had significantly higher HbA1c level than those in the highest cognitive quartile (unadjusted OR = 2.08; 95% confidence interval (CI) = 1.37–3.15). Nonwhite race (black or other), longer duration of diabetes mellitus, higher CES-D score (more-depressed mood), and taking insulin were all associated with higher HbA1c level. Older age was associated with lower HbA1c level.

Figure 2 shows ORs and 95% CIs of higher HbA1c level for the lowest-performing cognitive group (quartile 1) compared with the highest-performing cognitive group (quartile 4) derived using different ordered logistic regression models. The change of the OR from the unadjusted model to the models adjusting for different independent variables was examined to assess their confounding or mediating effects on the relationship between cognitive impairment and glycemic control. When adjusting for diabetes

Table 2. Risk of Worse Glycemic Control

Variable	OR (95% Confidence Interval)	
	Unadjusted Model	Fully Adjusted Model
Cognitive function		
Quartile 4 (best)	Reference	Reference
Quartile 3	1.10 (0.70–1.73)	1.29 (0.79–2.10)
Quartile 2	1.36 (0.90–2.06)	1.22 (0.75–2.00)
Quartile 1 (worst)	2.08 (1.37–3.15)	1.80 (1.11–2.92)
Age, per level	0.84 (0.70–1.00)	0.76 (0.63–.091)
Female sex	1.05 (0.80–1.37)	1.14 (0.79–1.63)
Race		
White	Reference	Reference
Black	2.05 (1.34–3.14)	1.50 (0.96–2.34)
Other	3.33 (1.90–5.83)	2.89 (1.49–5.60)
Education, per level	0.89 (0.75–1.05)	1.05 (0.84–1.31)
Annual household income, per level	0.92 (0.80–1.05)	1.10 (0.93–1.29)
Uninsured	0.89 (0.45–1.77)	0.77 (0.34–1.75)
Duration of diabetes mellitus, per level	1.65 (1.39–1.97)	1.70 (1.40–2.07)
Social support for diabetes care		
High	Reference	Reference
Intermediate	1.37 (0.84–2.23)	1.50 (0.82–2.74)
Low	1.31 (0.86–1.98)	1.41 (0.83–2.41)
Depressed mood		
No	Reference	Reference
Mild	1.61 (1.21–2.13)	1.54 (1.09–2.18)
Moderate to severe	2.40 (1.61–3.57)	2.42 (1.48–3.97)
Understanding of diabetes mellitus		
Low	Reference	Reference
Intermediate	1.20 (0.69–2.07)	0.83 (0.46–1.49)
High	1.06 (0.69–1.64)	0.87 (0.49–1.55)
Hyperglycemic treatment		
Oral medicines	1.21 (0.81–1.81)	NA
Insulin	3.77 (2.84–5.00)	NA
Functional limitations		
Activity of daily living limitations	1.04 (0.90–1.20)	NA
Instrumental activity of daily living limitations	1.08 (0.93–1.25)	NA
Diabetes mellitus comorbidity: Total Illness Burden Index, per quartile	1.24 (1.09–1.41)	NA

Note: Odds ratios (ORs) derived using an ordered logistic regression model with glycosylated hemoglobin level (<7.0, 7.0–7.9, ≥8.0 mg/dL) as the dependent variable. ORs greater than 1 indicate greater odds of worse glycemic control.

mellitus–related social support (the second line), the OR for worse glycemic control increased from 2.08 in the unadjusted model to 2.20 as the result of a high proportion of individuals receiving a higher level of social support in the lowest cognitive quartile and an association between higher level of social support and better glycemic control. Because depressed mood was significantly associated with higher HbA1c level (unadjusted model in Table 2) and worse cognitive function (Table 1), the OR dropped from 2.08 to 1.77 when adjusting for depression (the third line). When self-reported knowledge of diabetes mellitus (the fourth line) was adjusted for, the OR dropped from 2.08 to 1.97, consistent with the hypothesis that understanding acts as a mediator between cognitive impairment and glycemic control. Adjusting for use of diabetes mellitus treatment (oral medicines and insulin) (the fifth line) reduced the OR significantly, probably because of the high proportion of individuals with diabetes mellitus taking insulin in the lowest cognitive quartile (Table 1) and the strong association between use of insulin and higher HbA1c level (OR = 3.77). When functional disability and diabetes mellitus comorbidity (the sixth line) were adjusted for, the OR dropped slightly, from 2.08 to 1.96. In the fully adjusted model, the OR of worse glycemic control for the lowest-performing cognitive quartile remained significant (OR = 1.80, 95% CI = 1.11–2.92).

Value of Social Support for Diabetes Mellitus Care

Figure 3 demonstrates the ORs for the risk of worse glycemic control for mutually exclusive groups categorized based on the level of cognitive function and social support for diabetes mellitus care. The ORs indicate risk for each group compared with the group with the best cognitive function and highest level of social support (OR = 1.0 as reference). For individuals in the worst cognitive quartile, the risk of worse glycemic control in those with a high level of social support was considerably lower than that of those with an intermediate level ($P = .17$) and those with a low level of social support ($P = .02$). A significant trend was found of lower risk with higher levels of social support in this cognitive group (the test for trend, $P = .02$).

Sensitivity Analysis

Some of the independent variables included in the analyses (e.g., HRS-cog score, social support for diabetes mellitus care, duration of diabetes mellitus, and self-reported diabetes mellitus knowledge score) were missing in more than 10% of observations. For the 11.0% of individuals represented by a proxy, cognitive function was imputed using a proxy rating of respondent memory in a manner similar to previous studies,[3,20] and the other variables were imputed using a conditional mean imputation procedure and missing-value regressions in Stata. For the conditional mean imputation, the mean value of the other respondents' observations by each cognitive level was used. The analyses using these imputation procedures generated results similar to those in the complete case analysis.

The analysis was also repeated using data on cognitive function and depressive symptoms from the 2002 wave of the HRS (rather than the 2004 wave) to check the robustness of the results. Similar results were obtained for the relationship between cognitive impairment and worse glycemic control (adjusted ORs of higher HbA1c for cognitive quartile 3, 2, and 1 compared with quartile 4 were 1.02, 1.01, and 1.47 ($P = .14$), respectively).

DISCUSSION

In a nationally representative sample of U.S. adults, it was found that cognitive impairment was associated with worse glycemic control in those with diabetes mellitus. In particular, individuals in the worst quartile of cognitive function

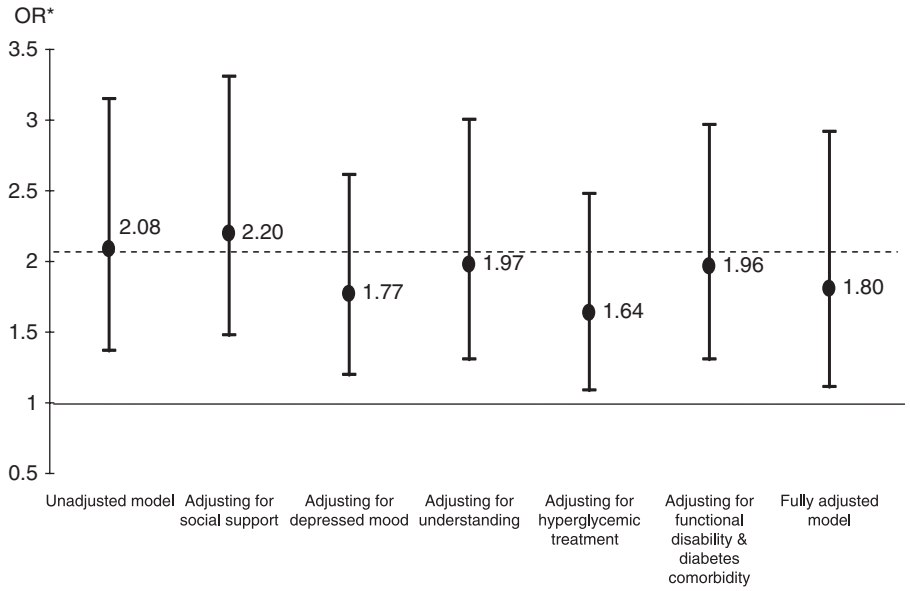

Figure 2. Change of strength of association between the worst cognitive quartile and worse glycemic control after adjusting for different independent variables. *Note*: *OR indicates the odds ratio of higher glycosylated hemoglobin for the worst cognitive quartile (quartile 1) compared to the best cognitive quartile (quartile 4). ORs greater than 1 indicate greater odds of worse glycemic control. Whiskers indicate 95% confidence intervals.

had significantly higher risk of poor glycemic control than those in the highest cognitive function quartile, independent of sociodemographic characteristics and other clinical factors. It was also found that, for individuals with poor cognitive function, a high level of social support for diabetes mellitus care significantly ameliorated the risk of worse glycemic control. Consistent with prior studies,[10,13] individuals with depressed mood had higher risk of poor

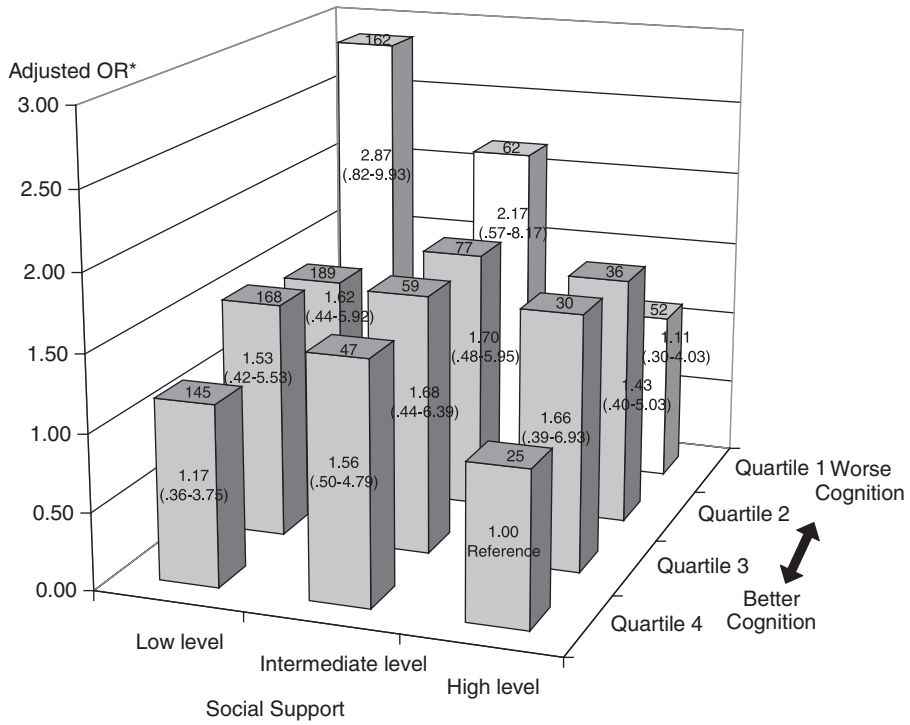

Figure 3. Odds ratios (ORs) for risk of worse glycemic control according to level of cognitive function and social support for diabetes care.*Note*: *Adjusted ORs derived using an ordered logistic regression model with glycosylated hemoglobin level (<7.0, 7.0–7.9, ≥8.0 mg/dL) as the dependent variable. The ORs indicate a relative strength of risk for the groups categorized based on the level of cognitive function and social support for diabetes mellitus care compared with the group of the best cognition function and the highest level of social support (OR = 1.0 as reference). The number on the front side of the bar indicates the OR for each group, and 95% confidence intervals are in the parentheses. The number on top of the bar indicates the sample size.

glycemic control, independent of cognitive impairment and level of social support. To the authors' knowledge, this is the first population-based study to examine an association between cognitive function and glycemic control in adults with diabetes mellitus and the modifying effects of a high level of social support on this association.

Effective self-management of diabetes mellitus often requires the coordination of multiple daily tasks requiring complex cognitive functioning. Potential mechanisms leading from worse cognitive function to worse glycemic control may include difficulties with learning and retaining new knowledge about diabetes mellitus and self-care skills, recognizing the importance of diabetes mellitus self-care, planning and organizing daily tasks for glycemic control, and motivation to adhere to self-care plans. It has been suggested that knowledge about diabetes mellitus was associated with self-management behaviors and glycemic control in individuals with diabetes mellitus.[30] The current study found that the risk of poor glycemic control for individuals with diabetes mellitus in the lowest cognitive function quartile remained high even after adjusting for self-reported knowledge about diabetes mellitus. This suggests that understanding and knowledge may be necessary, but not sufficient, for successful diabetes mellitus self-care,[31] which is also consistent with other studies suggesting an association between health literacy,[8] numeracy,[9] and impairment of executive control function and management of diabetes mellitus.[5,7]

Numerous studies have examined the relationship between diabetes mellitus and poor glycemic control and the risk of the development or progression of cognitive impairment, although the causal mechanisms are unclear.[32–38] The current study hypothesized that cognitive impairment leads to poor glycemic control due to less-effective self-management of diabetes mellitus. The findings that individuals with low levels of cognition reported higher levels of social support for their diabetes mellitus care than those with normal cognition and that higher levels of social support ameliorated the negative relationship between cognitive function and glycemic control support this hypothesis. Prior studies have suggested that social support is associated with better performance on self-care tasks but not with better glycemic control.[39,40] This is consistent with the current finding that social support for diabetes mellitus care was a modifier of the relationship between cognitive function and glycemic control. The results of the current study support a recent Institute of Medicine report that highlighted the importance of caregiver involvement in chronic illness management for older adults.[41]

The strengths of the current study include its nationally representative sample of U.S. adults and direct measures of cognitive function and HbA1c. It was possible to use important clinical and social information specific to diabetes mellitus care obtained from the population-based disease-specific survey. This study also has a number of potential limitations that should be considered when interpreting the results. The HRS-cog has been used consistently in the HRS, but it has not been calibrated and validated with other commonly used cognitive scales. A recently completed dementia substudy of the HRS—the Aging, Demographics, and Memory Study—administered the MMSE and HRS-cog to each respondent, so future analyses of these data will allow a calibration and validation of the instrument. For reliability of the cognition test, the analysis was repeated using cognition data from two waves of the HRS 2 years apart, and the results were consistent. Some of the independent variables were based on respondent self-report and thus may be subject to response bias. Although there were some missing data, the results were robust even after repeating the analysis using several different imputation procedures. The difference in timing between the 2003 Mail Survey on Diabetes and the 2002 and 2004 waves of the HRS may have resulted in some measurement error, because the clinical characteristics (e.g., HbA1c, cognitive function, depressed mood) and associated diabetes mellitus survey responses may have changed over time. Because this is a cross-sectional study, the direction of causality between cognitive impairment and glycemic control is not certain.

In summary, thse findings suggest that cognitive impairment is associated with worse glycemic control in older adults with diabetes mellitus, but the presence of a high level of social support for diabetes mellitus care may ameliorate this negative relationship. A comprehensive geriatric assessment aimed at identifying the presence of cognitive impairment, depressed mood, and level of social support may be important in identifying older adults with diabetes mellitus who are at risk for poor glycemic control and need additional support for the care of their diabetes mellitus. The growing number of older adults with diabetes mellitus makes targeting interventions to improve glycemic control an especially important public health goal.

ACKNOWLEDGMENTS

The National Institute on Aging (NIA) provided funding for the Health and Retirement Study (U01 AG09740), data from which were used for this analysis. The Health and Retirement Study is performed at the Survey Research Center, Institute for Social Research, University of Michigan. Additional support was provided by NIA grant R01 AG027010.

Conflict of Interest: The editor in chief has determined that none of the authors have a conflict of interest with reference to this paper.

Author Contributions: Toru Okura and Kenneth M. Langa: study concept and design, acquisition of data, analysis and interpretation of data, and preparation of manuscript. Michele Heisler: study concept and design, interpretation of data and preparation of manuscript.

Sponsor's Role: The funding agencies had no role in the study design; in the collection, analysis, and interpretation of data; in the writing of the report; and in the decision to submit the article for publication.

[Acknowledgments section added after online publication August 13, 2009]

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