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Associations of literacy with diabetes indicators in older adults

Melissa Lamar, Ph.D.^{1,2}, Robert S. Wilson, Ph.D.^{1,2,3}, Lei Yu, Ph.D.^{1,3}, Bryan D. James, Ph.D.^{1,4}, Christopher C. Stewart, Ph.D.², David A. Bennett, M.D.^{1,3}, and Patricia Boyle, Ph.D.^{1,2}

¹Rush Alzheimer's Disease Center, 1750 W Harrison Street, Suite 1000,

²Department of Behavioral Sciences, 1645 W Jackson Blvd, Suite 400, Chicago, IL, 60612, USA.

³Departments of Neurological Sciences, Rush University Medical Center, Chicago, IL, 60612, USA.

⁴Internal Medicine, 1653 W Congress Parkway, Rush University Medical Center, Chicago, IL, 60612, USA.

Abstract

Background: Literacy, the ability to access, understand, and utilize information and concepts from diverse sources in ways that promote good outcomes is key to successful aging. Domain-specific health and financial literacy are particularly relevant to older adults as they face increasingly complex health and financial demands including those related to chronic conditions like type 2 diabetes. We therefore investigated the associations of literacy, including health and financial literacy, with diabetes indicators (i.e., hemoglobin A1c and blood glucose) in a community-based cohort study of aging.

Methods: Participants were 908 non-demented older adults (age~81y;75% women) from the Rush Memory and Aging Project. Literacy was measured using questions designed to assess comprehension of health and financial information and concepts and yielded a total score and domain-specific health and financial literacy scores. Non-fasting hemoglobin A1c and blood glucose samples were collected, participants were queried about diabetes status, and medications for diabetes were visually inspected and coded. Participants also underwent a cognitive assessment, medical history, and depressive symptom screening.

Results: In separate multivariable linear regression models, total (p-values 0.03) and health (p-values 0.009) literacy were inversely associated with hemoglobin A1c and blood glucose levels after adjusting for age, sex, education, hypertension, global cognitive functioning and depressive symptoms. Financial literacy was inversely associated with hemoglobin A1c levels in adjusted

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Corresponding Author: Melissa Lamar, Ph.D., Associate Professor, Rush Alzheimer's Disease Center, Rush University Medical Center, 1750 W Harrison Street, Suite 1000, Chicago, IL, 60612. Phone: (312) 942-3365, melissa_lamar@rush.edu.

Competing Interest
None declared.

models ($p=0.04$). Sensitivity analyses conducted among individuals without diabetes revealed similar results.

Conclusion: Lower literacy levels are associated with higher diabetes indicators, particularly hemoglobin A1c which is suggestive of longer-term glycemic instability. Further, these associations are independent of diabetes status.

Introduction

Literacy is a key determinant of independence and health across the lifespan but is increasingly important at older ages when individuals face increasingly complex medical and financial pressures. Health literacy, defined as the ability to access, understand, and utilize health information and concepts in ways that promote good health outcomes (1–3), is critical to navigating self-care and lifestyle modifications associated with chronic diseases commonly faced by older persons such as type 2 diabetes. Likewise, adequate financial literacy (3), which may be relevant to preventing cost-related nonadherence in high-risk groups such as individuals with diabetes and other chronic conditions (4). Approximately 10 million individuals 65 are currently diagnosed with diabetes and 48.3% of remaining individuals in this same age range have prediabetes, i.e., elevated levels of hemoglobin A1c or blood glucose (5). When combined with the fact that adults 65 and older display surprisingly low levels of health and financial literacy (6, 7), it is important to ascertain the relationship between literacy and diabetes indicators in older adults with and without diabetes and to determine whether such associations are independent of diabetes status.

Our group and others have investigated the relationship between literacy and various negative health outcomes. Lower levels of health and financial literacy are associated with less frequent participation in health promoting behaviors (1, 8), poorer decision making (3), greater cognitive decline (9), incident dementia (10) and mortality (11). Despite the fact that poor cognition is linked to lower health literacy in adults with diabetes (12), and that lower health literacy, and to a lesser extent financial literacy, have been associated with poorer self-management of diabetes (13) and nonadherence to glucose-lowering agents [for review(14)], no study, to our knowledge, has examined the association of literacy with hemoglobin A1c and blood glucose levels and determined whether these associations are independent of diabetes status. This is particularly important given that older adults without diabetes but with elevated levels of diabetes indicators may benefit from improvements in literacy and subsequently health promoting behaviors to reduce diabetes risk.

This study examines the associations between literacy, i.e., health, financial, and total literacy, and objectively measured diabetes indicators, i.e., hemoglobin A1c and blood glucose levels, in a community-dwelling cohort of older adults with and without diabetes. Based on previous studies in patients with diabetes (15–17), we hypothesize that lower levels of health, financial, and total literacy would be associated with elevated levels of hemoglobin A1c and blood glucose. Declines in cognition are seen with aging (18, 19) and diabetes (20, 21) and also contribute to lower literacy in older adults (2); however, our work suggests that literacy, regardless of type, is a relatively distinct construct influenced by but not equivalent to cognition. Thus, we further hypothesize that the associations between our

three literacy measures and diabetes indicators will remain after controlling for age, global cognitive functioning and other relevant factors.

Methods

Participants

Individuals included in this research were participants from the Rush Memory and Aging Project (MAP; 1997-present), an ongoing longitudinal clinical-pathologic cohort study of aging (22, 23). The Institutional Review Board of Rush University Medical Center approved all studies and participants gave written informed consent in accordance with the Declaration of Helsinki. Participants were enrolled without known dementia and underwent annual clinical evaluations. Participants are asked to provide their Medicare Healthcare Insurance Claim number or social security number at the time of enrollment. Our most recent assessment of this information (April, 2018) revealed that 1,863 of the 1,929 MAP participants (96.57%) provided this information; thus, over 95% of our sample has health insurance in the form of Medicare.

MAP started in 1997 with an assessment of literacy introduced in 2010 (24). To date, 1,939 participants have enrolled and 1,921 have completed baseline evaluation including a cognitive evaluation. At the time of these analyses 1,146 participants were alive and active in MAP; of those, 1,056 had available literacy data. We excluded 62 participants who had dementia at the time of their literacy assessment (defined below). Of the remaining 994 participants, 908 (91%) participants had complete data on literacy and diabetes indicators.

Clinical Diagnosis

All participants underwent uniform structured clinical evaluations (23). The diagnosis of dementia was made by experienced clinicians and followed the National Institute of Neurologic and Communicative Disorders and Stroke and the Alzheimer's Disease and Related Disorders Association criteria (25). All participants in the current analyses were without dementia at the time of the literacy assessment.

Literacy Assessment

Literacy was assessed with 32 questions measuring knowledge of health and financial information and concepts, and numeracy (i.e., simple calculations) (1, 3). The health literacy component consisted of 9 questions assessing knowledge on leading causes of death in old age, the ability to follow prescription instructions, and understand drug risk and Medicare [e.g., Medicare Part D covers which of the following? (a) Inpatient hospital services, (b) Outpatient physician services, or (c) Prescription drug benefits']. The financial literacy component consisted of 23 questions, many adapted from the Health and Retirement Survey. Financial literacy questions assessed knowledge of economic concepts [e.g., 'A mutual fund is an investment that holds what? (a) Only stocks, (b) Only bonds, or (c) Stocks and bonds'] and ability to perform simple monetary calculation [e.g., 'If a television set is on sale for \$899, which is \$200 off its normal price, what is the normal price? (a) \$699, (b) \$1,099, or (c) \$1,299']. Questions, either multiple choice or true/false, were scored as correct or incorrect, and expressed as the percent correct of all items (0–100%) calculated separately

for health and financial literacy components. A composite score for total literacy was obtained by averaging health and financial literacy percentages. Total, health, and financial literacy scores have been shown to possess adequate psychometric properties (1, 3), and relate to many health behaviors (1, 9, 10).

Diabetes Indicators

Standard procedures were used to collect non-fasting blood samples. Phlebotomists and nurses skilled in venipuncture collected the blood specimen using sterile techniques. Specimens were then transferred to Quest Diagnostics for analyses. Tests important to this study involved a complete blood count for the quantification of hemoglobin A1c, expressed as a percentage of hemoglobin, and a basic metabolic panel which included a measurement of blood glucose (mg/dL). We investigated hemoglobin A1c and blood glucose given that each represents a distinct metric of blood sugar control: glucose for short- and hemoglobin A1c for long-term (i.e., 3-month) indicators of health.

Participants were queried about diabetes status and supplied all medications prescribed by a doctor, vitamins, supplements, and over-the-counter remedies/medicines taken in the 2 weeks prior to the study visit. Visual inspection of all containers allowed for medication documentation. Medications were coded using the Medi-Span Drug Data Base system (26) including prescription medications for diabetes (insulin and non-insulin related). An individual was deemed positive for diabetes based on self-reported diabetes and/or possessing prescription medications for diabetes.

Covariates

In addition to age, sex and years of education, we adjusted for variables outlined below. Given that over 95% of MAP participants are insured through Medicare, we did not adjust for insurance status or access to care.

Hypertension Status —Given hypertension is present in ~70% of individuals with diabetes in the US (27), we included hypertension status as a covariate. Blood pressure (BP) was measured in the right arm with a mercury sphygmomanometer by trained research assistants (28). Two seated BP readings were taken at 30 second intervals following a 5-minute rest period; 1 minute after being requested to stand, a standing BP was taken. Systolic and diastolic BP was calculated separately by averaging all three readings. Hypertension was defined as systolic BP ≥ 140 mmHg or diastolic BP ≥ 90 mmHg or antihypertensive medication use (as outlined above). Individuals missing BP measurements (4.8% of the sample) were still coded if their antihypertensive medication use was documented (32 were on medication, 15 were not).

Global Cognitive Functioning —All participants underwent an annual cognitive evaluation detailed elsewhere (2, 3, 22, 23). Briefly, cognitive tests were administered in an identical fashion at annual evaluations. A global composite score was created by converting raw scores on the 19 cognitive tests to standard (z) scores using the mean and standard deviation from the baseline evaluation. A person's standard scores across all tests were then averaged to yield a single composite score summarizing level of global cognitive function.

Depressive Symptomatology —Depressive symptoms were assessed with a 10-item version (29, 30) of the Center for Epidemiologic Studies of Depression scale (31). Participants were asked whether or not they experienced each of ten symptoms much of the time in the past week. The score reflected the total number of symptoms experienced (maximum=10).

Statistical Analyses

We tested bivariate associations between key participant characteristics and diabetes indicators, i.e., hemoglobin A1c and blood glucose levels, using correlations or independent sample t-tests as appropriate. We used linear regression models to examine the associations of literacy – total, health, and financial literacy (separately) – with diabetes indicators (separately for hemoglobin A1c and blood glucose). In these models, each diabetes indicator was the continuous outcome. All models included terms for age, sex, and education. Models were then repeated adding diabetes status (i.e., medication use and/or self-report of diabetes), hypertension status, global cognitive functioning, and depressive symptoms as covariates. We also performed a series of sensitivity analyses; e.g., we excluded individuals with self-reported diabetes and/or medication for diabetes to determine whether the relationship between literacy and diabetes indicators in older adults was independent of diabetes status. Analyses were programmed using SAS/STAT software, Version 9.4 of the SAS System for Linux (SAS Institute, Cary, NC).

Results

Participants were just over 80 years on average, and the mean years of education was approximately 15. Over 90% of participants were non-Latino White and the majority were female. Mean literacy scores ranged from roughly 70% for total literacy to just above 60% for health literacy. Average hemoglobin A1c was 5.9% or 41 mmol/mol and average blood glucose was 102.4 mg/dL. Approximately 10% of our sample was taking medication for diabetes; an additional 2% self-reported diabetes but were not taking medications for it. Almost 80% of our sample met criteria for hypertension. Other covariates are described in Table 1.

Bivariate correlations between key participant characteristics and diabetes indicators (Table 2) revealed that only hemoglobin A1c negatively correlated with education ($p=0.002$); neither hemoglobin A1c nor glucose correlated with age. Independent sample t-tests indicated that hemoglobin A1c levels did not differ by sex, but men (110.0 ± 45.0 mg/dL) had higher glucose levels than women (100.0 ± 28.2 mg/dL; $p=0.002$). All three literacy measures were negatively correlated with hemoglobin A1c (p -values 0.003), while total and health literacy scores were negatively correlated with glucose (p -values 0.01). Both diabetes indicators negatively correlated with global cognition and positively correlated with depressive symptoms (p -values 0.03).

Association of Literacy with Diabetes Indicators

We first examined the association of total literacy with indicators of diabetes. In a regression model adjusted for age, sex, and education, there was an inverse association of total literacy

with hemoglobin A1c ($p=0.0007$). This association of lower literacy scores with higher levels of hemoglobin A1c remained after additional adjustments for diabetes status, hypertension status, global cognitive functioning, and depressive symptoms (specific estimates in Table 3). Likewise, in a regression model adjusted for age, sex, and education, there was an association of lower total literacy with higher blood glucose levels ($p=0.01$) that remained after additional adjustments for diabetes and hypertension status, global cognitive functioning, and depressive symptoms (Table 3).

Next, we examined the association of health and financial literacy (separately) with diabetes indicators. In a regression model adjusted for age, sex, and education, there was an inverse association of health literacy ($p=0.004$) with hemoglobin A1c. This significant association of lower health literacy and higher hemoglobin A1c levels remained after adjustments for diabetes and hypertension status, global cognitive functioning, and depressive symptoms (specific estimates in Table 4). In a regression model adjusted for age, sex, and education, there was an inverse association of lower health literacy ($p=0.03$) with higher glucose levels that remained regardless of additional adjustments (Table 4).

There was an association of lower financial literacy (estimate = -0.004 , SE = 0.001 , $p=0.005$) with higher hemoglobin A1c levels after adjusting for age, sex, and education that remained after additional adjustments for diabetes and hypertension status, global cognitive functioning, and depressive symptoms (estimate = -0.002 , SE = 0.001 , $p=0.04$). The association of financial literacy with glucose was not significant regardless of adjustments.

Sensitivity analyses

To further examine the robustness of our findings, we conducted a series of sensitivity analyses. First, we excluded individuals who self-reported diabetes and/or were on medications for diabetes at the time of their evaluation ($n=114$) to determine whether our reported associations were independent of diabetes status but remained related to the spectrum of normal to preclinical levels of disease, i.e., prior to diagnosis or treatment. Without individuals with diabetes, the associations of lower total literacy with higher hemoglobin A1c and blood glucose levels were unchanged (p -values 0.04). Likewise, the associations of lower health literacy with higher levels of these same diabetes indicators were also unchanged (p -values 0.02). Analyses excluding individuals with diabetes revealed a similar association between lower financial literacy and higher hemoglobin A1c, however, the fully adjusted model was not significant (estimate = -0.001 , SE = 0.001 , $p=0.12$). Second, we investigated the association of literacy with diabetes status to help determine the explicit relationship of literacy to diabetes status in our sample. The associations of literacy – total, health, and financial literacy (separately) – with diabetes status were not significant regardless of adjustments (p -values 0.12).

Discussion

We investigated the association of literacy with diabetes indicators in a community-based study of more than 900 non-demented older adults with and without diabetes, the majority of whom (~95%) had Medicare. Lower levels of literacy, particularly health literacy, were associated with higher levels of hemoglobin A1c and blood glucose. Lower levels of

financial literacy were associated with higher levels of hemoglobin A1c. These findings were not driven by persons with self-reported diabetes and/or medications for diabetes. Results suggest an important link between literacy and diabetes indicators in old age, a link that is present among persons with elevated levels of diabetes indicators that may not come to the attention of the medical system for diabetes-related issues.

These results build upon the literature on literacy and diabetes in several ways. First, the majority of studies investigating the association of literacy, specifically health literacy, with diabetes indicators are conducted in patients with diabetes from primary care clinics (32, 33, 35) or community-based volunteers with diabetes (17, 36). In contrast, our study investigated the associations of literacy, health *and* financial literacy, with diabetes indicators in participants across the spectrum of normal, preclinical, and diabetic levels of hemoglobin A1c and blood glucose. Results suggest that lower levels of total and health literacy are associated with elevations in diabetes indicators. Second, sensitivity analyses excluding individuals with self-reported diabetes and/or medications for diabetes did not change these results. Taken together, this suggests that practitioners should not wait until they diagnose an older patient with diabetes to discuss information and concepts to promote good health outcomes, rather they should intervene to increase literacy at all levels of glycemic control. This is particularly important given that a recent meta-analysis found even slight increases in diabetes indicators increases the risk for cardiovascular disease, coronary heart disease and/or stroke in individuals with prediabetes (37).

Third, this study extends previous work (4, 13) demonstrating the importance of adequate levels of financial literacy for preventing cost-related nonadherence in individuals with diabetes. More specifically, our results revealed that lower levels of financial literacy were associated with higher levels of hemoglobin A1c, suggestive of longer-term glycemic instability, in individuals with and without diabetes. Thus, the association of literacy with diabetes indicators does not appear to be confined to total and health literacy but may extend to include financial literacy. Sensitivity analyses revealed a similar association between financial literacy and hemoglobin A1c independent of diabetes status; however, this association did not reach the statistical significance likely due to the reduced sample size. Whether these associations reflect cost-related nonadherence to a healthy lifestyle or portend development of incident diabetes in individuals at preclinical levels of risk is the focus of ongoing work in our group.

While the basis of the association between literacy and diabetes indicators in older adults remains unclear, literacy promotes engagement in positive health behaviors across the lifespan which may lead to better health status in older age. For example, literacy has been associated with physical and cognitive activity (1), smoking cessation (38), increased physical functioning, and slower declines in physical functioning over time (39). Although we did not assess specific health promoting behaviors associated with diabetes and/or blood sugar management, our reported relationship between literacy and diabetes indicators remained significant after controlling for factors associated with physical and mental health status including hypertension, global cognitive functioning, and depression. Additionally, these relationships were independent of diabetes status. There is also evidence that literacy is associated with increases in disease-specific knowledge (35, 36, 40), particularly when older

adults are diagnosed with a disease and exposed to the health care system. Our data would suggest, however, that literacy is involved with health indicators even before a medical condition explicitly manifests or is diagnosed. Thus, our findings suggest that higher literacy levels may provide health benefits even for older adults without overt disease. Future studies are needed to address this; however, we suspect that the benefits of increasing literacy may extend to a host of chronic diseases among older adults.

This study has a number of strengths including a detailed assessment of literacy, with a focus on domain-specific aspects that are important to successful aging regardless of diabetes status. We were able to use data from a fairly large cohort of community dwelling individuals free of dementia and conduct a series of sensitivity analyses considering the role of diabetes status. Furthermore, by adjusting for key characteristics known to impact literacy including global cognitive functioning, we were able to determine the independent relationship that literacy had to diabetes indicators. This study, however, is cross-sectional and does not address causality. Additionally, sensitivity analyses did not reveal associations between literacy and diabetes. While this is not uncommon in the literature (32–34), it may be due, in part, to an insufficient sample size of individuals meeting diabetes status criteria. Furthermore, meeting our study criteria for diabetes is not the same as meeting clinical criteria for diabetes. Our participants were primarily non-Latino White and highly educated, thus, our results may lack generalizability; more work is needed in racially and ethnically diverse populations. Even with these limitations, our findings associating literacy with diabetes indicators independent of diabetes status provide support for promoting literacy in older adults across the spectrum of health and disease.

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What is already known on this subject?

Lower levels of health and financial literacy are associated with less frequent participation in health promoting behaviors and poorer decision making. Despite the fact that lower health literacy, and to a lesser extent financial literacy, have been associated with poorer self-management of diabetes and nonadherence to glucose-lowering agents, no study, to our knowledge, has examined the association of literacy with diabetes indicators (i.e., hemoglobin A1c and/or glucose levels) in older adults without diabetes. This is particularly important given that older adults without diabetes but with elevated levels of diabetes indicators may benefit from improvements in literacy and subsequently health promoting behaviors to reduce diabetes risk.

What this study adds?

In a community-based sample of more than 900 non-demented older adults, lower levels of literacy, particularly health literacy, were associated with higher levels of hemoglobin A1c and blood glucose. Lower levels of financial literacy were associated with higher levels of hemoglobin A1c. These findings were independent of age, sex, education, other cardiovascular risk factors and global cognitive functioning; furthermore, they were not driven by persons with self-reported diabetes and/or medications for diabetes. Results suggests that practitioners should not wait until they diagnose an older patient with diabetes to discuss information and concepts to promote good health outcomes, rather they should intervene to increase literacy at all levels of glycemic control.

Table 1.

Participant Characteristics, Diabetes Indicators, and Literacy

	Values	Range
<i>Participant Characteristics</i>		
Age (years)	81.20±7.52	58.81 – 100.77
Education (years)	15.46 ±3.03	5 – 28
Sex (female), n	75.33%, n=684	
Global Cognitive Functioning	0.23±0.50	–1.56 – 1.63
Depressive Symptoms	0.88±1.43	0 – 9
<i>Diabetes Indicators</i>		
Hemoglobin A1c (%)	5.90±0.60	4.40 – 10.70
(mmol/mol)	41.00±6.6	25 – 93
Glucose (mg/dL)	102.44±33.41	44 – 345
<i>Literacy (%)</i>		
Total Literacy	68.90±13.88	2.17 – 100.00
Health Literacy	63.27±17.68	0 – 100.00
Financial Literacy	74.52±15.31	4.34 – 100.00

Note: Data indicates mean±standard deviation unless otherwise noted. Total literacy is the average of health and financial literacy scores.

Table 2.

Correlation of Key Participant Characteristics and Diabetes Indicators

	Hemoglobin A1c (%)	Glucose (mg/dL)
Age (years)	0.02 (0.40)	0.04 (0.22)
Education (years)	−0.10 (0.002)	−0.05 (0.13)
Global Cognitive Functioning	−0.11 (0.0009)	−0.09 (0.006)
Depressive Symptoms	0.07 (0.02)	0.07 (0.03)
Total Literacy	−0.13 (<0.0001)	−0.08 (0.01)
Health Literacy	−0.12 (0.0002)	−0.10 (0.003)
Financial Literacy	−0.09 (0.003)	−0.03 (0.30)
Glucose (mg/dL)	--	0.61 (<0.0001)

Note: Values are Pearson correlation coefficient (p-value) with significance set at $p < 0.05$.

Table 3.

Associations of Total Literacy with Diabetes Indicators

Adjusted for:	Hemoglobin A1c (%)		Blood Glucose (mg/dL)	
	Core	Fully adjusted	Core	Fully adjusted
Age	-0.001 (0.002, p=0.57)	0.001 (0.002, p=0.48)	0.02 (0.15, p=0.88)	0.19 (0.13, p=0.17)
Sex	0.12 (0.04, p=0.006)	0.05 (0.03, p=0.12)	11.77 (2.61, p=0.00001)	8.16 (2.32, p=0.0004)
Education	-0.01 (0.007, p=0.05)	0.002 (0.005, p=0.63)	-0.47 (0.40, p=0.23)	0.23 (0.35, p=0.50)
Total Literacy	-0.005 (0.001, p=0.0007)	-0.005 (0.001, p=0.00008)	-0.21 (0.09, p=0.01)	-0.19 (0.09, p=0.03)
Diabetes Status		1.10 (0.04, p<0.00001)		50.19 (3.01, p<0.00001)
Hypertension Status		0.09 (0.04, p=0.02)		0.19 (2.43, p=0.93)
Global Cognition		-0.01 (0.04, p=0.71)		-1.45 (2.44, p=0.55)
Depressive Symptoms		-0.0003 (0.01, p=0.98)		0.37 (0.68, p=0.58)

Note: Values are unstandardized coefficient (SE, p-value) from linear regression models with significance set at p<0.05.

Table 4.

Associations of Health Literacy with Diabetes Indicators

Adjusted for:	Hemoglobin A1c (%)		Blood Glucose (mg/dL)	
	Core	Fully adjusted	Core	Fully adjusted
Age	-0.001 (0.002, p=0.772)	0.001 (0.002, p=0.46)	0.04 (0.15, p=0.78)	0.18 (0.13, p=0.17)
Sex	0.09 (0.04, p=0.03)	0.02 (0.03, p=0.57)	10.51 (2.60, p=0.00006)	6.83 (2.28, p=0.003)
Education	-0.01 (0.006, p=0.01)	0.001 (0.005, p=0.86)	-0.58 (0.38, p=0.12)	0.20 (0.34, p=0.56)
Health Literacy	-0.003 (0.001, p=0.004)	-0.004 (0.001, p=0.00007)	-0.14 (0.06, p=0.03)	-0.16 (0.06, p=0.009)
Diabetes Status		1.09 (0.04, p<0.00001)		50.49 (3.01, p<0.00001)
Hypertension Status		0.08 (0.04, p=0.03)		0.08 (2.42, p=0.97)
Global Cognition		-0.03 (0.03, p=0.42)		-1.60 (2.32, p=0.49)
Depressive Symptoms		0.001 (0.01, p=0.90)		0.43 (0.68, p=0.52)

Note: Values are unstandardized coefficient (SE, p-value) from linear regression models with significance set at p<0.05.