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Cognitive function is a risk for health literacy in older adults with diabetes

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Abstract

AIMS—Cognitive impairment is common in older adults with diabetes, yet it is unclear to what extent cognitive function is associated with health literacy. We hypothesized that cognitive function, independent of education, is associated with health literacy.

METHODS—The sample included 537 African American, American Indian, and White men and women 60 years or older. Measures of cognitive function included the Mini-Mental State Examination (MMSE), Verbal Fluency, Brief Attention, and Digit Span Backward tests. Health literacy was assessed using the S-TOFHLA.

RESULTS—Cognitive function was associated with health literacy, independent of education and other important confounders. Every unit increase in the MMSE, Digit Span Backward, Verbal Fluency or Brief Attention was associated with a 20% ($p<.001$), 34% ($p<.001$), 5% ($p<.01$), and 16% ($p<.01$) increase in the odds of having adequate health literacy, respectively.

CONCLUSIONS—These results suggest that cognitive function is associated with health literacy in older adults with diabetes. Because poor cognitive function may undermine health literacy, efforts to target older adults on improving health literacy should consider cognitive function as a risk factor.

Keywords

cognition; health literacy; diabetes

INTRODUCTION

Health literacy is a multi-faceted concept, defined as “the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed

to make appropriate health decisions” [1]. Health literacy is a set of skills that are important for navigating the health care system and making appropriate health decisions. Inadequate health literacy has been linked to increased health disparities, unsuccessful self-care, poor health outcomes, poor use of health care services, and among elderly persons, poor overall health status and high mortality rates [2].

Previous studies have linked health literacy with a broad set of cognitive abilities. Some health literacy skills, such as reading and numeracy, that were previously considered to be part of the global construct of cognitive function are now being recognized as fundamental cognitive abilities necessary for navigating and understanding the health care system [3-5]. Available data on the association of cognitive function with health literacy are limited, but there are reasons to believe that poor cognitive performance may contribute to low literacy skills. Individuals with inadequate health literacy have lower verbal ability for oral expression and verbal communication; lower mental processing ability for speed and efficiency of thought, comprehension of text and numerical information; poorer memory ability for recalling spoken instructions; lower perceptual speed ability for performance of e-health searches; and poorer executive function ability for critical thinking, weighing options, and making decisions and inferences [6-10].

Diabetes is a complex chronic disease for which successful management depends largely on self-care education and management. It requires a rigorous self-monitoring regimen including blood glucose and medication management and self-regulation of diet and physical activity to prevent and treat hypo- and hyperglycemia, along with regular foot, eye, and dental exams [11]. Diabetes self-management relies heavily on printed and verbal instructions and requires high health literacy skills [12]. There is a strong association between inadequate health literacy [13].

Older adults with diabetes have unique issues related to cognitive functioning that may affect their health literacy skills. Although cognitive impairment increases with age, this impairment is more significant in individuals with diabetes; up to 80% of individuals with Alzheimer's disease have been reported to have either type 2 diabetes or impaired fasting glucose [14]. Diabetes has been found to affect some domains of cognition such as processing speed and memory, but greater attention is now being directed to the association between diabetes and the executive functioning domain of cognition [15-17]. Executive function is a primary domain of cognition that involves a broad set of cognitive abilities such as sustaining attention, working memory, organization, and information processing that are necessary for intentional, problem-solving, and goal-directed behaviors, such as those required for diabetes self-care [18]. Diabetes-related cognitive deficits likely pose an increased risk to health literacy.

Because relatively little is known regarding the impact of cognitive function on health literacy, we examined the relation of cognitive function to health literacy in older adults with diabetes. This topic is particularly important because cognitive impairment is common in patients with diabetes, but cognitive function is often not screened or evaluated in this population [19]. Delineating the independent association of cognitive function with health literacy may have important implications, namely in the form of targeted interventions or educational strategies that are tailored to accommodate the cognitive changes associated with diabetes to address health literacy limitations.

MATERIALS and METHODS

Sample

Data for this study came from a larger study designed to document the beliefs and attitudes of diabetes management in older adults. Data collection was conducted from June 2009 through February 2010, and consisted of an interviewer-administered, fixed response questionnaire and a finger stick blood draw to test for hemoglobin A1C (HbA1c). All data collection was completed by trained research personnel. A federally authorized Institutional Review Board (FWA #00001435) approved all sampling, recruitment and data collection procedures. All participants gave written informed consent.

The research was conducted in eight south central North Carolina counties. A total of 593 African American, American Indian, and White men and women were recruited for this study. Inclusion criteria were age 60 years or older and having had a diabetes diagnosis for at least two years. We did not obtain data to differentiate between type 1 and type 2 diabetes. However, 92% of the participants reported that they were diagnosed with diabetes after the age of 35. There is a high likelihood that our data reflect a group of older adults with predominantly type 2 diabetes.

Project exclusion criteria were used to ensure that study participants were mentally competent to give consent and to participate in the study. We based our procedures on experience in other surveys conducted with rural older adults (e.g., [20,21]). Those with severe cognitive impairment or dementia were excluded from this study, and the clock-drawing test (CDT) was used to screen for this exclusion. The CDT has been found to be sensitive and useful in the clinical assessment of demented patients [22,23]. In addition, we recruited largely through community organizations, describing the study as one in which older adults would respond to questionnaires; anyone with obvious dementia would likely not have been referred. No one to whom we administered consent was unable to execute it. However, we excluded from the data analysis 26 participants with a MMSE score lower than 18. This may minimize findings related to severe cognitive impairment. We also excluded participants with a diagnosis of end-stage renal disease. The goal of the sampling plan was to recruit 100 participants for each ethnic/gender cell, with each cell having participants spread across educational attainment categories.

Participants were recruited from various organizations and locations within each county using site-based sampling [24]. Study staff members have conducted research in the region since 1996 [25]. Formal and informal community leaders provided support with study recruitment by introducing the study staff to recruitment locations and by verifying the legitimacy of the research project to elder participants. The number of participants from each type of recruitment location included: 124 from community-based organizations (veteran, civic groups, senior clubs, etc.), 40 from health-related community events, 43 from churches, 13 from flyer postings and public recruitment, 81 from senior housing, and 104 from congregate meal sites. An additional 188 were recruited through social networks of participants (106), community leaders (36), interviewers (22), and lists of past participants in studies that had used site-based sampling (24). The final sample in these analyses included 537 participants who had complete data.

Personal Characteristics and Potential Confounders

Personal characteristics included gender (male and female), age (continuous), education (< high school, high school graduate, and > high school), and ethnicity (non-Hispanic White, American Indian, and African American). Health indicators included self-reported medical conditions and depressive symptoms. Self-reported medical conditions were assessed by asking participants if they had ever been told by a doctor that they had any of the following

conditions: stroke, heart disease, and hypertension. The 20-item CES-D (Center for Epidemiologic Studies-Depression) was used to assess depressive symptoms, with responses “yes” and “no” based on the validation of this modification for this population [26]. A higher score indicates more depressive symptoms. The study obtained data on diabetes-related variables including duration of diabetes (measured in years) and the 16-item “Diabetes Knowledge Test” to evaluate participants’ knowledge of their diabetes in areas including nutrition, exercise, and glucose management and testing [27]. A higher score indicates greater diabetes knowledge. Medication for the treatment of diabetes was based on two separate yes/no questions, “Are you now taking insulin?”, and “Are you now taking diabetes pills?”. Blood glucose control was assessed by measuring HbA1c from a finger-stick blood sample. We used the procedures for the handheld Bayer A1cNow+ machine, which has demonstrated precision and accuracy in HbA1c testing [28].

Primary Predictor Variable: Measures of Cognitive Function

We selected cognitive tests that were widely used and cognitive domains, including global ability and executive function, that have been associated with diabetes [15,29]. The Mini-Mental State Examination (MMSE), a test of global cognitive ability, is among the most frequently used cognitive screening measures in studies of older adults [30]. Three measures of executive functioning were used. The Animal Verbal Fluency test assesses language ability related to executive function [31]. The Brief Attention Test is one of the most commonly used cognitive measures to assess attention and executive function [32]. The Digit Span Backward test from the Wechsler Memory Scale-III is a well-known and validated measure of working memory [33] and executive function [34]. These measures draw on a variety of cognitive skills such as sustaining attention, concentration, and organization that can have a tremendous impact on the individual's capacity to learn new information, perform what is already known, and adapt to new environments and challenges.

Outcome Variable: Health Literacy

All study participants were assigned to complete the widely used S-TOFHLA [35]. The S-TOFHLA includes both a reading comprehension and a numeracy section. Scores from each section are combined to give a score ranging from 0 to 100 and used to categorize participants into two levels of functional health literacy: inadequate (0 to 53) and adequate (54 to 100) [35].

Statistical Analysis

Two sets of analyses were performed. First, descriptive statistics were used to describe the study sample. Participants with inadequate health literacy were compared to participants with adequate health literacy in unadjusted analyses. A chi-square statistic was used to examine group differences in categorical variables. A t-test statistic was used to test differences in continuous variables between the two groups. Second, adequate health literacy was compared with the four measures of cognitive function in adjusted analyses. Separate multivariate logistic regression models were created to examine each of the cognitive measures as the primary predictor variables and adequate health literacy as the outcome. The models were adjusted for personal characteristics including gender, age, education, and ethnicity, health indicators including stroke, heart disease, hypertension, and depressive symptoms, and diabetes related variables including diabetes duration, diabetes knowledge score, taking insulin, taking diabetes pills, and HbA1c (Table 2). Statistical analysis was performed using SAS 9.1 (SAS Institute, Inc., Cary, NC).

RESULTS

The sample consisted of 333 women and 204 men. Approximately 55% of the study sample had inadequate health literacy. In bivariate analyses, age, education, and ethnicity were significantly associated with health literacy (Table 1). Specifically, those who had inadequate health literacy were more likely to be older and have lower levels of education. American Indian participants had the lowest levels of health literacy of the three ethnic groups. Participants who had been diagnosed with a stroke were less likely to have adequate health literacy. Those with higher depressive symptoms were more likely to have inadequate health literacy. Gender and duration of diabetes were marginally associated with health literacy; men and those with a longer duration of diabetes were more likely to have inadequate health literacy. Those with lower diabetes knowledge were much less likely to have adequate health literacy. Medications for the treatment of diabetes as well as HbA1c were not associated with health literacy. Statistically significant bivariate associations were observed between health literacy level and the score on all four cognitive tests.

In multivariate analysis, significant associations were seen for health literacy and education, ethnicity, and diabetes knowledge (Table 2). Participants with greater than a high school education were significantly more likely to have adequate health literacy than those with less than a high school education. Inadequate health literacy was greater for American Indian participants than for White participants. Higher diabetes knowledge was significantly associated with adequate health literacy.

All four indicators of cognitive function were significantly associated with health literacy, after adjustment for gender, age, education, ethnicity, stroke, heart disease, hypertension, depressive symptoms, diabetes duration, diabetes knowledge, taking insulin, taking diabetes pills, and HbA1c. Every unit increase in the MMSE was associated with a 20% increase in the odds of having adequate health literacy. For each unit increase in the Digit Span Backward, the odds of adequate health literacy increased by an estimated 34%. Every unit increase in the Verbal Fluency or Brief Attention was associated with a 5% and 16% increase in the odds of having adequate health literacy, respectively.

DISCUSSION

As in other studies [7,10], the present results suggest that inadequate health literacy is high among older adults with diabetes. About 55% of the study sample had inadequate health literacy. In addition, the study indicates that those with less than a high school education and members of minority populations, particularly American Indian participants, are more likely to have inadequate health literacy. Previous studies also show that the personal characteristics of those having inadequate literacy skills overlap with those identified at highest risk for health problems, poor health outcomes, and increased use of health care services [2].

Inadequate health literacy is highly prevalent in older adults [36]; however, there are few data to indicate that cognitive function is a risk factor for health literacy particularly among older adults with diabetes [7,10]. This study found a clear relationship between cognitive function and health literacy, adjusting for education and other confounders. This relationship is consistent with previous studies that strongly suggest that the problem of limited health literacy mostly reflects individual differences across a broad set of cognitive abilities [3,7,37]. Health literacy requires reading and numeracy abilities, but also involves a multitude of cognitive processes such as speed and efficiency of thought and tasks of executive function including working memory, organization, and problem solving [9,10,38,39]. For example, we found a strong association between health literacy and the

Digit Span Backward, a measure of working memory and executive function. Previous studies have identified working memory as a cognitive ability relevant to recalling of medical information and understanding of text [40], and the findings have been used to design health materials that minimize cognitive demands. More specifically, increases in the use of working memory resources have an adverse impact on recall of medical information while learning or recalling of medical information is more effective when the load on working memory is kept to a minimum [41].

This study has limitations. The sample was not randomly selected, so the results may not be generalizable. However, the sample was large and included considerable variation in ethnicity and educational attainment. Though we included multiple indicators of executive function as well as a more crude, global screening tool (i.e., MMSE), we did not include other cognitive domains such processing speed. Our selection of the MMSE and specific cognitive tests were guided by previous studies of cognitive function in older adults with diabetes [15,16,42]. The results of this study demonstrate that each of the cognitive tests was independently and significantly associated with health literacy. Future research should more fully explore the relationships of other cognitive domains with health literacy. The S-TOFHLA has been widely used to identify patients with inadequate health literacy, but it is limited to aspects of reading comprehension and numeracy. Prior studies suggest that estimates of inadequate health literacy varied by the assessment tool used [43].

Limitations notwithstanding, the results of this study have important implications. Treatment for diabetes typically is multifaceted and often delivered through Diabetes Self-Management Education (DSME) programs. Health literacy skills are necessary for many self-care activities associated with DSME programs [13]. Inadequate health literacy poses significant diabetes self-care barriers for all older adults, but the impact for those with low cognitive function is likely to be more intensified [44]. Before beginning a DSME program, patients' cognitive function should be evaluated to determine their ability to comprehend and perform self-care skills. Cognitive function may need to be assessed more frequently in this patient population to keep pace with cognitive changes associated with diabetes that may occur relatively quickly [45,46].

Our findings may inform educational strategies that reduce demands on older adults' cognitive abilities. Research has begun to document potential strategies to compensate for cognitive impairment by using patient-centered instructions for medications that older adults could comprehend easily. The instructions contain simpler text and sentence structure matching the cognitive ability of the individual [47]. Other studies have focused on the effect of short-term memory impairment on processing health information. Older adults with short-term memory loss have a lower capacity to process multiple bits of information at any one moment [48]. Older adults learn faster if new health information presented during an instruction session is limited to three to five points [49].

This study aims to provide information about cognitive function as a risk for health literacy in older adults with diabetes. Perhaps an important message is that diabetes self-management education needs to incorporate cognitive screening instruments to identify patients who require special efforts to achieve self-care goals. In addition, interventions that aim to improve diabetes care of those with inadequate health literacy are more likely to be successful if they are multifaceted and aim to accommodate cognitive processes that may be affected by aging and diabetes [50].

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References

1. Nielsen-Bohlman, L.; Panzer, AM.; Kindig, DA. Health literacy: A prescription to end confusion. The National Academies Press; Washington, DC: 2004.
2. Berkman ND, Sheridan SL, Donahue KE, Halpern DJ, Crotty K. Low health literacy and health outcomes: an updated systematic review. *Ann Intern Med.* 2011; 155:97–107. [PubMed: 21768583]
3. Baker DW, Gazmararian JA, Sudano J, Patterson M, Parker RM, Williams MV. Health literacy and performance on the Mini-Mental State Examination. *Aging Ment Health.* 2002; 6:22–29. [PubMed: 11827619]
4. Murray C, Johnson W, Wolf MS, Deary IC. The association between cognitive ability across the lifespan and health literacy in old age: the Lothian Birth Cohort 1936. *Intelligence.* 2011; 39:178–187.
5. Wolf MS, Wilson EA, Rapp DN, Waite KR, Bocchini MV, Davis TC, et al. Literacy and learning in health care. *Pediatrics.* 2009; 124(Suppl 3):S275–281. [PubMed: 19861481]
6. Czaja SJ, Charness N, Fisk AD, Hertzog C, Nair SN, Rogers WA, et al. Factors predicting the use of technology: findings from the Center for Research and Education on Aging and Technology Enhancement (CREATE). *Psychol Aging.* 2006; 21:333–352. [PubMed: 16768579]
7. Federman AD, Sano M, Wolf MS, Siu AL, Halm EA. Health literacy and cognitive performance in older adults. *J Am Geriatr Soc.* 2009; 57:1475–1480. [PubMed: 19515101]
8. Manly JJ, Touradji P, Tang MX, Stern Y. Literacy and memory decline among ethnically diverse elders. *J Clin Exp Neuropsychol.* 2003; 25:680–690. [PubMed: 12815505]
9. Wilson EA, Wolf MS. Working memory capacity and the design of patient education materials. *Patient Education and Counseling.* 2009; 74:318–322. [PubMed: 19121915]
10. Wolf MS, Curtis LM, Wilson EA, Revelle W, Waite KR, Smith SG, et al. Literacy, cognitive function, and health: Results of the LitCog Study. *J Gen Intern Med.* 2012; 27:1300–1307. [PubMed: 22566171]
11. ADA. Standards of medical care in diabetes--2012. *Diabetes Care.* 2012; 35(Suppl 1):S11–63. [PubMed: 22187469]
12. White RO, Wolff K, Cavanaugh KL, Rothman R. Addressing health literacy and numeracy to improve diabetes education and care. *Diabetes Spectr.* 2010; 23:238–243. [PubMed: 21297890]
13. Nath C. Literacy and diabetes self-management. *Am J Nurs.* 2007; 107:43–49. quiz 49. [PubMed: 17563437]
14. Biessels GJ, Staekenborg S, Brunner E, Brayne C, Scheltens P. Risk of dementia in diabetes mellitus: a systematic review. *Lancet Neurol.* 2006; 5:64–74. [PubMed: 16361024]
15. Cukierman-Yaffe T, Gerstein HC, Williamson JD, Lazar RM, Lovato L, Miller ME, et al. Relationship between baseline glycemic control and cognitive function in individuals with type 2 diabetes and other cardiovascular risk factors: the action to control cardiovascular risk in diabetes-memory in diabetes (ACCORD-MIND) trial. *Diabetes Care.* 2009; 32:221–226. [PubMed: 19171735]
16. de Wet H, Levitt N, Tipping B. Executive cognitive impairment detected by simple bedside testing is associated with poor glycaemic control in type 2 diabetes. *S Afr Med J.* 2007; 97:1074–1076. [PubMed: 18250916]
17. Munshi M, Grande L, Hayes M, Ayres D, Suhl E, Capelson R, et al. Cognitive dysfunction is associated with poor diabetes control in older adults. *Diabetes Care.* 2006; 29:1794–1799. [PubMed: 16873782]
18. Brands AM, Biessels GJ, de Haan EH, Kappelle LJ, Kessels RP. The effects of type 1 diabetes on cognitive performance: a meta-analysis. *Diabetes Care.* 2005; 28:726–735. [PubMed: 15735218]
19. Iwata I, Munshi MN. Cognitive and psychosocial aspects of caring for elderly patients with diabetes. *Curr Diab Rep.* 2009; 9:140–146. [PubMed: 19323959]
20. Bell RA, Arcury TA, Snively BM, Smith SL, Stafford JM, Dohanish R, et al. Diabetes foot self-care practices in a rural triethnic population. *Diabetes Educ.* 2005; 31:75–83. [PubMed: 15779248]
21. Bell RA, Quandt SA, Arcury TA, Snively BM, Stafford JM, Smith SL, et al. Primary and specialty medical care among ethnically diverse, older rural adults with type 2 diabetes: the ELDER Diabetes Study. *J Rural Health.* 2005; 21:198–205. [PubMed: 16092292]

22. Kirby M, Denihan A, Bruce I, Coakley D, Lawlor BA. The clock drawing test in primary care: sensitivity in dementia detection and specificity against normal and depressed elderly. *Int J Geriatr Psychiatry*. 2001; 16:935–940. [PubMed: 11607936]
23. Shulman KI. Clock-drawing: is it the ideal cognitive screening test? *Int J Geriatr Psychiatry*. 2000; 15:548–561. [PubMed: 10861923]
24. Arcury TA, Quandt SA. Participant recruitment for qualitative research: a site-based approach to community research in complex societies. *Human Organization*. 1999; 58:128–133.
25. Quandt SA, Bell RA, Snively BM, Smith SL, Stafford JM, Wetmore LK, et al. Ethnic disparities in glycemic control among rural older adults with type 2 diabetes. *Ethn Dis*. 2005; 15:656–663. [PubMed: 16259490]
26. Blazer D, Burchett B, Service C, George LK. The association of age and depression among the elderly: an epidemiologic exploration. *J Gerontol*. 1991; 46:M210–215. [PubMed: 1834726]
27. Samuel-Hodge CD, Keyserling TC, Park S, Johnston LF, Gizlice Z, Bangdiwala SI. A randomized trial of a church-based diabetes self-management program for African Americans with type 2 diabetes. *Diabetes Educ*. 2009; 35:439–454. [PubMed: 19383882]
28. Bode BW, Irvin BR, Pierce JA, Allen M, Clark AL. Advances in Hemoglobin A1c Point of Care Technology. *J Diabetes Sci Technol*. 2007; 1:405–411. [PubMed: 19885097]
29. Hassing LB, Grant MD, Hofer SM, Pedersen NL, Nilsson SE, Berg S, et al. Type 2 diabetes mellitus contributes to cognitive decline in old age: a longitudinal population-based study. *J Int Neuropsychol Soc*. 2004; 10:599–607. [PubMed: 15327738]
30. Folstein MF, Folstein SE, McHugh PR. “Mini-mental state”. A practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res*. 1975; 12:189–198. [PubMed: 1202204]
31. Newcombe, F. *Missile Wounds of the brain: A Study of Psychological Deficits*. Oxford University Press; London: 1969.
32. Schretlen, D. *Brief Test of Attention*. Psychological Assessment Resources, Inc.; Lutz, FL: 1997.
33. Baddeley A. Working memory. *Science*. 1992; 255:556–559. [PubMed: 1736359]
34. Wechsler, D. *Wechsler Adult Intelligence Scale - Revised*. The Psychological Corporation; New York, NY: 1981.
35. Nurss, J.; Parker, RM.; Williams, MV.; Baker, DW. *Directions for administration and scoring technical data, Short Test of Functional Literacy in Adults (STOFHLA)*. Center for the Study of Adult Literacy; 1998.
36. Kutner, M.; Greenberg, E.; Jin, Y.; Paulsen, C. *The health literacy of America's adults: results from the 2003 National Assessment of Adult Literacy*. Government Printing Office; Washington, DC: 2006. Available from <http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2006483>.
37. Manly JJ, Schupf N, Tang MX, Stern Y. Cognitive decline and literacy among ethnically diverse elders. *J Geriatr Psychiatry Neurol*. 2005; 18:213–217. [PubMed: 16306242]
38. Insel K, Morrow D, Brewer B, Figueredo A. Executive function, working memory, and medication adherence among older adults. *J Gerontol B Psychol Sci Soc Sci*. 2006; 61:P102–107. [PubMed: 16497953]
39. Velanova K, Lustig C, Jacoby LL, Buckner RL. Evidence for frontally mediated controlled processing differences in older adults. *Cereb Cortex*. 2007; 17:1033–1046. [PubMed: 16774962]
40. Wingfield A, Tun PA. Cognitive supports and cognitive constraints on comprehension of spoken language. *J Am Acad Audiol*. 2007; 18:548–558. [PubMed: 18236643]
41. Sweller J, Chandler P, Tierney P, Cooper M. Cognitive load as a factor in the structuring of technical material. *Journal of Experimental Psychology: General*. 1990; 119:176–192.
42. Nguyen HT, Evans MK, Zonderman AB. Influence of medical conditions on executive and memory functions in low socioeconomic status African Americans. *Arch Clin Neuropsychol*. 2007; 22:689–698. [PubMed: 17574385]
43. Al Sayah F, Williams B, Johnson JA. Measuring health literacy in individuals with diabetes: A systematic review and evaluation of available measures. *Health Educ Behav*. 2012

44. Sinclair AJ, Girling AJ, Bayer AJ. Cognitive dysfunction in older subjects with diabetes mellitus: Impact on diabetes self-management and use of care services. All Wales Research into Elderly (AWARE) Study. *Diabetes Res Clin Pract.* 2000; 50:203–212. [PubMed: 11106835]
45. Toro P, Schonknecht P, Schroder J. Type II diabetes in mild cognitive impairment and Alzheimer's disease: Results from a prospective population-based study in Germany. *J Alzheimers Dis.* 2009; 16:687–691. [PubMed: 19387105]
46. Whitmer RA. Type 2 diabetes and risk of cognitive impairment and dementia. *Curr Neurol Neurosci Rep.* 2007; 7:373–380. [PubMed: 17764626]
47. Murray MD, Young JM, Morrow DG, Weiner M, Tu W, Hoke SC, et al. Methodology of an ongoing, randomized, controlled trial to improve drug use for elderly patients with chronic heart failure. *Am J Geriatr Pharmacother.* 2004; 2:53–65. [PubMed: 15555479]
48. Stevens B. How seniors learn. *Issue Brief Cent Medicare Educ.* 2003; 4:1–8. [PubMed: 14992211]
49. Cornett, S. [November 5, 2012] The effects of aging on health literacy. 2006. from http://medicine.osu.edu/sitetool/sites/pdfs/ahecpublic/HL_Module_Elderly.pdf
50. Wallace A. Low health literacy: Overview, assessment, and steps toward providing high-quality diabetes care. *Diabetes Spectrum.* 2010; 23:220–227.

Table 1

Characteristics of Participants, n = 537

	S-TOFHLA Score		<u>P-value</u>
	<u>Inadequate</u>	<u>Adequate</u>	
Total sample (%)	54.8	45.2	
Gender (%)			0.06
Female	51.6	48.4	
Male	59.8	40.2	
Age; mean±SD [range]	71.0±7.4 [60-89]	68.7±6.5 [60-91]	<0.001
Education (%)			<0.001
<High school	74.3	25.7	
High school graduate	48.9	51.1	
>High school	39.3	60.7	
Ethnicity (%)			<0.001
Non-Hispanic white	44.5	55.5	
African American	55.8	44.2	
American Indian	66.7	33.3	
Stroke (%)			0.03
Yes	18.4	26.3	
No	81.6	73.7	
Heart disease (%)			0.31
Yes	26.9	30.9	
No	73.1	69.1	
Hypertension (%)			0.46
Yes	58.2	61.3	
No	41.8	38.7	
CESD; mean±SD [range]	4.17±3.56 [0-16]	3.44±3.26 [0-15]	0.01
Duration diabetes, years			0.06
mean±SD [range]	15.5±12.4 [2-63]	13.6±11.3 [2-67]	
Diabetes Knowledge Test			<0.001
mean±SD [range]	9.5±2.8 [0-15]	10.9±2.1 [3-15]	
Taking insulin (%)			0.07
Yes	60.4	39.6	
No	52.2	47.8	
Taking diabetes pills (%)			0.22
Yes	56.3	43.7	
No	50.4	49.6	
HbA1c; mean±SD [range]	7.0±1.4 [4-13]	6.9±1.3 [4-13]	0.55
Cognitive tests; mean±SD [range]			
MMSE	25.4±3.7 [18-30]	28.0±2.4 [18-30]	<0.001
Verbal Fluency	13.0±4.8 [3-29]	15.5±5.70 [2-33]	<0.001
Brief Attention	5.1±2.2 [1-10]	6.4±2.3 [1-10]	<0.001

S-TOFHLA Score			
	<u>Inadequate</u>	<u>Adequate</u>	<u>P-value</u>
Digit Span Backward	4.2±1.8 [0-12]	6.0±2.4 [0-14]	<0.001

SD = standard deviation.

Table 2

Multivariate logistic regression results of the association between cognitive function and adequate health literacy

Independent Variables	Adjusted Odds Ratio (95% CI) [†]	Adjusted Odds Ratio (95% CI) [†]	Adjusted Odds Ratio (95% CI) [†]	Adjusted Odds Ratio (95% CI) [†]
Female	1.48 (0.97-2.25)	1.45 (0.94-2.23)	1.38 (0.89-2.15)	1.57 (1-2.47) [*]
Age	0.97 (0.94-1)	0.97 (0.94-1)	0.97 (0.94-1) [*]	0.97 (0.93-1)
> High school	1.97 (1.16-3.34) [*]	2.27 (1.33-3.87) ^{**}	2.1 (1.22-3.61) ^{**}	1.94 (1.11-3.4) [*]
High school graduate	1.68 (1.01-2.81) [*]	1.86 (1.11-3.12) [*]	1.61 (0.94-2.75)	1.46 (0.85-2.54)
American Indian	0.37 (0.22-0.63) ^{***}	0.38 (0.22-0.65) ^{***}	0.38 (0.22-0.65) ^{***}	0.36 (0.21-0.64) ^{***}
African American	0.74 (0.45-1.2)	0.87 (0.52-1.43)	0.74 (0.44-1.22)	0.7 (0.42-1.18)
Yes stroke	1.48 (0.9-2.44)	1.26 (0.77-2.06)	1.33 (0.8-2.21)	1.48 (0.88-2.5)
Yes heart disease	1.23 (0.78-1.94)	1.17 (0.74-1.85)	1.27 (0.8-2.02)	1.39 (0.86-2.25)
Yes hypertension	1.14 (0.75-1.74)	1.29 (0.84-1.98)	1.16 (0.75-1.81)	1.26 (0.8-1.99)
CESD	0.95 (0.89-1.01)	0.95 (0.89-1.01)	0.94 (0.88-1.01)	0.96 (0.9-1.03)
Diabetes duration	1 (0.98-1.01)	1 (0.98-1.01)	0.99 (0.97-1.01)	0.99 (0.97-1.01)
Diabetes knowledge	1.14 (1.04-1.25) ^{**}	1.22 (1.12-1.34) ^{**}	1.16 (1.06-1.27) ^{**}	1.16 (1.05-1.27) ^{**}
Yes taking insulin	0.74 (0.42-1.31)	0.65 (0.36-1.17)	0.76 (0.42-1.38)	0.74 (0.4-1.36)
Yes taking diabetes pills	0.73 (0.42-1.26)	0.7 (0.4-1.23)	0.67 (0.38-1.19)	0.65 (0.36-1.18)
HbA1c	1.02 (0.87-1.2)	1.01 (0.86-1.18)	1.01 (0.86-1.19)	1.05 (0.89-1.24)
Cognitive measures [‡]				
MMSE	1.20 (1.11-1.3) ^{***}			
Verbal Fluency		1.05 (1.01-1.1) ^{**}		
Brief Attention			1.16 (1.05-1.28) ^{**}	
Digit Span Backward				1.34 (1.19-1.51) ^{***}

[†]95% confidence interval.

[‡]The associations between adequate health literacy and test scores on four different measures of cognitive function after adjustment for covariates are shown. The table shows odds ratios simultaneously adjusted for gender, age, education, ethnicity, stroke, heart disease, hypertension, depressive symptoms, diabetes duration, diabetes knowledge, taking insulin, taking diabetes pills, and HbA1c. The adjusted odds ratio represents the increased odds of having adequate health literacy for every unit increase in each cognitive test.

^{*} p <.05

^{**} p<.01

^{***} p<.001.