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Limited Health Literacy and Decline in Executive Function in Older Adults

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*Limited health literacy is associated with worse executive function, but the association between limited health literacy and decline in executive function has not been established because of a lack of longitudinal studies. The authors aimed to examine this association by studying a prospective cohort in the setting of a randomized controlled trial to promote walking in older adults. Participants were community-dwelling older adults (65 years of age or older) who scored 2 or more on the Mini-Cog, without depression (score of less than 15 on the 9-item Patient Health Questionnaire), and who completed baseline and 12-month evaluations (*n = *226). Health literacy was measured using the Short Test of Functional Health Literacy in Adults. Executive function measured at baseline and 12 months using the Trail Making Test (TMT), Controlled Oral Word Association Test, and Category Fluency. The associations between health literacy and 12-month decline in each test of executive function were modeled using multivariate linear regression. Health literacy was*

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*found to be limited in 37% of participants. Limited health literacy was associated with reduced performance on all 3 executive function tests. In fully adjusted models, limited health literacy was associated with greater 12-month decline in performance on the TMT than higher health literacy (*p = *.01). In conclusion, older adults with limited health literacy are at risk for more rapid decline in scores on the TMT, a measure of executive function.*

Health literacy is the degree to which individuals have the capacity to obtain, process, and understand health information, skills, and services needed to make informed health decisions and take informed actions (Paasche-Orlow, 2011). Limited health literacy is associated with worse physical and mental health in community dwelling older adults (Wolf, Gazmararian, & Baker, 2005), poor use of preventive health services (Scott, Gazmararian, Williams, Baker, 2002), increased rates of hospitalizations among Medicare enrollees (D. W. Baker et al., 2002), and higher mortality (Bostock & Steptoe, 2012; Sudore et al., 2006; Wolf, Feinglass, Thompson, & Baker, 2010). The prevalence of limited health literacy (scoring in the below basic or the basic skill level on the National Assessment of Adult Literacy) has been reported to be 36% among adults in the United States; however, it is higher among those older than 65 years of age; 59% of this population exhibit limited health literacy (D. W. Baker, Gazmararian, Sudano, & Patterson, 2000; Institute of Education, 2012).

Limited health literacy has been shown in cross-sectional studies to be associated with lower scores on cognitive tests measuring memory, processing speed, and executive function (Federman, Sano, Wolf, Siu, & Halm, 2009; Levinthal, Morrow, Tu, Wu, & Murray, 2008; Manly et al., 1999; McDougall, Mackert, & Becker, 2012; Morrow et al., 2006), which includes working memory, planning, attention, problem solving, verbal fluency, and reasoning (Stuss & Levine, 2002). The association between limited health literacy and impairment of specific cognitive functions appears to be independent of the influence of age, demographics, and education status. Several studies have suggested that limited literacy has a more significant association with executive function deficits than years of education (Dotson, Kitner-Triolo, Evans, & Zonderman, 2009; Kave et al., 2012). In view of the decline in executive function in older adults that may occur years before clinically evident dementia (Grober et al., 2008; Manly et al., 2008), limited health literacy may be a predictor of declining executive function over time. A single study has examined aspects of the relationship between literacy and executive function longitudinally: older adults who scored worse on an English literacy test showed a greater decline in executive function over more than 3 years of follow-up (Manly, Schupf, Tang, & Stern, 2005). This analysis did not, however, include data about medical comorbidities and used only verbal fluency measures of executive function. Inclusion of medical comorbidities is important because several chronic diseases, including diabetes and cardiovascular disease, which are more poorly controlled among those with limited health literacy, are independently associated with cognitive decline (D. W. Baker et al., 2007; Schillinger et al., 2002).

In the present study, we aimed to extend these findings by examining the changes over time in the relation between health literacy and three widely accepted measures of executive function. We hypothesized that in a cohort of community dwelling older adults, limited health literacy would be associated with a more rapid decline in executive function compared with those with higher health literacy.

Method

To study the association between limited health literacy and executive function, we analyzed data collected at the baseline and 12-month visits of a randomized controlled trial to improve walking in older adults. The study required all participants to use a pedometer and to record their daily steps. In addition, participants in the intervention group were exposed to a computer-based conversational agent about walking.

Participants

Participants were recruited from two internal medicine and one geriatrics ambulatory care sites at the largest safety-net hospital in Boston, Massachusetts. Once provider approval was obtained for participation in the clinical trial, potentially eligible participants were mailed opt-out recruitment letters. Those who did not opt out were invited to participate.

Inclusion criteria were the following: age 65 years or older, ability to speak English, no plans to move from the area over the next year, inactivity (over the past 6 months had not engaged regularly in moderate-intensity or more vigorous physical activity 3 or more days per week for at least 20 min per day), free of any medical condition or disorder that would limit participation in moderate intensity physical activity (e.g., sustained walking), including life-threatening disorders, myocardial ischemia, complex cardiac arrhythmias or significant left ventricular dysfunction, and major functional disabilities relating to gait or balance, as assessed by patients' primary care physicians. Exclusion criteria included the following: timed maximal walking velocity of less than 0.5 m/sec based on a standard fitness and mobility assessment, cognitive impairment as assessed by the Mini-Cog (score of less than 2), significant level of depressive symptoms (score of 15 or more on the nine-item Patient Health Questionnaire [PHQ-9]), unable to complete in-clinic training session with tablet computer, and unable to exhibit comprehension of the protocol at the time of the informed consent process. We obtained Boston University Medical Campus Institutional Review Board's approval for this study.

Data Collection

Data were collected during face-to-face sessions in a well-lit, quiet, private room using trained research personnel who administered structured research protocols. Subjects who agreed to participate in the study and passed final screening procedures completed the 90-minute baseline assessment that included sociodemographic information, depressive symptoms, executive function measures, and health literacy. Participants were randomized into treatment groups on the basis of their health literacy level (stratified block randomization). During the 30-minute 12-month follow-up visit the measures of executive function were retested by research personnel who were blinded to past test results.

Variables of Interest

Health Literacy

We assessed *health literacy*, the main independent variable, using the Short Test of Functional Health Literacy in Adults (S-TOFHLA; (D. W. Baker, Williams, Parker, Gazmararian, & Nurss, 1999). The S-TOFHLA consists of two medically related passages with keywords missing. Using a modified Cloze procedure, participants select the

appropriate word for each omitted word from a list of four choices. The S-TOHFLA has good internal consistency (Cronbach's $\alpha = .97$) and is well correlated with the Rapid Estimate of Adult Literacy in Medicine (Spearman correlation 0.80) and the full Test of Functional Health Literacy in Adults (Spearman correlation = 0.91), two other measures of health literacy (D. W. Baker, 1999). Limited health literacy was defined as scores from 0 to 22, and higher health literacy was defined as scores from 23 to 36 on the S-TOFHLA, using previously established cut-offs for this measure (Schillinger et al., 2002).

Covariates

Factors were included as covariates on the basis of past literature regarding cognitive decline (e.g., age, sex, race, education, comorbidities, and the PHQ-9; Kester & Scheltens, 2009) and the study design (e.g., randomization group, clinic site). Age was classified as follows: 65–69 years, 70–74 years, 75–79 years, and 80+ years. Sex was categorized as male and female. Race was grouped into White, Black, and other. Education was classified into less than high school, high school, and more than high school. Number of comorbidities, collected from medical record review using the Charlson Comorbidity Index, was classified as 0, 1, and 2 or more (25). PHQ-9 scores were categorized as minimal (1–4), mild (5–9), and moderate (10–14). The study locations included two internal medicine clinics and one geriatrics clinic.

Outcomes of Interest

Executive Function

Executive function was assessed using three commonly used neurocognitive measures: The Trail Making Test (TMT), FAS, and Category Fluency. The TMT (Reitan, 1965) consists of two parts: TMT A and TMT B. TMT A requires an individual to draw lines sequentially connecting 25 encircled numbers distributed on a sheet of paper. Task requirements are similar for TMT B except the person must alternate between numbers and letters (e.g., 1, A, 2, B, 3, C). Participants are instructed to complete each part of the TMT as quickly and accurately as possible. When an error is made, they are instructed to return to the circle where the error originated and continue. Maximum time given for TMT A is 150 seconds and for TMT B is 300 seconds. The score on each part is the amount of time required to complete the task. A higher score indicates worse executive function. For analyses, we used the delta TMT (TMT B – TMT A) scores as construct validity testing of the TMT and its derived tests have found that the delta TMT was the best TMT measure of executive function (Sanchez-Cubillo et al., 2009). The test–retest reliability of this test has been shown to be high (Giovagnoli et al., 1996).

To assess phonemic or letter verbal fluency a form of the Controlled Oral Word Association Test (FAS) was used, in which participants are instructed to verbally generate words that began with the letters F, A, and S in three separate, 1-minute trials (Thurstone, 1938). If they use proper nouns or use words that do not begin with the three letters, they are scored as incorrect. The final score is the average number of correct words generated. For semantic or category verbal fluency, participants are asked to name examples of animals and vegetables in two separate 1-minute trials (Goodglass & Kaplan, 1972). The score for each is the number of animals and vegetables named. These two scores are combined to give one score for Category Fluency.

Test–retest reliability results are $r = 0.82$ and $r = 0.68$ for FAS and Category Fluency, respectively (Vlaar & Wade, 2003).

Primary Outcome

The primary outcomes of interest were change in scores on each of the three neurocognitive measures between baseline and 12 months, similar to how these outcomes have been operationalized by other authors (L. D. Baker et al., 2010a, 2010b). The change score for delta TMT was calculated as the difference in score at 12 months from score at baseline (delta TMT 2 – delta TMT 1). A greater increase in the time to complete the TMT indicates a greater decline in executive function. The change score for FAS was calculated as the difference in average score at 12 months from baseline. Similarly, the change score for Category Fluency was calculated as the difference in the average score at 12 months from baseline. A greater decrease in the average score on the FAS and Category Fluency tests indicate a greater decline in executive function.

Statistical Analysis

The neurocognitive test performance measures and change scores were each examined for normality and outliers. Each of these was found to reasonably satisfy the normality assumption. The chi-square test was used to assess differences between participants in the two health literacy categories by the covariates. The independent samples *t* test was used to compare baseline and 12-month follow-up neurocognitive test performance for each measure of executive function by health literacy category. The associations between health literacy and baseline neurocognitive scores were examined through multivariable linear regression models, adjusting for clinic location, age, sex, race, education, number of comorbidities, and PHQ-9 score based on review of the literature for factors that have been shown to be associated with health literacy and cognitive function (Ble et al., 2005; Brickman et al., 2005; Paasche-Orlow, Parker, Gazmararian, Nielsen-Bohlman, & Rudd, 2005). Change scores from baseline to 12 months for each of the neurocognitive outcomes were also analyzed through multivariable linear regression, with baseline neurocognitive scores (to control for difference in baseline performance) and randomization group (to control for the effect of the intervention) added to the set of covariates included in the baseline models. Model fit was summarized with the R^2 statistic; regression diagnostics including plots of residuals, residuals versus fitted values, and residuals versus quantiles were examined to assess appropriateness of the linear model. Last, sensitivity analysis was done after excluding those who were not native English speakers. A significance level of 0.05 was set for all analyses; all analyses were conducted using SAS/STAT 9.2 of the SAS System for Windows 2002–2008 (SAS Institute Inc., Cary, North Carolina).

Results

We restricted our analysis to the 226 of 263 (85.9 %) participants who had health literacy and executive function data at baseline and 12 months. The demographic characteristics of the entire sample as well as stratified by health literacy category are shown in Table 1. Those with limited health literacy were more likely to be Black, have a lower education level, and have a higher number of comorbidities when compared with those with higher health literacy. Participants who did not complete the 12-month follow-up were more likely to be in the limited health literacy category (56.8% vs. 37.2%, $p = .02$), had

Table 1. Demographic information

	Total ($N = 226$), n (%)	Limited health literacy ($n = 84$), n (%)	Higher health literacy ($n = 142$), n (%)	Chi-square statistic (df)	p*
Randomization				0.143 (1)	.705
Control	114 (50.4)	41 (48.8)	73 (51.4)		
Intervention	112 (49.6)	43 (51.2)	69 (48.6)		
Age (years)				1.132 (3)	.769
65–69	105 (46.5)	39 (46.4)	66 (46.5)		
70–74	57 (25.2)	24 (28.6)	33 (23.2)		
75–79	45 (19.9)	15 (17.9)	30 (21.1)		
80+	19 (8.4)	6 (7.1)	13 (9.2)		
Sex				0.108 (1)	.742
Female	143 (63.3)	52 (61.9)	91 (64.1)		
Race				45.538 (2)	<.001
Black	142 (62.8)	76 (90.5)	66 (46.5)		
White	67 (29.6)	4 (4.8)	63 (44.4)		
Other	17 (7.5)	4 (4.8)	13 (9.2)		
Education				46.530 (2)	<.001
Less than high school	48 (21.2)	34 (40.5)	14 (9.9)		
High school	68 (30.1)	32 (38.1)	36 (25.4)		
More than high school	110 (48.7)	18 (21.4)	92 (64.8)		
Number of comorbidities[a]				8.222 (2)	.016
None	107 (47.3)	30 (35.7)	77 (54.2)		
1	63 (27.9)	26 (31.0)	37 (26.1)		
2+	56 (24.8)	28 (33.3)	28 (19.7)		
PHQ-9 score				4.928 (2)	.085
Minimal (1–4)	186 (82.3)	63 (75.0)	123 (86.6)		
Mild (5–9)	30 (13.3)	16 (19.0)	14 (9.9)		
Moderate (10–14)	10 (4.4)	5 (6.0)	5 (3.5)		

*Test statistic, df, and p value from chi-square test.

[a]Comorbidities from chart review: Myocardial infarction, congestive heart failure, peripheral vascular disease, cerebrovascular disease, dementia, chronic pulmonary disease, connective tissue disease, ulcer disease, diabetes mellitus, diabetes with end organ damage, moderate or severe renal disease, mild liver disease, moderate or severe liver disease, malignancy.

PHQ-9 = nine-item Patient Health Questionnaire.

Table 2. Executive function at baseline and 12-month follow-up, by health literacy

Time	Limited health literacy ($n = 84$)	Higher health literacy ($n = 142$)	t test statistic (df)	p^a
Delta Trail Making Test (seconds),[b] *M* (*SD*)				
Baseline	159.2 (68.2)	84.5 (59.0)	8.62 (222)	<.001
12 months	178.1 (58.6)	93.6 (67.1)	9.50 (222)	<.001
Change[e]	18.8 (65.5)	9.1 (52.3)	1.14 (136)	.258
FAS (average number),[c] *M* (*SD*)				
Baseline	22.0 (10.5)	34.3 (12.9)	–7.71 (202)	<.001
12 months	22.2 (11.0)	35.3 (13.4)	–7.49 (222)	<.001
Change[e]	0.02 (9.4)	1.1 (9.2)	–0.83 (221)	.407
Category Fluency (average number),[d] *M* (*SD*)				
Baseline	24.1 (6.0)	29.8 (7.9)	–6.04 (211)	<.001
12 months	23.7 (6.8)	29.5 (8.2)	–5.48 (223)	<.001
Change[e]	–0.5 (5.2)	–0.2 (5.5)	–0.40 (223)	.686

[a]Test statistic and p value from two-sided t test.

[b]Delta Trail Making Test: Time in seconds for TMT B (draw lines sequentially connecting 25 alternating numbers and letters) minus time in seconds for TMT A (draw lines sequentially connecting 25 encircled numbers). Maximum time allotted is 150 s for TMT A and 300 s for TMT B.

[c]FAS: Number of words that begin with letters F, A, and S in three separate, 1 minute trials. Proper nouns and incorrect words excluded from final score, which is average of the three trials.

[d]Category Fluency: Number of animals and vegetables named in two separate 1-min trials. The final score is average of the two trials.

[e]Change: Score at 12-month follow-up minus score at baseline.

a worse baseline delta TMT performance (144.2 s vs. 112.6 s, $p = .02$), and had a higher percentage with history of myocardial infarction (8.1% vs. 0.4%) and diabetes (48.6% vs. 29.2%) compared with those who completed the 12-month interview. Two participants at baseline and three at follow-up were top-coded for TMT A at 150 seconds; for TMT B, 38 participants at baseline and 63 at follow-up were top-coded at 300 seconds.

At baseline, those with limited health literacy were 74 s slower on delta TMT (159.2 vs. 84.5, $p < .001$), scored 12 fewer words on FAS (22.0 vs. 34.3, $p < .001$) and 6 fewer words on Category Fluency (24.1 vs. 29.8, $p < .001$) compared to higher heath literacy participants (Table 2). In the adjusted model at baseline, those with limited health literacy were 49 s slower on delta TMT ($p < .001$), scored 8 fewer words on FAS ($p < .001$) and 2 fewer words on Category Fluency ($p = .062$) compared with higher health literacy participants (data not shown). In addition to health literacy, other variables that were significantly associated with baseline neurocognitive performance were race and education for delta TMT; age for FAS; and sex, race, and education for Category Fluency.

At the 12-month follow-up, individuals with limited health literacy were 84 seconds slower on delta TMT (178.1 vs.93.6, $p < .001$), scored 13 fewer words on FAS (22.2 vs. 35.3, $p < .001$) and 6 fewer words on Category Fluency (23.7 vs. 29.5, $p < .001$) compared to higher heath literacy participants. In the unadjusted results for the change in executive function there was no significant difference between limited and higher health literacy participants (Table 2). Table 3 shows the linear regression models for change in executive function from baseline to 12-month follow-up. Adjusted

Table 3. Linear regression for change in executive function from baseline to 12 months

Variable	Change in delta TMT[a] (seconds)			Change in FAS[b] (average number)			Change in category fluency[c] (average number)		
	β (95% CI)[d]	F	p[e]	β (95% CI)[d]	F	p[e]	β (95% CI)[d]	F	p[e]
Health literacy									
Low	23.8 (5.3, 42.2)	6.46 (1, 204)	.012	–1.8 (–4.8, 1.2)	1.44 (1, 205)	.232	–0.4 (–2.2, 1.3)	0.22 (1, 207)	.641
High (ref)									
Baseline scores	–0.5 (–0.6, –0.3)	59.61 (1, 204)	<.001	–0.3 (–0.4, –0.2)	26.90 (1, 205)	<.001	–0.2 (–0.4, –0.1)	21.26 (1, 207)	<.001
Randomization									
Intervention	9.2 (–4.7, 23.1)	1.71 (1, 204)	.193	0.2 (–2.1, 2.6)	0.04 (1, 205)	.841	–0.5 (–1.9, 0.9)	0.46 (1, 207)	.500
Control (ref)									
Clinic[¶]									
Clinic 2	–12.2 (–32.5, 8.1)	2.43 (2, 204)	.090	–2.1 (–5.5, 1.2)	9.20 (2, 205)	<.001	0.6 (–1.4, 2.6)	0.80 (2, 207)	.449
Clinic 3	–22.8 (–48.0, 2.4)			5.4 (1.2, 9.6)			1.3 (1.2, 3.9)		
Clinic 1 (ref)									
Age (years)									
70–74	–1.2 (–23.9, 21.6)	0.50 (3, 204)	.685	0.4 (–3.5, 4.2)	1.46 (3, 205)	.227	–0.7 (–2.9, 1.6)	2.57 (3, 207)	.055
75–79	10.2 (–14.6, 35.0)			0.3 (–3.9, 4.4)			0.5 (–2.0, 2.9)		
80+	0.2 (–35.9, 36.3)			–4.3 (–10.3, 1.8)			–3.4 (–6.9, 0.2)		
65–69 (ref)									
Sex									
Female	–15.4 (–30.2, –0.6)	4.21 (1, 204)	.042	1.1 (–1.4, 3.5)	0.71 (1, 205)	.400	0.3 (–1.2, 1.8)	0.13 (1, 207)	.714
Race									
Black	15.6 (–7.3, 38.7)	1.30 (2, 204)	.274	–4.9 (–8.7, –1.0)	4.53 (2, 205)	.012	–1.2 (–3.6, 1.1)	0.81 (2, 207)	.446
Other	7.1 (–28.8, 42.9)			–3.2 (–9.0, 2.6)			–1.2 (–4.7, 2.3)		
White (ref)									
Education									
Less than high school	26.0 (1.6, 50.4)	3.17 (2, 204)	.044	–2.7 (–6.7, 1.3)	1.49 (2, 205)	.229	–1.7 (–4.1, 0.7)	1.50 (2, 207)	.226
High school	10.7 (–10.0, 31.4)			–0.1 (–3.4, 3.3)			–0.3 (–2.3, 1.8)		

More than high school (ref)									
Number of Comorbidities[g]									
1	3.9 (–15.6,23.5)	1.42 (2, 204)	.244	–0.2 (–3.4, 3.1)	0.30 (2, 205)	.743	–1.2 (–3.2, 0.8)	1.48 (2, 207)	.231
2+	14.9 (–6.0,35.9)			1.0 (–2.5, 4.5)			–1.2 (–3.3, 0.9)		
0 (ref)									
PHQ-9[h]									
Mild (5–9)	–9.4 (–34.3,15.5)	0.43 (2, 204)	.653	0.3 (–3.9, 4.6)	0.81 (2, 205)	.447	0.7 (–1.9, 3.1)	2.10 (2, 207)	.125
Moderate (10–14)	2.7 (–40.1, 45.5)			3.6 (–3.1, 10.3)			3.5 (–0.6, 7.5)		
Minimal (1–4) (ref)									
R^2	0.28			0.24			0.17		
F	4.77 (17, 204)			3.71 (17, 205)			2.48 (17, 207)		
p	<.001			<.001			.001		

*Change in delta TMT: Delta TMT score at 12-month follow-up minus score at baseline, in seconds. A greater increase in time for delta TMT indicates more rapid decline in executive function.

[b]Change in FAS: Score at 12-month follow-up minus score at baseline, average number. Greater decrease in average number for FAS indicates more rapid decline in executive function.

[c]Change in Category Fluency: Score at 12-month follow-up minus score at baseline, average number. Greater decrease in average number named for Category Fluency indicates more rapid decline in executive function.

[d]Tukey adjusted confidence intervals (except for Baseline scores).

[e]Global p value (from Type III F statistic for variable).

[f]Clinic location: Clinic 1 and Clinic 2 - Internal medicine clinics, Clinic 3 - Geriatrics clinic.

[g]Comorbidities from chart review: Myocardial infarction, congestive heart failure, peripheral vascular disease, cerebrovascular disease, dementia, chronic pulmonary disease, connective tissue disease, ulcer disease, diabetes mellitus, diabetes with end organ damage, moderate or severe renal disease, mild liver disease, moderate or severe liver disease, malignancy.

PHQ-9 = nine-item Patient Health Questionnaire.

for baseline scores, limited health literacy was associated with greater decline in performance on delta TMT than was higher health literacy. This association remained significant after adjusting for randomization group, clinic location, age, sex, race, education, number of comorbidities, and PHQ-9 score. In the fully adjusted model baseline scores, female sex and less than high school education were also significantly associated with change in delta TMT.

Similarly, after controlling for baseline scores there was an association between limited health literacy and change in FAS scores. However, in the fully adjusted model only baseline scores, geriatrics clinic location and black race were significantly associated with change in score on FAS.

Controlling for baseline scores, there was no significant association between limited health literacy and change in Category Fluency scores. In the fully adjusted model, only baseline performance was significantly associated with change in Category Fluency scores. Regression diagnostics were examined for each model and in each case indicated good model fit. Similar results were found for the sensitivity analysis excluding the 15 participants who were not native English speakers (data not shown).

Discussion

In this population of community-dwelling older adults without cognitive impairment (as assessed by the Mini-Cog), we found that participants with limited health literacy had a greater decline in performance on delta TMT over a period of 12 months than did participants with higher health literacy. However, we did not observe the same result for the FAS and Category Fluency tests. These observations were independent of the influence of a range of factors known to be associated with cognitive decline including sociodemographic characteristics, level of education, and medical comorbidities.

The fact that differential performance on the delta TMT by level of health literacy was observed after12 months is a novel finding of what appears to be a more rapid decline in this test of executive function for older adults with limited health literacy. One explanation is that older adults with limited health literacy skills have built up fewer cognitive reserves throughout life and may therefore be more susceptible to cognitive decline associated with aging. Cognitive reserve is associated with higher levels of education, physical activity, leisure time activities, and larger social networks through the entire life span (Scarmeas & Stern, 2003; Tucker & Stern, 2011). It has been suggested that people with more cognitive reserve have developed a set of skills or repertoires that allows them to cope with progressing neuropathology better than those with lower cognitive reserve. The significant decline in cognition in those with limited health literacy was not observed over the course of 12 months for our measures of verbal fluency. While verbal fluency represents executive function, the FAS and Category Fluency tasks also reflect non–executive function dimensions such as lexical representation and semantic memory (Nutter-Upham et al., 2008). Delta TMT is a more specific measure of executive function measuring cognitive flexibility (Charlson, Pompei, Ales, & MacKenzie, 1987), which may partially explain our differential findings across these three measures. Alternatively, FAS and Category Fluency may be more closely linked to characteristics such as level of education than to health literacy and may be more subject to practice effects than the TMT. Practice effects have been reported for verbal fluency measures (Glanz, Healy, Hviid, Chitnis, & Weiner, 2012).

Another explanation could be that our observation period of 12 months may have been too short to observe changes in FAS and Category Fluency. For example, in the Baltimore Longitudinal Study of Aging, executive function of a community dwelling cohort was measured every 2 years for an average of 15 years to detect age associated cognitive decline (Grober et al., 2008).

Aspects of our study that lend weight to our conclusions include the diversity of our cohort, the use of standardized measures of executive function administered by trained study staff who were not aware of subjects' health literacy status, the longitudinal follow-up and an analytic design that accounted for an important array of characteristics. Nonetheless, this study has several important limitations. First, we did not control for number and type of medications. Medications have been shown to influence performance on cognitive testing (Puustinen, 2012; Waldstein et al., 2010). It is possible that part of this effect would be collinear with the Charlson Comorbidity Index, which we included. However, further research would be needed to evaluate this potential confounder. Second, because this cohort includes subjects from one city, the findings may not be generalizable and should be confirmed with future studies. Third, these analyses were conducted in the context of a randomized controlled trial to promote walking. Because people might have varied in their level of exercise during the intervention period and physical activity might benefit cognition (L. D. Baker et al., 2010b; Kramer, Erickson, & Colcombe, 2006), this might have affected our results. We limited this potential confounder by controlling for randomization group in our analyses. However, it is still possible that our findings would be different if we had included participants who were unable or unwilling to participate in a walking study. As such, the generalizability of our findings may be limited by a selection bias introduced by study enrollment criteria. While we excluded those who scored less than 2 on the Mini-Cog at baseline, we did not assess and control for mild cognitive impairment at baseline using a general battery of neurocognitive assessments. However, in addition to the Mini-Cog, we included baseline performance in executive function for each of the three outcome measures in our linear regression models. This is a more specific method to control for baseline cognitive performance than would be afforded by tests relating to other cognitive domains. Fourth, we modeled our outcome variables in a linear manner. Although this approach is consistent with past literature using these tests, it is unclear whether other approaches—such as treating them as categorical variables—may be more appropriate. For example, a change in TMT from 80 to 100 seconds may be clinically more significant than a change from 180 to 200 seconds. It is unfortunate that because no validated categorical thresholds have been presented we have stuck with a linear representation to be consistent with the literature (L. D. Baker et al., 2010a, 2010b; Grober et al., 2008). Fifth, because of the size of the study and imbalance in certain characteristics (e.g., 90.5% of those with limited health literacy were Black) future research will need to examine interactions effects. Also, our sample size was somewhat lower than planed as a result of loss to follow-up. The participants who were lost to follow-up had more limited health literacy and worse baseline delta TMT scores than those who were not lost to follow-up, which may have actually reduced the size of the effect of health literacy on executive function. Last, we have presented data on the relationship between health literacy and decline in a specific cognitive domain: executive function; however, health literacy itself may in several ways reflect various cognitive domains. The present study does not include data to ascertain how health literacy is based on different elements of cognition.

Conclusion

In this study, we showed a relationship between limited health literacy in older adults and a more rapid decline in an executive function measure over a period of only 1 year. Manly and colleagues (2005) reported similar findings over the course of a 3-year observation period in a study of verbal fluency measures. This is an important finding because lower executive function is associated with worse chronic disease management (Insel, Morrow, Brewer, & Figueredo, 2006; Stilley, Bender, Dunbar-Jacob, Sereika, & Ryan, 2010), worse functional status and ability to perform instrumental daily life activities (Pereira, Yassuda, Oliveira, & Forlenza, 2008; Reppermund et al., 2011), and greater risk for falls (Herman, Mirelman, Giladi, Schweiger, & Hausdorff, 2010; Montero-Odasso, Verghese, Beauchet, & Hausdorff, 2012; Muir, Gopaul, Montero Odasso, 2012; Yogev-Seligmann, Hausdorff, & Giladi, 2008). Progressive decline in executive function has been shown to be associated with decline in everyday function (Tomaszewski Farias et al., 2009) and hence may be a pathway for higher rates of functional impairment for people with limited health literacy.

Cognitive reserve is not fixed and evolves during the lifespan; even late-stage interventions for age associated cognitive decline in older adults hold promise to boost cognitive reserve (Tucker & Stern, 2011). Identification of high-risk populations such as those with limited health literacy is therefore clinically important and can make way for the development of early, more intensive, and targeted interventions.

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