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In search of 'low health literacy': Threshold vs. gradient effect of literacy on health status and mortality

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ABSTRACT

Studies have demonstrated significant associations between limited literacy and health outcomes. Yet differences in literacy measurement and the cutoffs used for analysis have made it difficult to fully understand the relationship between literacy and health across the entire spectrum of literacy (i.e., whether the relationship is continuous and graded or whether a threshold exists below which literacy is independently associated with health). To analyze this question, we re-examined the relationship between literacy, baseline physical functioning and mental health, and all-cause mortality for a cohort of 3260 US community-dwelling elderly who were interviewed in 1997 to determine demographics, socioeconomic status, chronic conditions, self-reported physical and mental health (SF-36 subscales), health behaviors, and literacy based upon the Short Test of Functional Health Literacy in Adults (S-TOFHLA). All-cause mortality was determined using data from the US National Death Index through 2003. Seven categories of S-TOFHLA literacy scores were created and used in this analysis instead of the existing three categories identified with the measure. In multivariate analyses, a continuous, graded relationship between literacy and baseline physical functioning was identified. However, participants scoring below the third literacy category had significantly worse mental health compared to the highest literacy category, displaying a notable threshold. Finally, all six literacy categories were significantly associated with greater all-cause mortality risk compared to the highest literacy category, but again there was a marked threshold below the third category at which the adjusted mortality rate significantly increased compared to all other categories. We conclude that the nature of the relationship between literacy and health may vary depending upon the outcome under examination.

Introduction

Health literacy, as defined by the Institute of Medicine and National Library of Medicine is "the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions" (Institute of Medicine, 2004). It is a multifaceted concept, of which reading ability is a fundamental component (Baker, 2006; Rudd, Kirsch, & Yamamoto, 2004). An individual's ability to read, comprehend, and take action based on health-related material is closely related to the more general ability to read, comprehend, and take action based on non-health materials. Regardless of the terms and measures used, the field of *health literacy* is based on numerous studies that have found associations between measures of literacy skills and a wide variety of health outcomes (Baker, 2006; Dewalt, Berkman, Sheridan, Lohr, & Pignone, 2004). Studies have linked lower adult literacy with more infrequent use of preventive services, delays in diagnoses, poor understanding of one's medical condition and treatment, non-adherence to medical instructions, inadequate self-management skills, worse physical and mental health, and increased mortality (Baker, Wolf, Feinglass, Gazmararian, & Thompson, 2007; Dewalt et al., 2004; Sudore et al., 2006; Wolf, Gazmararian, & Baker, 2005; Wolf, Knight et al., 2006).

However, it remains unclear whether the relationship between literacy and health outcomes is continuous and graded, or whether there is a threshold below which an individual's reading ability is so limited that he or she is unable to do the essential things needed to prevent disease and injury, seek prompt medical attention, and perform essential self-management tasks (e.g., take medications correctly). What is the requisite level of literacy skills necessary to adequately process, understand and act on health information? If such a threshold effect for inadequate literacy exists, screening tests could identify those patients who are at greatest risk, and it would be possible to develop more explicit guidelines and standards for the design of appropriate health materials and instructional strategies (Baker, 2006; Rudd, 2007; Weiss et al., 2005; Wolf, Davis et al., 2006).

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Efforts to understand the exact relationship between literacy and health have been hampered because studies have used different health literacy measures and have sometimes varied the cutoffs used for analysis. Current tools tend to use three literacy categories (i.e., inadequate, marginal, adequate; Baker, 2006). In some studies, individuals identified as having marginal literacy skills on the two most commonly used health literacy measures (REALM, S-TOFHLA) had outcomes that were intermediate between those with adequate and inadequate literacy, suggesting the likelihood that the relationship between literacy and health outcomes is linear (Baker et al., 2002; Davis et al., 1993; Dewalt et al., 2004; Wolf et al., 2005). However, other studies using the same measures have found that individuals with inadequate literacy had worse outcomes for functional health status, risk of hospitalization, and mortality, but those with marginal literacy were not at higher risk Baker et al., 2007; (Schillinger et al., 2002; Wolf et al., 2005). These latter studies support a possible threshold effect of literacy on health. However, prior health literacy studies have not included analyses allowing for multiple literacy categories, and therefore were not able to detect subtle differences between and within the standard three categories.

To examine this question, we used data from a previous large study of Medicare Managed care enrollees 65 years of age and older. Participants in this study completed detailed questions about mental and physical health, health behaviors, and chronic diseases. All completed the Short Test of Functional Health Literacy in Adults (S-TOFHLA), which has a range of scores from 0 to 100 but also categorizes individuals as having adequate, marginal, or inadequate literacy. Previous analyses from this cohort have found that individuals with inadequate literacy had worse baseline health, worse mental health, and higher mortality (Baker et al., 2007; Wolf et al., 2005). For the current study, we re-examined the associations between literacy skills, baseline physical functioning and mental health, and all-cause mortality using a larger number of categories for the S-TOFHLA to determine if the relationships were continuous and graded, or if a threshold exists below which literacy is independently associated with health.

Methods

Study design and sample

The study design for this project was approved by the Institutional Review Board of Northwestern University. The initial recruitment and baseline data collection for this study have been described previously (Gazmararian et al., 1999). Briefly, new Medicare enrollees age 65 and older in four health plans (Cleveland, Houston, Tampa, and Ft. Lauderdale/Miami) of a national managed care organization were sent a letter of introduction three months after their enrollment, between July and December 1997. One week later, interviewers called each new enrollee via telephone to determine eligibility. Individuals were ineligible if they were not comfortable speaking English or Spanish; were blind or had a severe vision problem; or did not know what year or month it was, what state they lived in, what year they were born, or their address.

A total of 7471 older adults were reached by phone and invited to partake in a one time, in-home interview. Of those contacted, 3247 refused to participate and no questions could be asked to determine eligibility. Of the 4224 interviewees, 737 did not meet eligibility criteria and were excluded. Among the 3487 people who were eligible and agreed to participate, 143 did not show for their interview. Following American Association of Public Opinion Research (AAPOR) guidelines for calculating participation rates, it was estimated that 54.2% of all enrollees who were eligible for the study participated in the interview (AAPOR Standard Definitions, 2004). A total of 84 people had vision difficulties that prevented them from completing the literacy testing, yielding 3260 participants with complete data. Participants were very similar to non-participants. For these analyses, we also excluded 304 participants who were administered the Spanish version of the S-TOFHLA, as the comparability between the scores on the English and Spanish versions has never been properly tested (Aguirre, Ebrahim, & Shea, 2005; Parker, Baker, Williams, & Nurss, 1995). This left a final total of 2956 participants.

Baseline interview and literacy assessment

The interviewer-administered survey assessed the following patient characteristics during a 1-h, in-home interview: demographic and socioeconomic characteristics (age, gender, race/ethnicity, education, household income, occupational class), health behaviors (smoking, alcohol consumption, exercise), body mass index (BMI), self-reported presence of chronic medical conditions (hypertension, diabetes, heart disease, chronic obstructive pulmonary disease or asthma, arthritis, or cancer), depression (measured by the Geriatric Depression Scale), self-rated physical function and mental health status (measured by the SF-36), impairments in instrumental activities of daily living (iADLs) and ADLs, use of health care services and prescription medications taken (Sheikh & Yesavage, 1986; Ware, Kosinki, & Keller, 1994).

Literacy was evaluated by measuring enrollees' reading fluency using a shortened version of the Test of Functional Health Literacy in Adults (S-TOFHLA) that included two reading passages (36 items, 2 points each) and four "numeracy" items (7 points each) to assess comprehension of hospital forms and labeled prescription vials that contained numerical information (Baker, Williams, Parker, Gazmararian, & Nurss, 1999). This test assesses the ability to read and understand prose, document, and quantitative skills. The sum of the two sections yields the S-TOFHLA score, which ranges from 0 to 100. Respondents who could not read at all ($N = 10$) were assigned a score of zero. The S-TOFHLA divides respondents into three categories. Those with scores from 0 to 55 on the S-TOFHLA are classified as having *inadequate literacy*. This term was chosen to indicate that individuals in this category will often be unable to read and comprehend even the simplest materials, including prescription bottles and appointment slips. Those with scores between 56 and 66 are classified as having *marginal literacy*, indicating that they are usually able to read and comprehend the simplest materials, but they will struggle with materials that are even slightly more difficult. Finally, those with scores from 67 to 100 are classified as having *adequate literacy*; this latter group is able to successfully complete most of the reading tasks required to function in the health care setting but yet may misread the more difficult material, particularly if it contains numerical information or requires calculations.

As described in the introduction, the typical three-category classification of the S-TOFHLA is inadequate to examine whether relationships between this test and study outcomes are linear or have a threshold effect. Therefore, for the purposes of this study, S-TOFHLA scores were divided into seven categories that were chosen to provide an adequate number of study subjects in each category across as large a spectrum of health literacy as possible (Fig. 1). Deciles were originally sought out of the 100 point scoring of the S-TOFHLA, however based on an examination of the frequency distribution we created the following categories: Category 1 = 0–30 ($n = 332$); Category 2 = 31–50 ($n = 311$); Category 3 = 51–60 ($n = 224$); Category 4 = 61–70 ($n = 237$); Category 5 = 71–80 ($n = 297$); Category 6 = 81–90 ($n = 484$); and Category 7 = 91–100 ($n = 1071$).

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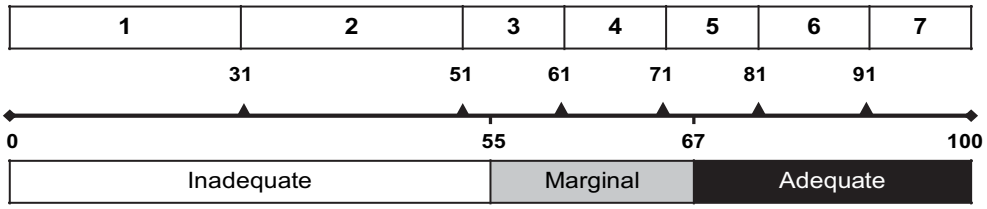

Fig. 1. New and Old S-TOFHLA Categories.

Identification of participant deaths

We used the National Death Index (NDI) to identify deaths occurring between 1997 and the end of 2003. The NDI provided possible matches based on participants' name, social security number and birth information (month, day, and year). A total of 714 death certificates contained information that exactly matched a participant's first and last name, social security number, and birth date. An additional 101 matches were identified from death certificates which matched on at least three of these four identifiers, as well as on additional identifiers such as race, sex, and marital status. Cause of death was determined from ICD-9 codes, and participants were classified as having a cardiovascular death, cancer death, other death, or being alive through 2003.

Statistical analysis

All analyses were conducted using Stata version 9 (College Station, Texas). Chi-square tests were used to examine bivariate associations between health literacy (as seven categories) and binary variables (yes or no), while analysis of variance (ANOVA) was used to compare means for continuous variables. Linear regression models were conducted to estimate the relationship between literacy (seven categories) and SF-36 physical function and mental health status measures, all of which were assessed at baseline, while adjusting for relevant covariates (age, gender, race/ethnicity, household income, education, occupational class, number of self-reported chronic conditions). Income was imputed based on age, gender, race/ethnicity, S-TOFHLA score, past occupation, and health status for 16 percent of participants who refused to report their income. For mental health, baseline physical function and any limitations in activities of daily living (yes/no) or instrumental activities of daily living (yes/no) were also included in multivariate analysis. Likewise, mental health was included in the model for physical function following assumptions made about the relationship between physical function and mental health in prior analyses (Wolf et al., 2005). Site was entered in all of the models to adjust for differences that potentially might exist between study locations. For all analyses, a p value of 0.05 was used to determine statistical significance. The model fit for multivariate linear regression models was assessed by the proportion of the variance explained (adjusted r^2) by the overall model and with F statistics.

The relationship between literacy and time to death was examined using Kaplan–Meier curves, and unadjusted hazard ratios (HR) were initially determined from Cox proportional hazards models. The seven identified categories of S-TOFHLA scores were entered as separate indicator variables in the model, with Category 7 set as the default referent group. Covariates identified above, including baseline functional health status from the SF-36 were included in multivariate Cox models. For all outcomes, interaction terms between literacy and all other significant variables were included in the models to determine whether associations between literacy, functional health status, and mortality varied according to these characteristics.

Results

Among the 2956 participants included in analyses, the proportion of subjects in each of the seven S-TOFHLA categories (from lowest to highest) was 11.2%, 10.5%, 7.6%, 8.0%, 10.1%, 16.4%, and 36.2% respectively. Individuals with lower literacy skills were significantly older, more likely to be non-white, had a lower household income and less education (Table 1). Lower literacy scores were also significantly associated with abstinence from alcohol consumption, less frequent physical activity, and being underweight (BMI < 18.5 kg/m^2). With the exception of alcohol consumption and BMI, the relationship between literacy and demographic, socioeconomic, and physical activity measures were notably linear and graded.

Subjects with lower literacy skills were more likely to report the presence of one or more activity limitations and worse baseline physical functioning and mental health compared to individuals in higher literacy categories (Table 1). In multivariate regression analyses that controlled for demographic and socioeconomic factors, health behaviors, and number of chronic conditions, a continuous, graded relationship was evident between literacy scores and baseline physical functioning (Fig. 2). Participants with literacy scores in the lowest three categories (1, 2, 3) had significantly poorer physical functioning on the SF-36 summary scale compared to those in category 7 (Category 1: $\beta = -7.8$, 95% Confidence Interval (CI) -11.4 to -4.2; Category 2: $\beta = -6.4$, 95% CI -9.8 to -2.9; and Category 3: $\beta = -5.8$, 95% CI -9.5 to -2.1 respectively).

However, the relationship between literacy and mental health appeared to show a threshold rather than continuous relationship after controlling for the above covariates, physical functioning and activity limitations (Fig. 3). Participants with literacy scores falling within Categories 1 and 2 had significantly worse mental health compared to those in Category 7 (Category 1: $\beta = -5.2$, 95% CI -7.6 to -2.8; Category 2: $\beta = -3.8$, 95% CI -6.2 to -1.5).

A total of 767 (25.9%) participants died during an average follow-up of 67.8 months. The all-cause mortality rates for the seven literacy categories (from lowest to highest) were 43.4%, 37.2%, 31.5%, 25.6%, 24.3%, 21.7%, and 14.7% ($p < 0.001$; Table 1). In multivariate analyses controlling for demographics, socioeconomic status, and baseline health (number of chronic conditions, physical functioning, activity limitations, mental health), the relationship between literacy and mortality was notably complex. Adjusted mortality rates were very similar for those in the middle of the literacy score distribution (categories 3–6), while mortality was markedly lower for those in the highest literacy category (7) compared to all other groups (Fig. 4). Adjusted hazard ratios for the middle categories 3 through 6 compared to category 7 were 1.58, 1.42, 1.56, and 1.43; all of which were statistically significant ($p < 0.001$).

At the other end of the spectrum, a marked threshold was noted at the third literacy category, below which the adjusted mortality rates increased compared to the four middle literacy categories. Compared to those in the highest category, the adjusted hazard

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Table 1
Participant characteristics stratified by literacy (S-TOFHLA) scores.

Variable	S-TOFHLA score category							*P* value
	1 ($n = 332$)	2 ($n = 311$)	3 ($n = 224$)	4 ($n = 237$)	5 ($n = 297$)	6 ($n = 484$)	7 ($n = 1071$)	
Age (years), Mean (SD)	76.3 (7.4)	75.0 (7.0)	74.0 (6.4)	73.7 (6.1)	72.5 (6.2)	72.0 (6.0)	70.9 (5.1)	<0.001
Female, %	58.7	58.9	49.8	53.8	58.1	56.4	59.7	0.09
Race/ethnicity, %								<0.001
White	56.9	59.8	67.4	71.4	71.5	79.0	91.2	
African American	27.3	24.8	13.1	10.5	11.1	4.0	6.6	
Hispanic, Spanish-speaking	12.7	12.3	16.1	14.5	11.1	15.6	0.0	
Hispanic, English-speaking	2.1	2.6	2.3	2.5	3.6	0.9	1.3	
Other	1.1	0.6	1.1	1.1	2.7	0.5	0.9	
Annual income, %								<0.001
<$10,000	35.5	34.7	26.2	22.4	18.3	15.6	7.5	
$10,000–$14,999	31.8	28.2	27.7	27.1	26.1	23.3	19.4	
$15,000–$24,999	25.5	27.9	33.0	33.2	35.6	35.6	37.1	
$25,000–$34,999	4.7	5.6	10.1	11.2	12.6	13.9	15.8	
≥$35,000	2.4	3.7	3.0	6.1	7.5	11.6	20.3	
Years of school completed, %								<0.001
Grades 1–8	49.7	33.8	26.2	22.7	15.3	9.2	2.2	
Grades 9–11	21.1	27.0	29.2	19.9	21.3	16.3	11.6	
High school grad/GED	18.7	25.4	26.6	35.7	36.8	39.4	38.5	
>High school	10.5	13.8	18.0	21.7	26.7	35.1	47.8	
Chronic conditions, mean (SD)	1.7 (1.2)	1.7 (1.2)	1.7 (1.3)	1.6 (1.2)	1.6 (1.2)	1.5 (1.2)	1.5 (1.2)	<0.05
Physical function, mean (SD)	41.3 (11.9)	42.0 (12.0)	42.9 (12.0)	44.7 (11.0)	45.1 (10.8)	46.7 (10.6)	46.7 (10.7)	<0.001
Mental health, mean (SD)	51.2 (11.5)	52.6 (10.2)	54.5 (9.5)	55.2 (8.8)	54.7 (9.1)	55.2 (8.2)	55.9 (7.2)	<0.001
IADL limitation, %	49.7	43.9	40.1	33.6	27.3	25.2	20.5	<0.001
ADL limitation, %	11.8	6.5	5.6	5.8	3.0	2.6	2.7	<0.001
Smoking, %								0.09
Never	42.9	48.2	41.9	41.9	40.1	38.7	37.3	
Former	43.4	41.4	46.4	44.4	49.1	47.9	50.2	
Current	13.7	10.4	11.6	13.7	10.8	13.4	12.5	
Current alcohol Use, %								<0.001
None	75.5	76.9	64.0	65.7	68.3	57.5	55.4	
Light to moderate	23.4	21.1	34.1	32.1	29.3	39.2	39.5	
Heavy	1.1	2.0	1.9	2.2	2.4	3.3	5.1	
Vigorous physical activity								<0.001
4 or more times per week	26.4	35.6	37.9	41.5	41.9	49.5	48.4	
3 times per week	14.0	12.3	19.7	15.2	14.1	14.9	15.1	
1–2 times per week	15.3	14.2	10.6	15.2	17.4	14.4	16.3	
Less than once per week	44.3	37.9	31.8	28.1	26.6	21.2	20.2	
Body mass index (kg/m^2), %								<0.005
<18.5	9.7	5.9	4.1	4.0	4.5	5.0	3.6	
18.5–24.9	57.4	58.0	67.0	56.3	55.4	59.6	57.4	
25–29.9	22.9	24.5	18.7	28.2	26.1	23.6	27.1	
30 or greater	10.0	11.6	10.1	11.6	14.1	11.8	12.0	
Died during follow-up, %	43.4	37.2	31.5	25.6	24.3	21.7	14.7	<0.001

ratios for the lowest two literacy categories were 2.29 (95% CI 1.74–3.02) and 1.88 (95% CI 1.44–2.46). To further test for the presence of a threshold effect in the relationship between literacy and mortality, we combined literacy categories 1 and 2 and categories 3–6. Individuals in the combined categories 1 and 2 had significantly greater all-cause mortality compared to the combined categories 3, 4, 5, and 6 (HR 1.36, 95% CI 1.14–1.62).

No significant interactions with literacy and variables of interest were identified for either baseline physical function and mental health, or mortality.

Discussion

Our findings suggest that the nature of the relationship between literacy and health may vary depending upon the outcome under examination. We found that literacy, as measured by the S-TOFHLA, had a continuous and graded relationship with baseline physical functioning across the entire range of S-TOFHLA scores. There are two possible explanations. First, the S-TOFHLA could be merely another measure that partly captures the variance in health outcomes explained by the multifaceted domain of socioeconomic status. Many studies have shown a continuous, graded relationship between socioeconomic status and various health outcomes (Elo & Preston, 1996; Erikson & Torssander, 2008; Kitigawa & Hauser, 1973; Marmot et al., 1991). Literacy may simply be a robust surrogate of the underlying latent variables in the pathways that mediate the relationship (e.g., poor nutrition, greater exposure to environmental toxins, greater psychological stress, and poor access to quality health care).

Alternatively, literacy could be causally associated with physical functioning. Each incremental decrease in the cognitive skills encompassing reading fluency may lead to progressively lower understanding of how to stay healthy, when to seek medical care, and how to properly follow medical regimens to recover from acute illnesses and to care for chronic health conditions. Over a lifetime, these deficiencies may take a toll on physical health, resulting in progressively worse baseline physical functioning across the entire spectrum of literacy in cross-sectional analyses. Both of these

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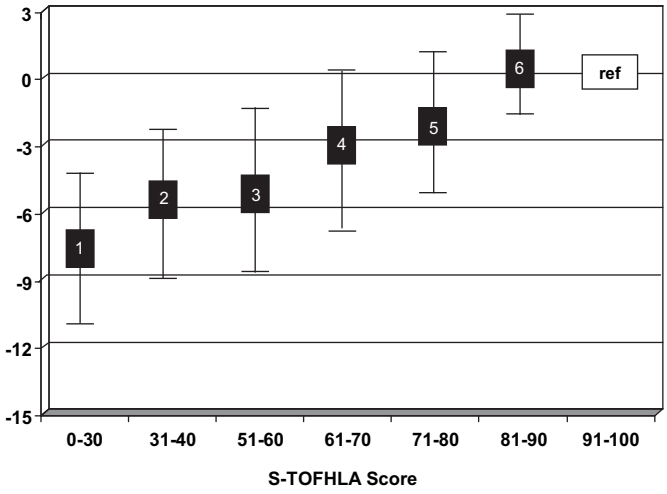

Fig. 2. Adjusted Differences in Physical Function by S-TOFHLA Score. Note: Scores on *Y*-axis reflect adjusted differences on scores from the SF-36 physical functioning summary scale. Higher scores equate to better function.

explanations are possible. The strength of the independent association between literacy and physical functioning (i.e., after adjusting for education and income) makes it unlikely that literacy is merely capturing residual confounding, so some causal association between literacy and physical functioning is likely.

The association between literacy skills, baseline mental health, and mortality, however, displayed apparent threshold effects below the third literacy category. Those scoring below 0–50 (Categories 1 and 2) had progressively worse mental health and were at significantly greater risk of all-cause mortality than higher literacy categories even after adjusting for other predictors. As described above for physical functioning, it is possible these relationships could be explained by literacy being a marker of socioeconomic status, although the relationship between socioeconomic status and mental health specifically is less well established (Kosteniuk & Dickinson, 2003; Lorant, Deliege, Eaton, Robert, & Ansseau, 2003; Ulbrich, Warheit, & Zimmerman, 1989).

For mental health, it may be reasonable to consider possible causal pathways that would support a threshold effect. Individuals with very low reading ability may consequently have very low self-esteem and experience shame (Parikh, Parker, Nurss, Baker, &

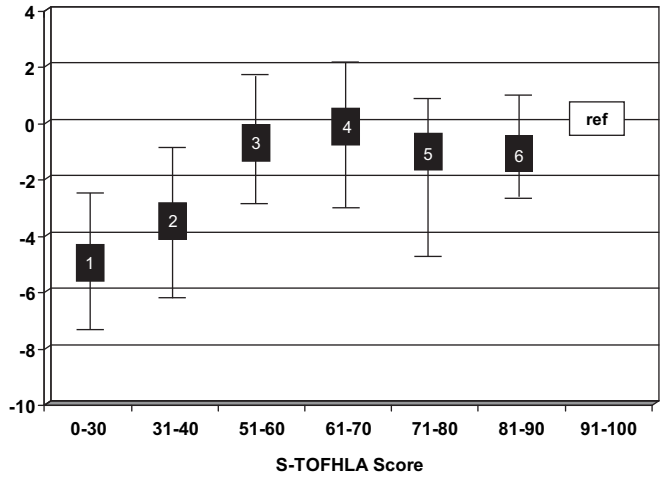

Fig. 3. Adjusted Differences in Mental Health by S-TOFHLA Score. Note: Scores on *Y*-axis reflect adjusted differences on score from the SF-36 mental health summary scale. Higher scores equate to better mental health.

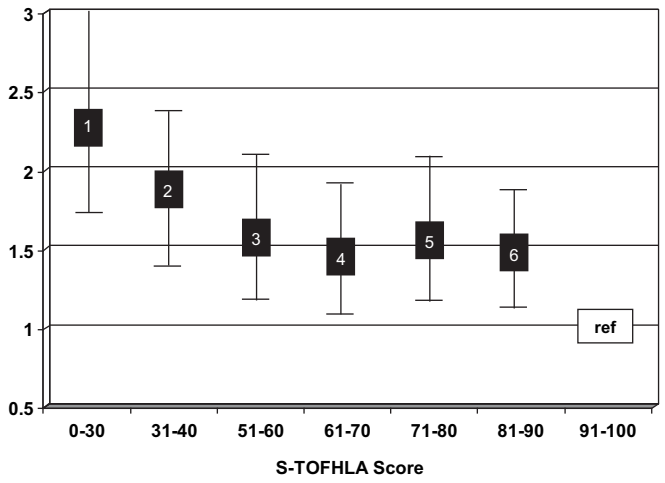

Fig. 4. Adjusted Hazard Ratios for Mortality Risk by S-TOFHLA Score.

Williams, 1996; Wolf et al., 2007). They may also be prone to anxiety about their ability to do certain health tasks, especially for older adults like those in this study who may have greater concerns about living independently as they age. Those with intermediate reading ability may not experience these thoughts and emotions. Finally, it is possible that the causal direction between literacy and mental health is in the opposite direction; individuals with very poor mental health may have had difficulty completing the S-TOFHLA resulting in spuriously lower scores. Prospective studies would be needed to examine the latter explanation.

In a similar manner, the threshold effect that was revealed in mortality analyses might be explained by whether or not an individual has the adequate level of knowledge and skills to sufficiently manage one's day-to-day health needs, especially as these may increase with age. Yet the reason why the association between literacy and physical functioning was linear and the associations between literacy, mental health, and mortality were thresholds is not clear. We believe that a likely explanation, at least when comparing physical function and mortality, is the difference in study design for the two analyses. The analysis of literacy and physical functioning was cross-sectional, as both literacy and physical functioning were measured at the time of study entry. Yet at the time of study entry, literacy may have served as a proxy for socioeconomic status over the course of an individual's entire life (i.e., individuals with lower literacy had worse education during childhood, less desirable jobs, lower income, worse housing, etc.). Similarly, physical functioning at the time of study entry may also reflect the cumulative insults to a person's health over their life. This blending of causal influences and summation of health events could result in a linear association between literacy and physical functioning.

In contrast, the prospective analysis of mortality examined the independent risk conveyed by literacy after adjusting for baseline socioeconomic status and baseline health over the comparatively short six year follow-up period. In this situation, a participant's S-TOFHLA score may have been a more pure indicator of the person's functional literacy skills and less a proxy for individuals' lifetime socioeconomic status. In creating the original S-TOFHLA scoring system of adequate, marginal, and inadequate, the developers postulated that there was likely to be a threshold in literacy skills (i.e., the adequate-marginal cutoff) below which people will be less able to perform essential tasks and, therefore, will experience worse health outcomes (Parker et al., 1995). The finding of a threshold effect for the prospective analysis of mortality – and mental health – supports this. If this explanation is correct, then if

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we had been able to do a prospective analysis of changes in physical functioning during follow-up we would also expect that a threshold effect would be seen.

A surprising finding was that individuals in the highest literacy category had substantially lower risk-adjusted mortality even compared to those with only slightly lower literacy scores that were still in the traditional "adequate" range. This is unlikely to be due to chance alone because of the large sample size in each of these categories. The original conceptualization of the S-TOFHLA categories was that all individuals in the "adequate" group would be similarly able to do essential health care tasks, although only those at the upper end of the S-TOFHLA would be able to read and comprehend the most difficult tasks such as informed consent forms and health insurance information. However, this could be incorrect, and individuals with only the highest literacy skills might have been able to achieve greater understanding of health information. Alternatively, very high literacy scores could be a surrogate for unmeasured socioeconomic factors, such as net worth. The magnitude of the difference in adjusted mortality rates between categories 6 and 7 makes it improbable that this is the whole explanation. A very high S-TOFHLA score could also be a marker for other (non-socioeconomic) unmeasured confounders, such as cognitive ability, self-efficacy, nutrition, health knowledge, and propensity to seek out health information. More evidence is needed to confirm the direct effect of higher literacy on lower risk-adjusted mortality, and to more precisely identify what functional aspects of literacy account for this relationship.

Interestingly, when we take into account the lower mortality for individuals in the highest reading category, the magnitude of the association between literacy and mortality is substantially greater than what we have published previously when we used the entire "adequate" group as the referent (previous adjusted hazard ratio 1.52 for Inadequate vs. Adequate, compared to the current adjusted hazard ratio 2.24 for Category 1 vs. Category 7; Baker et al., 2007; Wolf et al., 2005, see Fig. 1). What then is the more accurate reflection of literacy's impact on health, and should the cutoffs for inadequate, marginal, and adequate literacy be changed? Based on the present findings, researchers might first consider modifying the S-TOFHLA reference score category to 91–100 (Category 7) rather than 67–100 for future studies. This would acknowledge a larger number of individuals as having notable difficulty when seeking to access and understand existing health information and services; a group that could be referred to as having 'limited' literacy skills. Such a change could be justified, as patients across literacy categories 1 through 6 had significantly worse mental health and greater mortality risk compared to those in category 7. Since patients in categories 1 and 2 had worse health outcomes compared to those in literacy categories 3 through 6, it would also still be important to distinguish between these two groups. Therefore, the corresponding cutoffs to categories 1 and 2 (0–50) and categories 3 through 6 (51–90) could be used to identify 'inadequate' (or 'low') and 'marginal' literacy groups. A word of caution; by narrowing the 'adequate literacy' category to only the highest S-TOFHLA scores, the gap between adequate and inadequate literacy skills is widened. It will therefore become more challenging to demonstrate the health benefits of interventions designed to mitigate the effects of low literacy (Pignone, DeWalt, Sheridan, Berkman, & Lohr, 2005).

This study has several limitations. Although it is one of the most common instruments used to measure literacy, the S-TOFHLA is not a comprehensive measure of the construct more broadly defined by the Institute of Medicine as *health literacy*. Instead, the S-TOFHLA has been conservatively classified as a basic assessment of adult general literacy skills in the context of health care; perhaps also tapping into latent cognitive abilities (Baker, Wolf, Feinglass, & Thompson, 2008; Wolf, et al. 2009). Whatever the classification, the S-TOFHLA has differentiated individuals according to their ability to understand health information, perform health behaviors, and achieve desirable outcomes in numerous studies (Dewalt et al., 2004). Another problem with the S-TOFHLA is an inherent ceiling effect. With more than a third of patients falling in the referent group (Category 7), we cannot fully examine the relationship between literacy, physical and mental health, and mortality. In addition, as previously described, only half of eligible new Medicare managed care enrollees participated, and non-participants had slightly higher socioeconomic status. The association between health literacy and mortality, in particular, may have differed among non-participants. Finally, our study was limited to people 65 years or older, so we cannot extrapolate our findings to younger individuals.

In summary, our findings offer researchers new classifications to explore in future studies that use the S-TOFHLA as a literacy assessment. However, further investigation confirming that a threshold effect exists between literacy and various health outcomes is still warranted. This line of inquiry should also extend beyond the study of this single, somewhat crude measure of literacy to other new and more comprehensive assessments as they are developed. At this time, neither the S-TOFHLA or the Rapid Estimate of Adult Literacy in Medicine (REALM) are recommended as clinical screening tools (Paasche-Orlow & Wolf, 2007a). The present objective should be to better define the broader concept of health literacy and more fully understand the nature of its relationship with health outcomes (Paasche-Orlow & Wolf, 2007b). This will guide the development of robust intervention strategies that respond to those most affected by low health literacy, however defined, and ensure our health system communicates and engages with all patients in the most equitable manner.

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