Literacy Skills and Calculated 10-Year Risk of Coronary Heart Disease

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BACKGROUND: Coronary heart disease (CHD) is a leading cause of morbidity and mortality. Reducing the disease burden requires an understanding of factors associated with the prevention and management of CHD. Literacy skills may be one such factor.

OBJECTIVES: To examine the independent and interactive effects of four literacy skills: reading, numeracy, oral language (speaking) and aural language (listening) on calculated 10-year risk of CHD and to determine whether the relationships between literacy skills and CHD risk were similar for men and women.

DESIGN: We used multivariable linear regression to assess the individual, combined, and interactive effects of the four literacy skills on risk of CHD, adjusting for education and race.

PARTICIPANTS: Four hundred and nine English-speaking adults in Boston, MA and Providence, RI.

MEASURES: Ten-year risk of coronary heart disease was calculated using the Framingham algorithm. Reading, oral language and aural language were measured using the Woodcock Johnson III Tests of Achievement. Numeracy was assessed through a modified version of the numeracy scale by Lipkus and colleagues.

KEY RESULTS: When examined individually, reading ($p = 0.007$), numeracy ($p = 0.001$) and aural language ($p = 0.004$) skills were significantly associated with CHD risk among women; no literacy skills were associated with CHD risk in men. When examined together, there was some evidence for an interaction between numeracy and aural language among women suggesting that higher skills in one area (e.g., aural language) may compensate for difficulties in another resulting in an equally low risk of CHD.

CONCLUSIONS: Results of this study not only provide important insight into the independent and interactive effects of literacy skills on risk of CHD, they also highlight the need for the development of easy-to-use assessments of the oral exchange in the health care setting and the need to better understand which literacy skills are most important for a given health outcome.

KEY WORDS: cardiovascular disease; health literacy; communication skills; vulnerable populations.

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INTRODUCTION

Coronary heart disease (CHD) remains a leading cause of death and disability worldwide^{1,2}. The high disease burden of CHD has prompted the setting of 15 objectives for Healthy People 2010 under a broader goal “to improve cardiovascular health and quality of life through the prevention, detection, and treatment of risk factors...and prevention of recurrent cardiovascular events”³. However, this requires a thorough understanding of modifiable factors associated with CHD prevention and management.

Health literacy, the “degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions”⁴, may be one such factor. Low health literacy remains a formidable barrier to reducing gaps in health care quality and improving outcomes. Individuals with low health literacy find it difficult to understand directions for taking medicine, calculate a dose of an over-the-counter medication or comprehend a consent form^{5,6}. Low health literacy may also contribute to suboptimal care and outcomes through lower participation in screening programs⁷, reduced ability to act on and understand the advice of a health professional⁸, and limited ability to navigate the health care system^{9,10}. Reports from the 2003 National Assessment of Adult Literacy (NAAL) suggest that only 12% of the population is considered to have ‘proficient’ health literacy¹¹.

Evidence linking health literacy to CHD outcomes comes from studies of Medicare managed care enrollees¹²; rates of cardiovascular death were higher for those with inadequate literacy (19.3%) and marginal literacy (16.7%) compared with those with adequate health literacy (7.9%). Individuals with lower health literacy are also more likely to have or engage in CHD risk factors including smoking^{13,14}, hypertension^{15,16}, and diabetes¹⁶.

While these studies provide important insight into the relation between literacy and CHD, the majority assessed reading skills as a proxy for health literacy. This has two

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potential limitations. First, reading skills are only one component of health literacy. Other skills such as numeracy, writing, oral language (speaking) and aural language (listening) are less studied despite our dependence on the oral exchange to communicate symptoms, concerns, and treatment options. Second, it is unclear whether health literacy can, or should, be represented by a single dimension.

The objective of this study was to provide insight into the individual and combined effects of four health literacy skills on the calculated 10-year risk of CHD, using data from 409 individuals from the New England Family Study (NEFS). We hypothesized that in addition to reading skills, other measures of literacy (e.g., numeracy, oral language, aural language) would be associated with CHD risk. Because many people depend on non-written means of communication for health information^{17,18}, we also hypothesized that stronger oral or aural language skills may compensate for weaker reading or numeracy skills.

METHODS

Study Population

In 2001, the NEFS was established to locate and follow-up adult offspring of pregnant women originally enrolled in the Providence, Rhode Island and Boston, Massachusetts sites of the Collaborative Perinatal Project (CPP)¹⁹. The NEFS is a center comprised of numerous research projects, each following-up a different set of individuals²⁰. Data for the current analyses came from a NEFS study designed to assess pathways linking education and health. Eight hundred participants in their mid-40s were selected from the NEFS population through a multi-stage sampling procedure to ensure an adequate mix of educational attainment. Six hundred eighteen (77.3%) individuals were successfully located and interviewed. Study assessments had two components. All participants completed a structured interview in English, and they underwent a clinical assessment, which included a blood draw. Although study participants have been followed since birth, the current analyses are cross-sectional.

Measures

Ten-Year Calculated Risk of Coronary Heart Disease. We calculated the 10-year risk of having a hard coronary heart disease outcome (i.e., myocardial infarction or coronary death) as a percentage using the validated Framingham risk algorithm. The algorithm uses gender-specific Cox regression models that incorporate age, diabetes, smoking, total and HDL cholesterol, and systolic and diastolic blood pressure^{21,22}. The Framingham algorithm has good predictive validity for CHD events in the Framingham Heart Study (c-statistic = 0.74 and 0.77 for men and women, respectively)²². External validity tests with other samples have been performed where the risk algorithm was found to perform reasonably well in both black and white men (c-statistic ranged from 0.63 to 0.75) and women (c-statistic ranged from 0.66 to 0.83)²³.

Lipids were measured in non-fasting plasma samples and total cholesterol was measured enzymatically as described elsewhere²⁴. HDL cholesterol was determined using a direct

enzymatic colorimetric assay²⁵. Presence of diabetes and current smoking status were self-reported. Systolic and diastolic blood pressure were measured in seated, resting participants, using automated blood pressure monitors with good validity and reliability compared with auscultation²⁶. Five blood pressure readings were obtained; systolic and diastolic values were calculated as the mean of the lowest three systolic or diastolic blood pressure readings, excluding the first recorded blood pressure.

Literacy Skills. We measured four literacy skills: reading comprehension, numeracy, oral language (speaking), and aural language (listening). Reading comprehension, oral language, and aural language were assessed using subtests of the Woodcock Johnson III (WJ III) Tests of Achievement, a standardized test normed against a representative U.S. population, ages 24 months to 90 years and older²⁷. The WJ III produces both age- and grade-equivalent scores; grade equivalent scores were used in these analyses. The Tests of Achievement were administered to study participants by one of three interviewers trained on the administration of the WJ III by a psychologist external to the research team. Standard administration procedures were used; subjects answered questions of increasing difficulty until a ceiling was reached. As a result, the number of items for the WJ III subtests varies by study participant. Numeracy was assessed using an eight-item scale adapted from Lipkus et al.²⁸, described in more detail below.

Oral language was assessed by the WJ III test "Story Recall," in which participants listen to a pre-recorded short story (1–3 paragraphs) and are then asked to repeat the story back to the interviewer²⁷. Scores are based on the correct number of words or phrases spoken, and the reliability of the test is good with a one-year test-retest reliability of 0.70²⁷. This test is similar to commonly used "teach-back" methods that providers use to gauge patient communication, understanding, and recall of health messages and instructions.

Aural language, or listening comprehension, was assessed by the WJ III test "Understanding Directions," in which participants are given an illustrated drawing and are asked to complete a pre-recorded direction followed by a few-second pause to complete the task, when another direction is given. Difficulty increases as drawings become more complex and the tasks increase in number of components²⁷. Scores are based on the number of correct tasks completed. Reliability of this test is good with a one year test-retest reliability of 0.88²⁷. This test was selected for its similarity to experiences in the health care setting, where providers give patients a set of instructions for taking their medicine or preparing for a medical procedure, for example.

Reading comprehension was assessed using the "Passage Comprehension" test from the WJ III. This is a cloze test, where individuals fill in missing words from a sentence. Reliability for this test is good with a one-year test-retest reliability of 0.92²⁷.

Numeracy was assessed using eight items from the scale developed by Lipkus and colleagues^{28,29}. Three items were dropped from the Lipkus scale (item number 2 from the general numeracy scale, and items 3 and 7 from the expanded numeracy scale) due to time constraints for the full protocol, which took approximately 2 1/2 hours to complete. As such, three items were dropped to fit within the allotted timeframe for the construct. Based on the study by Lipkus et al.²⁸, the items with the highest (90.5%) and lowest (48.6%) correct were deleted

from the expanded numeracy scale, and the item with the highest percent correct (59.8%) was dropped from the general numeracy scale to minimize the bias that could arise from dropping the three easiest or hardest items.

Analogously to Lipkus²⁸, we conducted a factor analysis using the 8x8 matrix of tetrachoric correlations, which are used to assess the correlation among dichotomous variables. Factor analysis confirmed a one-factor solution, with all 8 items loading on the first factor (individual loadings each exceeded 0.4). The first factor accounted for 86.25% of the variance. Numeracy scores were based on the total number of correct responses (range: 0-8, mean = 5.47, SD = 1.85).

Demographic Covariates. Educational attainment represents the number of years of formal schooling a person reported, ranging from 7-21 years. Race was self-reported and categorized as non-Hispanic White, non-Hispanic Black, and Hispanic or other. Age of respondent and tobacco use were not included in the multivariable models as they are components of the Framingham risk score.

Analysis

Correlations, t-tests and chi-square tests were used to describe sample characteristics. We used multivariable regression to assess the individual, combined, and interactive effects of the four literacy skills on risk of CHD, adjusting for education and race. The regressions contained random intercepts to account for within family clustering. Analyses were stratified by gender to parallel the computation of the Framingham risk algorithm. Analyses of the 10-year risk of CHD were conducted on a log scale because the distribution of Framingham risk was right skewed. Because the interpretation of model coefficients on a log scale is not intuitive, we used adjusted predictions to illustrate the association between individual variables and CHD risk³¹. Specifically, we set each literacy skill in turn to its 10th, 50th, and 90th sample percentile (women and men combined) and computed sample average 10-year CHD risk predictions from the regression model.

RESULTS

Twenty-one individuals with previous heart disease were excluded from the analyses as were an additional 188 participants lacking one or more components used to calculate the Framingham risk. Accordingly, the sample size for the analysis was 409 (66% of the selected sample). No significant differences in gender, race, education, numeracy or aural language were found between those included and not included in the analytic sample (Table 1). Individuals included in the analyses were, however, slightly younger and had higher average grade equivalent scores for reading (12.7 vs. 11.6, $p = 0.02$), oral language skills (7.9 vs. 6.9, $p = 0.02$) and aural language skills (8.1 vs. 7.2, $p = 0.04$) than those excluded from the study. An examination of individual components of the Framingham risk algorithm revealed no differences between the analytic sample and those excluded from analysis.

Table 1. Sample Characteristics*

Characteristic	Analytic Sample	Excluded†	p-value
	M(SD) or P(n) n = 409	M(SD) or P(n) n = 188	
Education, years	13.6 (2.5)	13.7 (2.7)	0.60
Race			0.11
White	80.4% (329)	73.0% (135)‡	
Black	15.2% (62)	20.0% (37)	
Hispanic/other	4.4% (18)	7.0% (13)	
Gender			0.21
Male	41.5% (170)	36.2% (68)	
Female	58.5% (239)	63.8% (120)	
Age, years	42.2 (1.8)	43.0 (1.9)	0.001
Literacy Skills			
Reading	12.7 (4.7)	11.6 (5.0)	0.02
Numeracy	5.5 (1.8)	5.4 (2.0)	0.40
Oral language	7.9 (4.5)	6.9 (4.3)	0.02
Aural language	8.1 (4.4)	7.2 (3.7)	0.04
Algorithm components			
Systolic blood pressure	114.9 (15.7)	115.2 (15.3)	0.85
Diastolic blood pressure	75.6 (11.1)	75.8 (10.9)	0.91
Total cholesterol	197.4 (40.1)	187.2 (51.5)	0.42
HDL cholesterol	49.4 (16.6)	47.3 (16.0)	0.68
Smoker	27.4% (112)	28.0% (51)	0.87
Diabetes‡	3.4% (14)	4.4% (8)	0.58

* The sum of cells within each column may not equal the total N due to missing values

† Excluded due to missing values for one or more components of the Framingham algorithm

‡ Excludes diabetes only during pregnancy

Correlations among literacy skills ranged from 0.38 (reading and listening) to 0.60 (numeracy and reading). The mean estimated 10-year risk of CHD was significantly higher for men (6.7%) than women (2.6%) ($p < 0.001$ on the log scale). Several literacy skills showed significant gender differences. Men scored significantly higher on both reading (men = 13.3, women = 11.9, $p < 0.001$) and numeracy (men = 6.1, women = 5.1, $p < 0.001$) while women scored higher, on average, on aural language skills (men = 7.4, women = 8.2, $p = 0.02$). There were no gender differences in oral language skills.

Multivariable Regression

Figure 1 presents model-based predictions, based on the log model of 10-year risk of CHD, separately for men and women at the 10th, 50th and 90th sample percentile of each literacy skill, adjusted for demographic characteristics. For easier interpretation, log transformed CHD risk has been re-transformed to the original scale in Figure 1. In women, higher reading ($\beta = -0.027$, $p = 0.007$), numeracy ($\beta = -0.085$, $p = 0.001$), and aural language ($\beta = -0.028$, $p = 0.004$) skills were associated with significantly lower 10-year risk of CHD. In men, however, reading ($\beta = -0.013$, $p = 0.20$), numeracy ($\beta = -0.027$, $p = 0.36$), and aural language ($\beta = 0.003$, $p = 0.77$) skills had smaller log scale coefficients and were not significantly associated with risk of CHD. Oral language skills were not associated with risk for CHD for either gender.

For women, an increase in aural language skills from the sample 10th to the 90th percentile was associated with a reduction in predicted 10-year risk of CHD from 2.3% to 1.8%, an estimated reduction of 5 CHD events out of 1,000 women. An

Figure 1. Predicted 10-year CHD risk for the 10th, 50th, and 90th percentile of health literacy skills. Predictions (of CHD risk) illustrate separate regressions (of log CHD risk) for each literacy skill by gender¹. Black bar: 10th percentile of literacy skill. Dark gray bar: 50th percentile of literacy skill. Light gray bar: 90th percentile of literacy skill.

analogous increase in reading skills was associated with a reduction in predicted 10-year risk of CHD from 2.4% to 1.7%, an estimated reduction of 7 CHD events out of 1,000 women. An increase in numeracy skills from the 10th to the 90th percentile was also associated with a reduction in predicted 10-year risk of CHD from 2.4% to 1.6%, a projected reduction of 8 CHD events out of 1,000 women.

We then simultaneously examined reading, numeracy, oral and aural language in relation to predicted 10-year CHD risk among women. The final model included numeracy ($\beta = -0.134$, SE = 0.047, $p = 0.005$), aural language ($\beta = -0.071$, SE = 0.036, $p = 0.046$) and the interaction between numeracy and aural language ($\beta = 0.01$, SE = 0.006, $p = 0.119$). Reading did not contribute significantly to the model after controlling for numeracy. Although the interaction between numeracy and aural language was only marginally statistically significant, further data analyses (e.g., regression models stratified by aural language) confirmed that the interaction was present in the data, and not an artifact of multi-variable modeling

Figure 2. Predicted 10-year CHD risk among women based on the final multivariable regression (of log CHD risk) on numeracy, aural language and numeracy by aural language interaction¹. Solid line: aural language 10th percentile. Dashed line: aural language 50th percentile. Dotted line: aural language 90th percentile.

(Figure 2). Retaining the interaction also avoids potential bias due to model misspecification³². Women with the lowest 10-year risk of CHD had either high numeracy or high aural language skills. Women having difficulty with both numeracy and aural language skills were at highest risk, followed by those with low numeracy but moderate (50th percentile) aural language skills. The final multivariable model explained about 12% of the variation in CHD risk (adjusted $R^2 = 0.119$).

DISCUSSION

Literacy skills are important determinants of health, and affect one's ability to prevent, manage, and treat disease effectively. This is the first study to examine the individual and combined effects of four literacy skills simultaneously in relation to the calculated 10-year risk of CHD. Findings suggest that when examined individually, higher reading, numeracy, and aural language scores were associated with a lower risk of CHD, although these associations were significant only for women. When examined jointly, numeracy and aural language skills were the strongest predictors. Our results also highlight the importance of listening skills. As hypothesized, higher skills in one area (e.g., aural language) may compensate for difficulties in another (e.g., numeracy) resulting in an equally low risk of CHD. Our study also suggests that reading may not be the strongest literacy measure associated with CHD risk.

The lack of association between literacy skills and 10-year CHD risk among men was surprising, but consistent with other literature illustrating stronger associations of socioeconomic position (correlated with literacy skills) with obesity³³ and metabolic syndrome³⁴ (a risk factor for CHD) among women as compared to men. This is unlikely due to lack of power alone because coefficients for men were consistently smaller than those for women. One potential explanation relates to parity. Prospective studies have demonstrated that childbirth is associated with increased long-term central adiposity and decreased HDL cholesterol

levels^{35,36}. Given the inverse association between a woman's educational attainment and number of children born³⁷, and strong correlation between literacy skills and educational attainment, one potential explanation may be the literacy-related differences in parity. We, however, did not ask women in our study about number of pregnancies, and as a result are not able to test this hypothesis empirically.

This study has several limitations. First, the sample was not nationally representative. In particular, the sample contains few Hispanics and did not include immigrants or individuals for whom English is a second language. Second, risk factors for CHD are more prevalent among individuals with lower literacy and while we were able to account for race/ethnicity and educational attainment, there may be other unmeasured factors that may account for the association between literacy skills and risk of CHD. It is not clear, however, whether such factors such as obesity or other measures of socioeconomic status such as income should be treated as potential confounding factors or whether they are better described as mediators on the causal pathway between literacy skills and CHD risk. While education was used as a proxy for socioeconomic status in these analyses, the strong link between education and literacy skills and the uncertainty about their temporal order (i.e., do higher literacy skills result in higher education or vice-versa) suggests that by controlling for education, we may be underestimating the relationship between literacy and CHD risk.

Another limitation is that this study did not include writing which has also been cited as an important component of health literacy³⁸. It is also not clear whether our results were affected by the use of a modified numeracy scale. Finally, most of our literacy measures were not assessed within a health context and, thus, cannot be considered measures of "health literacy." While there are no currently available measures of the oral exchange in a health context, the measures used in this study are good proxies to capture such skills as they are readily available, normed, and validated. However, we do acknowledge that context is extremely important when studying health literacy and that the complexity of the health care system, the medical jargon used by many providers, and the exposure to novel health concepts all have the potential to exceed one's health literacy skills, even among those with adequate literacy. As such, findings from our study may only underestimate the true association between health literacy skills and risk of CHD.

In addition to further examining the association between literacy skills and risk of CHD, more work must be done to understand the mechanisms for the association. It is not known, for example, who among the sample had access to a physician, whether food or cigarette labels or risks were clearly understood, whether antihypertensive medications were taken as prescribed, or whether conversations with and recommendations by health care providers were effective and useful. Understanding why the association exists has important implications for interventions to lower risk of CHD, particularly among women.

While the results from this study provide important insight into the independent and interactive effects of literacy skills on risk of CHD, they also highlight the need for the development of easy-to-use assessments of the oral

exchange in the health care setting and the need to better understand which literacy skills specifically are most important for given outcomes.

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