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Does Numeracy Correlate with Measures of Health Literacy in the Emergency Department?

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Abstract

Objectives—To quantify the correlation between general numeracy and health literacy in an emergency department (ED) setting.

Methods—This was a prospective cross-sectional convenience sample study of adult patients in an urban, academic ED with 97,000 annual visits. General numeracy was evaluated using four validated questions; and health literacy using three commonly used validated screening tools (Short Test of Functional Health Literacy in Adults [S-TOFHLA], Rapid Estimate of Adult Literacy in Medicine-Revised [REALM-R], and the Newest Vital Sign [NVS]). Scores were dichotomized for health literacy tests to limited (low or marginal) vs. adequate health literacy, and the proportion of patients answering all numeracy questions correctly were calculated with the mean proportion of correct responses in these groups. The correlation between numeracy scores and scores on the health literacy screening tools was evaluated using Spearman's correlation.

Results—Four hundred forty-six patients were enrolled. Performance on questions evaluating general numeracy was universally poor. Only 18 patients (4%) answered all numeracy questions correctly, 88 patients (20%) answered zero questions correctly, and overall the median number of correct answers was one (IQR 1 to 2). Among patients with limited health literacy by any of the three screening tools used, the mean number of correct numeracy answers was approximately half that of patients with adequate health literacy. However, even among those with adequate health literacy, the average number of correct answers to numeracy questions ranged from 1.6 to 2.4 depending on the screening test used. When dichotomized into those who answered ≤50% vs. >50% of numeracy questions correctly, there was a significant difference between those with

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limited health literacy and those who scored ≤50% on numeracy. Health literacy screening results were correlated with general numeracy in the low to moderate range: S-TOFHLA $r_s = 0.428$ ($p < 0.0001$); REALM, $r_s = 0.400$ ($p < 0.0001$); and NVS, $r_s = 0.498$ ($p < 0.0001$).

Conclusions—Correlations between measures of general numeracy and measures of health literacy are in the low to moderate range. Performance on numeracy testing was nearly universally poor, even among patients performing well on health literacy screens, with a substantial proportion of the latter patients unable to answer half of the numeracy items correctly. Insofar as numeracy is considered a subset of health literacy, these results suggest that commonly used health literacy screening tools in ED-based studies inadequately evaluate and overestimate numeracy. This suggests the potential need for separate numeracy screening when these skills are important for health outcomes of interest. Providers should be sensitive to potential numeracy deficits among those who may otherwise have normal health literacy.

INTRODUCTION

It is estimated that over 80 million U. S. adults have limited health literacy (LHL), putting them at risk for a number of negative health outcomes, including but not limited to greater hospitalization, increased use of emergency care services, poorer medication adherence, and among geriatric populations, worse overall health status and greater mortality.[1,2] Relatively less is known about the role of numeracy in patient outcomes. Numeracy encompasses different levels of facility with numbers ranging from simple arithmetic, estimation, and computation to analytic tasks and understanding risk and probability.[3] Basic numeracy is called upon frequently during medical encounters in areas such as understanding medication dosing and frequency, informed decision-making regarding testing and treatment options, and in scheduling outpatient follow-up appointments. Both LHL and limited numeracy have been found to be highly prevalent in the emergency department (ED).[2,4,5] Although numeracy has often been considered a subset or domain of health literacy,[3] patients with limited numeracy may be subject to poor outcomes independent of those known to be associated with LHL.[4] Most commonly used health literacy screening tools do not explicitly incorporate a measure of numeracy, and are primarily designed to assess reading and writing domains.[5,6] Those that do include a numeracy component (Newest Vital Sign [NVS], Test of Functional Health Literacy in Adults [TOFHLA] numeracy) assess only select aspects of numeracy.

Physician gestalt is known to be an inaccurate means of evaluating for LHL, which emphasizes the need to use screening tools in making this assessment.[7-9] However, limited studies have analyzed whether health literacy screening tools adequately assess patients' numeracy skills. Without an established correlation between health literacy and numeracy in this population, it cannot be assumed that patients with adequate health literacy will also have adequate numeracy, or that patients with LHL are also innumerate. The purpose of this study was to quantify the correlation between numeracy and health literacy in ED patients.

METHODS

Study Design

We performed a cross-sectional study of a convenience sample of adult ED patients. This study was approved by the hospital institutional review board.

Study Setting and Population

Patients presenting from March 2011 through February 2012 to an urban, academic ED with over 97,000 annual visits were eligible. Our evaluation of numeracy and its correlation with health literacy screening tools was part of a larger study evaluating these tools.[9] As such, our study sample size was directed at this purpose, to verify a sensitivity of 90% with a 5% range of error and a baseline prevalence of 40%. This required enrollment of 346 patients with complete data. We assumed that just under 20% of subjects would have incomplete data based on prior experience, and so aimed to enroll 430 subjects. Research assistants prospectively identified all ED patients for inclusion by review of the electronic medical record dashboard, then administered health literacy and numeracy screening tools.

All ED patients ≥18 years old were eligible for the study. Exclusion criteria included prior enrollment in the study, altered mental status, aphasia, mental handicap, previously diagnosed dementia, insurmountable communication barrier, non-English speaking, sexual assault victims, acute psychiatric illness, corrected visual acuity worse than 20/100 using both eyes, or too ill to interview as determined by treating physicians. We recorded deidentified age, race, and sex for patients declining to participate.

Study Protocol

Research assistants received standardized training in administering all test instruments, which included the abbreviated Short Test of Functional Health Literacy in Adults (S-TOFHLA),[10] Rapid Estimate of Adult Literacy in Medicine (REALM-R), [11] and the NVS.[12,13] Training consisted of an in-person presentation, review of a pre-recorded training presentation, practice sessions administering the tools, and observed administration of at least the first screening. The informed consent language, instructions for enrollment, and explanation of the tools were crafted to avoid language that could invoke feelings of shame or guilt. Screeners read participants standardized instructions for each of the health literacy screening instruments. Questions were administered by providing a paper the patient could read and were read aloud. There was no time limit applied for numeracy questions and no indication to patients that they were being timed. Family members and friends, when present in the participants' rooms, were not allowed to assist.

In order to mitigate a potential source of bias, the order of screening tool administration was varied based on even or odd days of the week with the longest test (S-TOFHLA) given either as the first exam or the last exam. Enrollment times were varied by time of day and day of week. The ED uses a computerized electronic medical record for all documentation in the ED, and a central data repository developed internally for all hospital records. Participants' responses were recorded for each of the screening tools. Demographic

information was collected during the interview, and a separate electronic record review was conducted for each patient. Data were entered into a computerized form for analysis.

To assess numeracy we used four questions from the Schwartz-Lipkus scale that have been used in prior studies of general numeracy.[14,15] We report separately in more detail on the diagnostic accuracy and feasibility of the health literacy screening tools used in this study, which have been validated for use in the ED.[9,16] We use the results of these tests along with data we collected concurrently on general numeracy to evaluate the correlation between numeracy and health literacy performance.

Numeracy questions included

1. Imagine that we rolled a fair, six-sided die 1,000 times. Out of 1,000 rolls, how many times do you think the die would come up even (2, 4, or 6)?
2. In the BIG BUCKS LOTTERY, the chances of winning a $10.00 prize are 1%. What is your best guess about how many people would win a $10.00 prize if 1,000 people each buy a single ticket to BIG BUCKS?
3. In the ACME PUBLISHING SWEEPSTAKES, the chance of winning a car is 1 in 1,000. What percent of tickets to ACME PUBLISHING SWEEPSTAKES win a car?
4. Which of the following numbers represents the biggest risk of getting a disease? ___ 1 in 100, ___ 1 in 1000, ___ 1 in 10.

Outcome Measures

Primary outcome measures were 1) proportion answering all numeracy questions correctly; 2) proportion of correct numeracy responses; 3) comparison of groups with ≤50% vs. >50% correct on numeracy questions, and identified by the various screening tools as having LHL; and 4) correlation between performance on health literacy screening tools and general numeracy questions. Secondary outcomes included stratification of results by simple demographics including race and sex.

Data Analysis

Data analysis was performed using Wilcoxon rank sum tests for differences in numeracy score by health literacy measures, sex, and race; Spearman's coefficient for correlations between numeracy and health literacy scores; and Fisher's exact test for comparison of S-TOFHLA performance by dichotomized numeracy score. Statistical significance was assessed as $p < 0.05$. Data analysis was conducted using SAS 9.3. (SAS Institute, Cary, NC).

RESULTS

We approached 588 patients and excluded 142 patients for declining to participate (n = 124), impaired visual acuity (7), discharge prior to completion (4), insurmountable communication barrier (3), cognitive impairment (2), and prior enrollment (n = 2). We enrolled 446 patients (Table 1), of whom the percentage with LHL was 23.9% based on the STOFHLA, 48.5% based on the REALM-R, and 76.7% based upon the NVS (Table 2).

Overall, the average number of correct answers to the numeracy questions was 1.4 (SD ±1.05), with a median value of 1 (IQR 1 to 2). Only 18 patients (4%) answered all numeracy questions correctly, while 88 (20%) answered zero questions correctly. Across the four numeracy questions, the proportion of patients with correct answers ranged from 8.3% to 68.1% (Q1, 35.5%: Q2, 29.9%; Q3, 8.3%; Q4, 68.1%). Among patients with LHL by any of the three screening tools used, the mean number of correct numeracy answers was approximately half that of patients with adequate health literacy (Table 3).

Results for associations between dichotomized health literacy levels (limited vs. adequate) and frequency, mean, and dichotomized correct numeracy responses are provided in Tables 2, 3, and 4 respectively. There were significant differences in performance on the numeracy questions between patients with adequate health literacy and those with LHL. In examining the associations between dichotomized performance on the numeracy questions and dichotomized scores on the health literacy screens, the magnitude of association was greatest for the NVS (Table 4). Health literacy screening results had positive and moderate correlations with general numeracy: S-TOFHLA $r_s = 0.428$ ($p < 0.0001$); REALM, $r_s = 0.400$ ($p < 0.0001$); NVS, $r_s = 0.498$ ($p < 0.0001$). Women answered fewer numeracy questions correctly compared to men (1.3, vs. 1.6, $z = -2.5$, $p = 0.0059$). Black participants answered fewer numeracy questions correctly compared to white participants (1.2 vs. 1.9, $z = 6.6$, $p < 0.0001$).

DISCUSSION

Our findings show that both patients with adequate and low health literacy perform poorly on basic questions testing general numeracy, and that commonly used health literacy screening tools separate patients into groups that segregate differently based on numeracy testing (Table 4). Performance on numeracy questions was also worse among black subjects, which is consistent with findings from prior studies of numeracy among ED patients, and among females, which was not previously found in the few studies addressing numeracy in the ED.[5] While collectively, patients with adequate health literacy perform better than those with LHL on questions assessing general numeracy, the correlation between health literacy and numeracy performance ranges from 0.400 to 0.498. This moderate correlation suggests that health literacy screening tools insufficiently screen for numeracy, despite statistically significant differences between groups.

The original, long version of the TOFHLA is the only health literacy screening tool to explicitly include a numeracy component, doing so with a separate test component. However, the abbreviated version of this test used in our study includes no numeracy questions, and by design takes up to 7 minutes to complete, obviating its feasibility for the ED setting.[9] One ED-based study focusing on the ability of short subjective tests to replace more cumbersome health literacy and numeracy tests evaluated the mathematics subtest of the wide ranging achievement test (WRAT4), and a subjective numeracy scale (SNS) consisting of eight questions evaluating patient perceptions of their mathematical aptitude and preferences regarding the use of numbers. The WRAT and the SNS had a correlation coefficient of 0.57, and the WRAT4 correlated with the S-TOFHLA and the REALM with coefficients of 0.54 and 0.49 respectively. Correlations for the SNS with these tests were

0.36 for both. Although using different numeracy instruments, these results are consistent with our findings that the correlations between numeracy and health literacy instruments are in this same poor to moderate range. Only one of the health literacy tests we administered includes questions that evaluate numeracy (NVS), and the correlation between this test and numeracy questions was the highest of those tested. However, the NVS and the TOFHLA numeracy tools do not assess needed numeracy skills related to risk and probability. In light of these findings, separate testing for numeracy may be warranted when numeracy skills are thought to be important to health outcomes.

Numeracy is of particular importance for patients in the ED, where understanding estimates of risk and probability are critical to informed decision-making, and yet, that is where more basic skills in general numeracy are lacking. The implications of low basic numeracy are uniformly negative and reinforce already existing health care disparities. Evidence to date suggests that difficulties scheduling and keeping appointments, adhering to basic medication regimens, and following discharge instructions represent significant barriers to successful self-management. This is experienced by patients with poor numeracy, and increases ED usage, recidivism, and hospitalization, although prior research on health numeracy specifically is limited.[17-21] Low numeracy distorts perceptions of risks and benefits of screening and impairs risk communication, limiting prevention efforts among the most vulnerable. Numeracy is also associated with greater susceptibility to extraneous factors that can affect decision-making including the effects of mood or how information is presented (proportions, percentages, etc.), and to biases in judgment and decision-making such as framing and ratio bias effects.[22]

Even among patients with adequate numeracy skills, patients' understanding of their care in the ED is often limited to that which is successfully communicated by health care providers. Poor numeracy skills represent a significant additional barrier to communication that is likely undetected. As is the case with screening for LHL, there is a dearth of validated successful interventions to mitigate the effects of low numeracy. Some argue that this obviates efforts to screen for LHL or low numeracy.[23] Approaches attempting to address low numeracy might include detecting high-risk patients for individual interventions, which favors an approach that includes screening, and/or designing communication that improves the understandability of numerical information for all patients, in which case screening is perhaps less important.[22,24]

LIMITATIONS

This study was performed at a single academic site, which may limit generalizability to other settings. This observational trial also excluded several groups of previously described patients, limiting the external validity in dissimilar populations. Specifically, we cannot extrapolate the estimates of diagnostic accuracy for the health literacy screening instruments to patients with undue distress, sexual assault victims, acute psychiatric illness, altered mental status, aphasia, mental or visual handicap, dementia, non-English speaking individuals, or those with communication barriers. We did not assess these populations, and each instrument could be more or less accurate in these groups. Patients with low numeracy or health literacy may have been less willing to participate in a study aimed at determining

their skills due to a perceived risk or shame. We attempted to mitigate this using language and approaches sensitive to this issue.

Convenience sampling of patients in the ED setting is a limitation of this study that could result in oversampling certain populations. However, our sample demographics did not significantly differ from those of the general ED population or the population declining enrollment. The modified Schwartz-Lipkus scale used to determine numeracy is not a comprehensive determinant of health numeracy. Although it was chosen to represent a feasible measure of both computational skills and facility with risk values, it is a general numeracy tool with no specific health focus. This may limit its utility in this setting to some degree. However, there is no criterion standard for numeracy and no consensus as to which numeracy domains should be included in health specific testing. These questions have been previously used as a three-item general numeracy scale, in at least one other ED-based study,[5] and question 4 is used by the National Cancer Institute as a measure of numeracy in their Health Information National Trends Survey (HINTS).[25]

The extent to which the stress of being ill and in the ED affect performance on numeracy questions and whether any such deficits might differentially affect measures of numeracy versus those of health literacy is unclear. Limited data suggest there may be such an effect at least in screening related to cognition and depression.[26] Our study design excluded the sicker patients, avoiding the more likely instances where this might occur. Any observed deficits in these areas would reflect performance under the real-world conditions in the ED that we would be interested in capturing through measurement.

CONCLUSIONS

Correlations of measures of general numeracy and measures of health literacy are in the low to moderate range. Performance on numeracy testing was nearly universally poor in our sample of ED patients, even among patients performing well on health literacy screens, with a substantial proportion of patients with adequate health literacy unable to answer half of the numeracy items correctly. Insofar as numeracy is considered a subset of health literacy, our results suggest that commonly used health literacy screening tools in ED-based studies inadequately evaluate and overestimate numeracy. This suggests the potential need for separate numeracy screening when these skills are important for health outcomes of interest. Providers should be sensitive to potential numeracy deficits among those who may otherwise have adequate health literacy.

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Table 1

Patient Demographics (N=446)

Demographic characteristic	Mean (±SD)	Median (IQR)
Age, yrs	45.4 (±15.8)	47 (33-57)
Female	55.2%	
Ethnicity*		
White	30.5%	
Black	67.8%	
Other	1.8%	
Education level attained†		
Less than high school	18.0%	
Some college	49.9%	
College	32.1%	
Primary insurance†		
Private	33.5%	
Self-pay	26.5%	
Medicaid	20.0%	
Medicare	17.1%	
Private + Medicare	0.5%	
Other insurance	2.5%	
Has primary care physician	61.9%	
Employment status‡		
Employed	42.0%	
Unemployed	31.1%	
Disabled	16.1%	
Retired	10.7%	

*n=443

†n=445

‡n=440

Table 2

Frequency table for numeracy and health literacy measures

Test	Frequency	Percent
S-TOFHLA, n=435		
0:limited health literacy (0-22)	104	23.91
1:adequate health literacy(23-36)	331	76.09
REALM-R, n=435		
0:Low health literacy (<6 items correct)	211	48.51
1:Higher health literacy (>6 items correct)	224	51.49
NVS, n=429		
0: scoring <4	329	76.69
1: scoring 5 or 6	100	23.31
Numeracy score, n=446		
0	88	19.73
1	171	38.34
2	119	26.68
3	50	11.21
4	18	4.04
Dichotomized numeracy score		
2 or less correct numeracy answers	378	84.75
3 or 4 correct numeracy answers	68	15.25

	Mean (SD)	Median (IQR)
Continuous numeracy score	1.4148 (1.0518)	1 (1-2)

S-TOFHLA = Short Test of Functional Health Literacy in Adults; REALM-R = Rapid Estimate of Adult Literacy in Medicine-Revised; NVS = Newest Vital Sign

Table 3

Differences in numeracy score by health literacy measures, sex, and race

Test	n	Median (IQR)	Mean (SD)	z	p-value
S-TOFHLA				−6.29	<0.0001
0: limited health literacy (0-22)	104	1 (0-1)	0.8942 (0.8115)		
1: adequate health literacy(23-36)	331	1 (1-2)	1.6103 (1.0484)		
REALM-R				−7.92	<0.0001
0: Low health literacy (≤6 items correct)	211	1 (0-2)	1.0190 (0.8279)		
1: Higher health literacy (>6 items correct)	224	2 (1-3)	1.8304 (0.0721)		
NVS				9.76	<0.0001
0: scoring ≤4	329	1 (1-2)	1.1526 (0.8737)		
1: scoring 5 or 6	100	2 (2-3)	2.3800 (1.0228)		
Sex, n=444				2.54	0.0059
Female	245	1 (1-2)	1.2980 (0.9735)		
Male	199	1 (1-2)	1.5729 (1.1207)		
Race, n=435				6.58	<0.0001
White	135	2 (1-3)	1.9185 (1.0931)		
Black	300	1 (1-2)	1.1833 (0.9448)		

S-TOFHLA = Short Test of Functional Health Literacy in Adults; REALM-R = Rapid Estimate of Adult Literacy in Medicine-Revised; NVS = Newest Vital Sign

Table 4

Bivariate associations between dichotomized numeracy and health literacy measures

Test	n	Numeracy score, n (%)		p-value
		2 or fewer correct	3 or 4 correct	
S-TOFHLA, n=435				<0.0001
0: Limited health literacy (0-22)	104	101 (97.12)	3 (2.88)	
1: Adequate health literacy (23-36)	331	267 (80.66)	64 (19.34)	
REALM-R, n=435				<0.0001
0: Low health literacy (≤6 items)	211	203 (96.21)	8 (3.79)	
1: Higher health literacy (7+ items)	224	164 (73.21)	60 (26.79)	
NVS, n=429				<0.0001
0: scoring ≤4	329	309 (93.92)	20 (6.08)	
1: scoring 5 or 6	100	53 (53.00)	47 (47.00)	
Sex, n=444				0.0334
Female	245	216 (88.16)	29 (11.84)	
Male	199	160 (80.40)	39 (19.60)	
Race, n=435				<0.0001
White	135	94 (69.63)	41 (30.37)	
Black	300	275 (91.67)	25 (8.33)	

S-TOFHLA = Short Test of Functional Health Literacy in Adults; REALM-R = Rapid Estimate of Adult Literacy in Medicine- Revised; NVS = Newest Vital Sign