Numeracy and Home Blood Pressure Measurement Reporting

By

Vishal N. Rao

A Master's Paper submitted to the faculty of the Gillings School of Global Public Health at the University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Master of Public Health in the Public Health Leadership Program

Chapel Hill

2014

Table of Contents

Abstract

Background: Numeracy, a component of overall health literacy, affects the way patients understand and process numerical health information. Home blood pressure monitoring (HBPM), a valuable tool in predicting CVD risk and end-organ damage independent of office BPs, requires the self-measurement and reporting of numerical health information and may be limited by patient understanding. To my knowledge, the relationship between numeracy and quality of HBPM has not been previously described. In this study, I examined the association of numeracy level with the completeness of home BP reporting.

Methods: A systematic review of recent literature was conducted to describe the relationship between low numeracy and health-related skills, self-efficacy, and other health-related outcomes among patients with chronic disease. Following the literature review, I analyzed data from 420 adults participating in a four week BP measurement study who performed HBPM and completed a validated 3-item numeracy assessment. Participants were asked to complete triplicate home BP measurements twice daily for 5 consecutive days during week 1 and week 3. Demographic information and health literacy assessments were also collected. Total percentages of completed home BP readings by low vs. high numeracy level were summarized using descriptive statistics, and I performed multivariate regression analyses to identify potential confounders that may mediate the effect of numeracy on completion of home BP reporting.

Results: Four studies of numeracy published since 2010 were identified in the systematic review. Two studies measured health care utilization, one study measured diabetes self-efficacy, and two studies measured severity of diabetes as outcomes by numeracy level. The evidence was low for disease severity and was insufficient for self-efficacy and health care utilization. Among the 420 adults who performed HBPM, nearly one-third had low numeracy (score of 0 or 1) and two-thirds had adequate numeracy (score of 2 or 3). Those with adequate numeracy reported completing home BP readings more than those with low numeracy (96.2% vs. 93.7%; P=0.009), which held true after adjusting for potential confounders.

Conclusion: There is insufficient evidence in the current literature describing the relationship between numeracy and health-related skills. Among patients with borderline high blood pressures, higher numeracy level is associated with more complete reporting of home BP readings, although the difference is small. More research is needed to assess whether higher numeracy is a predictor of more accurate BP readings, and whether this trend holds true in the context of other numerical health parameters.

Numeracy as a Predictor of Health Outcomes: A Systematic Review

Abstract

Context: Numeracy, a component of overall health literacy, affects the way patients process medical information and their ability to understand risk and cost. Previous reviews found that evidence is low in describing how numeracy level affects quality of life, interpretation of health information, and self-efficacy, while evidence is insufficient in describing the effect of numeracy on health care utilization, knowledge, behavior, and taking medications.

Objective: To determine if there is a relationship between low numeracy level and health-related skills, self-efficacy, health care utilization, medication management, and disease severity among patients with chronic disease.

Data Sources: A systematic review of English articles using MEDLINE. Key words included: numeracy; health-related skills; skills; health-related tasks; tasks; self-efficacy; chronic disease.

Study Selection: Only studies describing numeracy and health-related skills, self-efficacy, health care utilization, medication management, and disease severity among patients or caregivers of patients with chronic disease, published between 01/01/2010 to 06/01/2014.

Results: Four studies were identified. Regarding health care utilization, one study reported that patients with low (vs. high) numeracy had higher odds of 30-day hospital recidivism after an episode of acute heart failure (odds of 1.41, 95% CI: [1.00-1.98]; $p=0.048$). One study found that participants with chronic kidney disease who had lower vs. higher numeracy scores were more likely not to be on kidney transplant lists (24.6% vs. 7.2%; $p=0.01$).Two studies examined glycosylated hemoglobin in Type 1 diabetic patients as a marker of disease severity and found parental numeracy had a moderate negative correlation ($r=-0.52$; $p<0.01$) with child glycemic control, while another reported a stronger association between higher numeracy and better glycemic control in adults with Type 1 diabetes (HbA_{1C} 8.4 vs. 9.2%; $p=0.004$). One study found no correlation between parental numeracy and caregiver diabetes self-efficacy (r=0.18; not significant).

Conclusion: Recent evidence demonstrates associations between numeracy and health outcomes, but evidence is low in relation to disease severity and insufficient in relation to self-efficacy and health care utilization. No recent evidence directly describes numeracy and completion of health-related skills involving numerical information. Future studies are needed to further evaluate the role numeracy plays in the quality of and successful completion of health-related skills performed by patients with chronic disease.

Introduction

Health literacy is the ability by which an individual can attain, process, and understand health information to make educated health decisions.[1] Numeracy, a component of overall health literacy, is the set of skills that is required for understanding and managing numerical health information.[2] Low numeracy is associated with fewer employment opportunities, reduced job growth, lower socioeconomic status, low literacy, and a poor home-learning environment.[3–5] Patient groups in the United States who have a high prevalence of low numeracy include older populations and those with lower socioeconomic status.[6,7] It is likely that low numeracy has a detrimental effect on health-related skills and other outcomes by influencing the way patients process medical information, affecting their understanding of risk and cost.[4,5] In addition to patient understanding and decision-making, numeracy level may influence self-efficacy and the patient's ability to perform health-related skills in and out of the medical setting.[4,8] Together, numeracy and the encompassing health literacy affect correct medication dosing, caregiver understanding of medical labels, nutrition label interpretation, and understanding intermediate health outcomes, such as body mass index and hemoglobin A1c.[4,5]

A previous systematic review investigated the relationship between low numeracy and various health outcomes, including health-related skills and self-efficacy.[9] However, it concluded there is low evidence of the role numeracy level may play on self-efficacy and quality of life, while there is insufficient evidence on the quality of health-related skills, such as taking medications, behavior, knowledge, health care utilization, and health outcomes (Table 1).[9] Furthermore, there is little evidence on numeracy level affecting patient behavior among patients with chronic diseases.[10] Although some studies have observed correlations in health literacy level and intermediate health markers,[9,11,12] numeracy has not been shown to directly affect health outcomes.[9] Among patients with chronic diseases such as hypertension, however, numeracy level affects a patient’s ability to understand the concept of blood pressure in his or her health. Addressing numeracy level may also be helpful in communicating the importance of blood pressure screening, medication management, and adherence. Furthermore, numeracy level may affect how well patients follow medical instructions outside of the clinic setting. The patient’s ability to follow medical instructions and perform health-related skills, such as home blood pressure monitoring and self-glucose level checks, will be important for physicians to provide appropriate care for those with chronic diseases.

To better understand the possible role of numeracy on management of chronic disease and related health outcomes, this review derived the following outcomes from a logic model developed by Berkman et al. for analyzing studies of health literacy and numeracy: health-related skills, self-efficacy, health care utilization, medication management, and disease severity.[9] The purpose of this systematic review is to primarily determine if there is a relationship between low numeracy level and health-related skills and self-efficacy, as well as examine the relationship between numeracy and health-care utilization, medication management, and disease severity among patients with cardiovascular or other chronic diseases. This review will also describe health disparities among those with low numeracy and areas where further research is needed.

Methods

Eligibility Criteria, Literature Search, and Data Abstraction

To determine the association between numeracy level and health-related skills, self-efficacy, health care utilization, medication management, and disease severity among patients with chronic disease, one author (VR) searched MEDLINE with the following terms: “numeracy” and either “health-related skills” “skills” health-related tasks” “tasks” or “self-efficacy”. One author (VR) performed a second search for “numeracy” and “chronic disease”. Medical Subject Headings (MeSH terms) were used where appropriate. The search was limited to full text articles and articles published between 01/01/2010 and 06/01/2014 because Berkman et al. had already evaluated numeracy level and its relation to health outcomes prior to 05/2010 (Table 1).[9] The five months of overlap was included to avoid any missed articles. Included studies consisted of patients with chronic diseases or their caregivers as the population, no specific age limit, and articles written in English as the language. One author (VR) read the titles or abstracts to determine their relevance to the search question. If the title or abstract suggested the article met the inclusion criteria as listed in Table 2, one author (VR) read the article text to assess whether it fully met the inclusion criteria. Articles were excluded if the population consisted of healthy individuals without chronic disease, adults with cognitive impairments, children undergoing psychiatric or cognitive development analysis, if the exposure was only health literacy, or if the studies were not published in English without an available English translation. Any overlapping articles from the systematic review by Berkman et al.[9] were excluded from review.

Data Synthesis

One author (VR) abstracted information from the article text into an Excel Spreadsheet database that included characteristics of each study population, type of study, goal of the study, type of numeracy measure, and results with regards to measurement outcomes of health-related skills, self-efficacy, health care utilization, medication management, or disease severity. One author (VR) assessed for presence of harms by numeracy assessment or measurements, and evaluated the effect of numeracy level on the outcomes of these studies.

Quality Assessment and Strength of Evidence

One author (VR) assessed and rated the quality of each article as good, fair, or poor on the presence of risk of bias, including selection bias, measurement bias, and confounding. A good quality study had minimal risk of selection bias, minimal risk of measurement bias, and minimal risk of confounding. A fair quality study had moderate risk of selection bias, moderate risk of measurement bias, and moderate risk of confounding that together might influence the results. A poor quality study had high risk of selection bias, high risk of measurement bias, and high risk of confounding that could fully explain the results. One author (VR) graded the overall strength of evidence of each outcome as high, moderate, low, or insufficient on the basis of risk of bias, consistency of the effect of numeracy, directness of the evidence, and precision using AHRQ guidance (Table 3).[13] Poor quality studies were omitted from further review.

Results

Study Selection

Four studies were identified for inclusion in this review. The initial search of MEDLINE yielded 162 unique articles, of which 115 were excluded following one author's (VR) screening of titles, and an additional 31 were excluded following the screening of abstracts based on inclusion and exclusion criteria. Of the remaining 16 studies, 9 were excluded after reading the full-text articles. Three of the remaining 7 articles overlapped with the systematic review performed by Berkman et al.[9] and were removed from review.[14–16] A PRISMA flow diagram summarizes the inclusion of studies (Figure 1). All four included studies were published in peer-reviewed journals between 01/01/2010 and 06/01/2014.[17–20]

Study Characteristics

Articles ranged in various study questions, inclusion criteria, types of outcomes, follow-up periods if applicable, and study design. A summary of study characteristics can be found in Table 4. Sample sizes ranged from 70[20] to 709 participants.[17] Studies included participants with a variety of chronic diseases, such as congestive heart failure (CHF),[17] chronic kidney disease (CKD),[18] and Type 1 diabetes.[19,20] Two studies were prospective cohort studies[17,18] and two studies were cross-sectional studies.[19,20] One study measured self-efficacy,[20] two studies measured health care utilization,[17,18] and two studies measured disease severity.[19,20] One study assessed numeracy among primary caregivers of pediatric populations,[20] while the others included participants ≥18 years of age.[17–19] Studies used a variety of numeracy assessments, including the standardized 3-item numeracy assessment,[21] the ―Subjective Numeracy Scale" measure,[22] the UK Skills for Life Programme,[19] the Parental Diabetes Numeracy Test (PDNT),[20] and the Short Test of Functional Health Literacy in Adults (STOFHLA).[23]

Risk of Bias within Studies

A summary for the quality assessment of included studies can be found in Table 5. Only one study used random sampling in the recruitment of participants.[19] The remaining studies recruited participants as they presented to clinics or hospitals.[17,18,20] All studies used multivariate regression models to control for potential confounders. The most common confounders included age, gender, race, and income level. The Marden (2012) study was assigned an overall quality of good,[19] while the McNaughton (2013), Abdel-Kader (2010), and Pulgarón (2014) studies were assigned an overall quality of fair.[17,18,20]

Results of Studies

Overall, studies reported various numeracy assessment measurements in the form of continuous or categorical outcomes. Outcomes included 30-day hospital recidivism,[17] hemodialysis modality and kidney transplantation status,[18] hemoglobin A1C,[19,20] and diabetes self-efficacy.[20]

<u>Disease Severity</u>

Two studies looked at glycosylated hemoglobin (A1C) as an indicator of severity of disease.[19,20] Among caregivers of Type 1 diabetics, Pulgarón (2014) reported that parental numeracy had a moderate negative correlation ($r=-0.52$; $p<0.01$) with child glycemic control.[20] In adult participants with Type 1 diabetes, Marden (2012) reported a stronger association between higher numeracy and better glycemic control (HbA_{1C} 8.4 vs. 9.2%; $p=0.004$) with no relationship between literacy and HbA_{1C}.[19]

<u>Self-Efficacy</u>

One study looked at diabetes self-efficacy and numeracy levels by participants.[20] Among parents and caregivers of patients with Type 1 diabetes, Pulgarón (2014) found that parental numeracy was not correlated with parental self-efficacy scores using the same self-management scale (r=0.18; not significant).[20]

Health Care Utilization

McNaughton (2013) reported patients with low numeracy to have a higher odds of 30-day hospital recidivism after an episode of acute heart failure (AHF) than patients with high numeracy (Odds 1.41, 95% CI: [1.00-1.98]; p=0.048).[17] The authors noted that management following acute heart failure involved daily weight checks, medication adherence, salt and fluid intake modulation, and other tasks involving numerical skills. In this case, hospital recidivism served as a marker for health care utilization.[17]

Abdel-Kader (2010) also reported on health care utilization, using dialysis modality, hemodialysis access type, and kidney transplant status as markers for utilization. Numeracy score was neither associated with dialysis modality or hemodialysis access type.[18] Transplant status, on the other hand, was associated with numeracy scores; a score of 0 vs. score of 3 correlated with 24.6% vs. 7.2% of not being on a transplant list (p=0.01).[18] However, the authors did not account for differences in income status, insurance status, or employment in their analyses. No studies reported harms of numeracy assessments or interventions.

Discussion

Current evidence demonstrates that low patient numeracy level is correlated with poorer health care utilization and disease severity, but there is no correlation with parental diabetes self-efficacy. The predominantly fair quality studies provide low evidence for the role of numeracy among patients and caregivers on disease severity in Type 1 diabetics. There is insufficient evidence for its role on health care utilization and self-efficacy.

The heterogeneity of study outcomes and types of numeracy assessments within this systematic review further limits the clarity of the association between numeracy and the patient's ability to manage health, successfully perform health-related skills, or utilize health care. The findings of this systematic review in relation to the limited outcomes of interest differ with those of a systematic review prior to 2010 that found low evidence for self-efficacy and insufficient evidence for disease severity as the outcomes.[9]

There are several limitations to this review. The search strategy focused mainly on health-related skills and self-efficacy as outcomes and did not include additional comprehensive key words for health care utilization, medication management, or disease severity as outcomes. There is a strong possibility that this search strategy did not capture all available articles on numeracy and the latter three outcomes mentioned during the timeframe of interest. The search strategy used only one database and did not fully replicate the methods performed by Berkman et al.,[9] which further minimizes the number of acceptable articles since 2010 that could have been evaluated in this review. The included number of studies was small, and their quality was variable. Studies looked at markers of disease severity, such as hemoglobin A1C, that may not directly correlate with the completion of diabetes-related health skills, which may include taking medications, self-glucose monitoring, or accessing regular diabetic care. With respect to the logic model proposed by Berkman et al.,[9] the indirect effect of numeracy on disease severity does not provide an indication to how health-related skills may mediate this relationship. Studies measuring health care utilization, such as hospital readmission post-discharge for AHF or transplant status among CKD patients, are limited by the heterogeneity of types of outcomes that provides less certainty in the direct relationship between numeracy level and aggregate outcomes. Given the scope of this review's primary purpose to describe all available studies since 2010 on numeracy and health-related skills and self-efficacy, the included studies were adequate to at least highlight that there are gaps in high quality evidence on numeracy in predicting the patient's ability to successfully complete health-related skills.

The included studies were also limited by the lack of uniform numeracy assessments, where five unique types of assessments were described. Of these numeracy measures, one was a subjective measure.[17] Furthermore, the studies described various levels of exposure by reporting either all numeracy scores or categorizing them differently into low and high numeracy. The cross-sectional design in two of the studies limits our understanding of whether addressing low numeracy skills may play a role in improving our outcomes of interest.[19,20] Studies were also inconsistent in describing and accounting for potential confounders, such as income level, insurance status, and employment status, when assessing the direct correlation of numeracy on outcomes.

Studies on the concept of numeracy as a component of overall health literacy in relation to health outcomes has become more common in recent years, and the evidence has improved for the outcome of disease severity while it has not improved for self-efficacy and health care utilization,[9] although the number of recent studies is limited. Numeracy has more recently been viewed alongside literacy as a set of essential skills in the patient's understanding of health risks, knowledge, and medical decision-making.[2,4,8] However, studies on numeracy and health-related skills, self-efficacy, and health care utilization continue to provide inconsistent findings for a few possible reasons. Many studies measure numeracy level on outcomes in different subpopulations, such as patients with chronic disease, children, and caregivers of different ages. The variable outcomes make them difficult to compare between subpopulations. These studies also vary in types of outcomes measured. The strongest contributing factor to these inconsistent findings may in fact be due to the abundant types of numeracy measures available, which increase heterogeneity of exposures, making it difficult to understand and compare results. To overcome heterogeneity of correlations, fewer valid numeracy assessments must be used with standardized categories of low and high numeracy to better compare the validity and reliability of results on skill outcomes. Such understanding is important in providing physicians with comprehensive clinical information when deciding on which medical interventions to pursue or knowing whom to screen and provide targeted numerical-based interventions to improve patient understanding of health. With the use of more standardized exposures and outcomes, future studies may better quantify and compare the effect of numeracy on health-skills across multiple subpopulations.

One population in which numeracy may be investigated is those with hypertensive disease. Since self-measured blood pressures (BPs) is a useful strategy for providing clinicians with a patient's out-of-office BP measurements and predicts risks of cardiovascular events and end-organ damage independent of office BP,[24–26] understanding the role numeracy plays in the patient's understanding of blood pressures or completion of out-of-office measurements would have potentially drastic effects in public health. Use of home blood pressure monitoring (HBPM) in the management of hypertension has shown to facilitate a reduction in systolic and diastolic BPs to a clinically small but significant amounts compared to clinic BP measurements,[27] although treatment thresholds tend to change. The reduced successful completion of this health-related skill limits monitoring of medical therapy among treated patients by leaving BP information underutilized in efforts to prevent secondary complications of chronic hypertension.[24–26] Therefore, addressing the barriers to successful completion, whether they be knowledge of health or understanding of numerical information, could benefit hypertension and other related chronic diseases. Additional outcomes also worth measuring include blood glucose monitoring, medication dosing and self-administration, daily weight checks, and the understanding and manipulation of health risk.

References

1. Nielsen-bohlman L, Panzer AM, Kindig DA. Health Literacy A Prescription to End Confusion. *Institute of Medicine of the National Acadmies*. 2004:1–41.

2. Rothman RL, Montori VM, Cherrington A, Pignone MP. Perspective: The Role of Numeracy in Health Care. *Journal of Health Communication*. 2008;13(6):583–95.

3. Lipkus IM, Samsa G, Rimer BK. General Performance on a Numeracy Scale among Highly Educated Samples. *Medical Decision Making*. 2001;21(1):37–44.

4. Reyna VF, Nelson WL, Han PK, Dieckmann NF. How numeracy influences risk comprehension and medical decision making. *Psychological Bulletin*. 2009;135(6):943–73.

5. Ciampa PJ, Osborn CY, Peterson NB, Rothman RL. Patient Numeracy, Perceptions of Provider Communication and Colorectal Cancer Screening Utilization. *Journal of Health Communication*. 2010;15(Suppl 3):157–168.

6. Taha J, Sharit J, Czaja SJ. The Impact of Numeracy Ability and Technology Skills on Older Adults' Performance of Health Management Tasks Using a Patient Portal. *Journal of Applied Gerontology*. 2012.

7. Garcia-Retamero R, Galesic M. Who profits from visual aids: overcoming challenges in people's understanding of risks. *Social Science & Medicine*. 2010;70(7):1019–25.

8. Chen Y, Feeley TH. Numeracy, Information Seeking, and Self-Efficacy in Managing Health: An Analysis Using the 2007 Health Information National Trends Survey (HINTS). *Health communication*. 2013;(February 2014):37–41.

9. Berkman ND, Sheridan SL, Donahue KE, et al. Health Literacy Interventions and Outcomes: An Updated Systematic Review. *Evidence report/technology assessment*. 2011;(199):1–941.

10. Cavanaugh K, Huizinga MM, Wallston KA, et al. Association of Numeracy and Diabetic

Control. *Annals of Internal Medicine*. 2008;148(10):737–46.

11. Willens DE, Kripalani S, Schildcrout JS, et al. Association of brief health literacy screening and blood pressure in primary care. *Journal of health communication*. 2013;18 Suppl 1:129–42.

12. DeWalt D a, Hink A. Health literacy and child health outcomes: a systematic review of the literature. *Pediatrics*. 2009;124 Suppl:S265–74.

13. Owens DK, Lohr KN, Atkins D, et al. AHRQ Series Paper 5: Grading the strength of a body of evidence when comparing medical interventionsdAgency for Healthcare Research and Quality and the Effective Health-Care Program. *Journal of Clinical Epidemiology*. 2010;63(5):513–23.

14. Osborn CY, Cavanaugh K, Wallston KA, Rothman RL. Self-Efficacy Links Health Literacy and Numeracy to Glycemic Control. 2010;15(Suppl 2):146–158.

15. Waldrop-Valverde D, Osborn CY, Rodriguez A, et al. Numeracy Skills Explain Racial Differences in HIV Medication Management. *AIDS and Behavior*. 2010;14(4):799–806.

16. Hassan K, Heptulla R a. Glycemic Control in Pediatric Type 1 Diabetes: Role of Caregiver Literacy. *Pediatrics*. 2010;125(5):e1104–8.

17. Mcnaughton CD, Collins S, Kripalani S, et al. Lower Numeracy Is Associated with Increased Odds of 30-Day Emergency Department and Hospital Recidivism for Patients with Acute Heart Failure. *Circ Heart Fail*. 2013;6(1):40–6.

18. Abdel-Kader K, Dew MA, Bhatnagar M, et al. Numeracy Skills in CKD: Correlates and Outcomes. *Clinical Journal of the American Society of Nephrology*. 2010;5(9):1566–73.

19. Marden S, Thomas PW, Sheppard Z a, et al. Poor numeracy skills are associated with glycaemic control in Type 1 diabetes. *Diabetic Medicine : A Journal of the British Diabetic Association*. 2012;29(5):662–9.

20. Pulgarón ER, Sanders LM, Patiño-Fernandez AM, et al. Glycemic control in young children with diabetes: The role of parental health literacy. *Patient Education and Counseling*. 2014;94(1):67–70.

21. Schwartz LM, Woloshin S, Black WC, Welch HG. The role of numeracy in understanding the benefit of screening mammography. *Annals of Internal Medicine*. 1997;127(11):966–72.

22. Fagerlin A, Zikmund-Fisher BJ, Ubel P a, et al. Measuring numeracy without a math test: Development of the Subjective Numeracy Scale. *Medical Decision Making*. 2007;27(5):672–80.

23. Baker DW, Williams MV, Parker RM, Gazmararian J a, Nurss J. Development of a brief test to measure functional health literacy. *Patient education and counseling*. 1999;38(1):33–42.

24. Hodgkinson J, Mant J, Martin U, et al. Relative effectiveness of clinic and home blood pressure monitoring compared with ambulatory blood pressure monitoring in diagnosis of hypertension: systematic review. *British Medical Journal*. 2011;342(d3621):1–17.

25. Tsunoda S, Kawano Y, Horio T, Okuda N, Takishita S. Relationship between home blood pressure and longitudinal changes in target organ damage in treated hypertensive patients. *Hypertension Research*. 2002;25(2):167–73.

26. Mulè G, Caimi G, Cottone S, et al. Value of home blood pressures as predictor of target organ damage in mild arterial hypertension. *Journal of Cardiovascular Risk*. 2002;9(2):123–9.

27. Agarwal R, Bills JE, Hecht TJW, Light RP. Role of Home Blood Pressure Monitoring in Overcoming Therapeutic Inertia and Improving Hypertension Control: A Systematic Review and Meta-Analysis. *Hypertension*. 2011;57(1):29–38.

Tables and Figures

Table 1: Summary of Numeracy Outcome Results from a Systematic Review by Berkman et al.[9]

Outcome	Articles	Low vs. Adequate Numeracy	Strength of Evidence
Accuracy of risk perception	6	Inconsistent	Insufficient
Behavior	1	No difference	Insufficient
Disease prevalence / severity	5	Inconsistent	Insufficient
Knowledge	5	Inconsistent	Insufficient
Self-efficacy	3	Decrease	Low
Skills	6	Taking medications: inconsistent Interpretation of health information: decrease	Taking medications: insufficient Interpretation of health information: low
Quality of life	1	Decrease	Low
Use of health care services	2	Inconsistent	Insufficient
Disparities	3	Numeracy partially mediates relationship between race and 2 outcomes and between sex and 1 outcome	Low

Table 2: PICOTTSS Study Eligibility Criteria

PICOTTSS	Inclusion	Exclusion
P: Population	People or caregivers of people with chronic disease	People who are healthy or have acute illness, adults with cognitive impairments, or children undergoing cognitive development assessments
I: Intervention / Exposure	Numeracy ± health literacy assessments or interventions	Health literacy assessments only
C: Comparator	Low numeracy scores or levels	
O: Outcomes	Health-related skills, self-efficacy, health care utilization, medication management, disease severity	
T: Time of exposure	Any	None
T: Time over which literature will be searched	Published since 2010 (01/01/2010 to 06/01/2014)	Anything prior to 01/01/2010
S: Setting	All countries	None
S: Study design	RCTs Cross-sectional studies Prospective or retrospective Cohort studies Ecological studies Case series	Studies that do not match search terms or published in non-English languages without available translation

Table 3: Strength of Evidence Grades and Definitions[13]

Grade	Definition
High	High confidence that the evidence reflects the true effect. Further research is very unlikely to change our confidence in the estimate of effect.
Moderate	Moderate confidence that the evidence reflects the true effect. Further research may change our confidence in the estimate of effect and may change the estimate.
Low	Low confidence that the evidence reflects the true effect. Further research is likely to change the confidence in the estimate of effect and is likely to change the estimate.
Insufficient	Evidence either is unavailable or does not permit a conclusion.

Table 4: Studies Addressing Health Numeracy and Health-related Outcomes

Authors, Year (Reference)	Study Design	Study objective	Total Participants, n	Participant Characteristics	Type of Numeracy Measure	Outcome	Results	Harms
McNaughton et al., 2013[17]	Prospective Cohort	Are low numeracy and health literacy associated with 30-day ED and hospital recidivism?	709 patients with acute coronary disease	Mean age: 61 years 56% Male 25% College graduates 52-61% low numeracy 35-41% low literacy	Subjective Numeracy Scale (Fagerlin 2007)	Odds of 30-day Recidivism by Health literacy and Numeracy following episode of Acute Heart Failure	Low numeracy associated with increased odds of recidivism within 30 days (1.41; 95%CI: [1.00-1.98]; p =0.048)	N/A
Abdel-Kader et al., 2010[18]	Prospective Cohort	Assess the association between numeracy and patients with CKD and whether it affects health care use	187 patients with stage IV or V Chronic Kidney Disease	Mean age: 52 years 62% Male 84% ≥12-grade education 51% low numeracy	Standardized 3-item assessment (Schwartz 1997)	Hemodialysis modality, access type, and kidney transplant utilization	Among those with end-stage renal disease, numeracy score was not associated with dialysis modality. Numeracy score was not associated with hemodialysis access type. Numeracy score was associated with transplant status, adjusting for covariates of age, race, and duration of follow-up.	N/A
Marden et al., 2012[19]	Cross-sectional	Assess numeracy and literacy skills on achieved glycemic control among Type 1 Diabetics.	112 patients with Type 1 Diabetic, ages 18-65, seen at DM or Endocrine clinics	Mean age: 43.8 years 47% Male Mean HbA_{1C}: 8.7 47% low numeracy 75% low literacy	UK Skills for Life Programme (25 numeracy sub-questions)	Mean HbA_{1C} by numeracy and literacy levels	High numeracy level achieved better HbA_{1C} than low numeracy level (8.4 vs. 9.2; p=0.004). Adjusted for DM duration, education, demographics, and socioeconomic factors. No significant relationship between literacy and glycemic control.	N/A
Pulgarón et al., 2014[20]	Cross-sectional	Assess parental health literacy and numeracy and glycemic control and parental diabetes self-efficacy in children with Type 1 DM.	70 primary caregivers of children with Type 1 DM	Mean child age: 6.8 years Mean mother's age: 40.1 years Mean HbA_{1C}: 8.4 Mean Numeracy score: 0.69 Mean Literacy score: 34.14	Parental Diabetes Numeracy Test (PDNT) Short Test of Functional Health Literacy in Adults (STOFHLA)	Mean HbA_{1C} and score from Perceived Diabetes Self-Management Scale (PDSMS)	Parent numeracy was negatively correlated with child's HbA_{1C} (r= -0.52, p<0.01). Parental self-efficacy was positively correlated with child's HbA_{1C} (r= -0.47, p<0.01). Parental numeracy was not a predictor of parental self-efficacy (r=0.18, not significant).	N/A

N/A, no harms mentioned

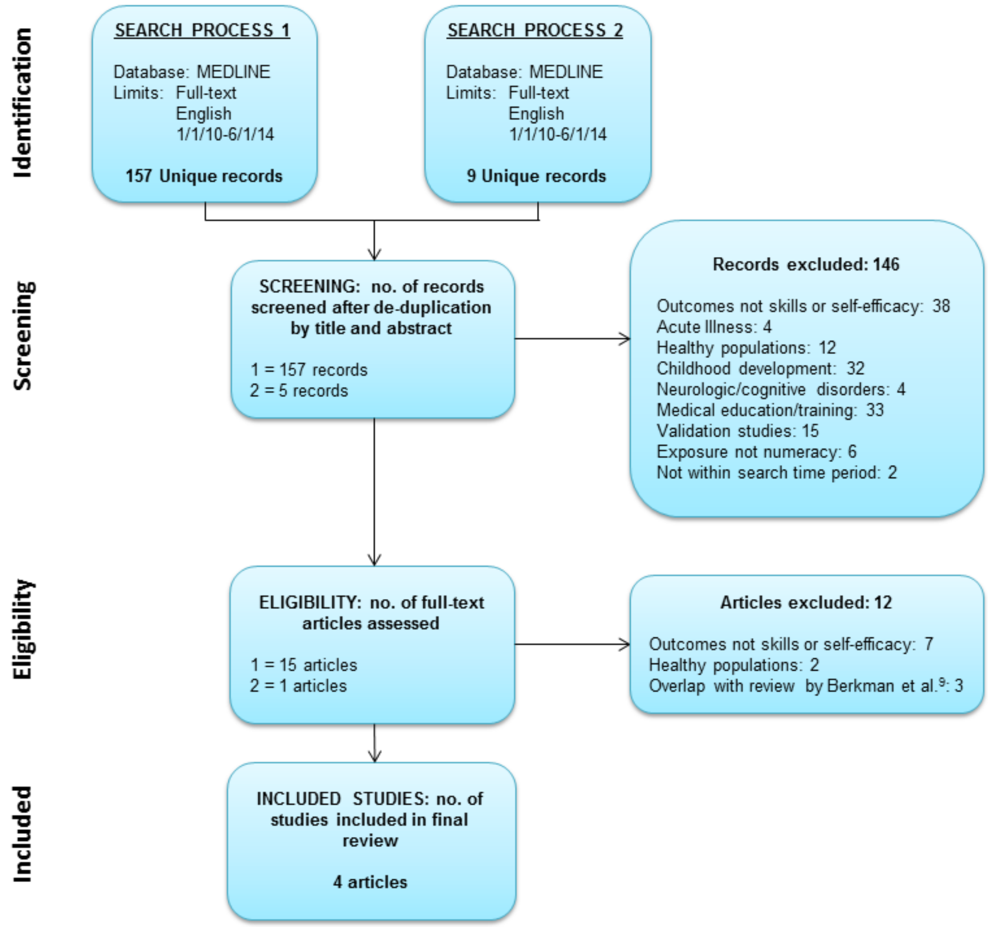
Table 5: **Quality Assessment of Included Studies**

Authors, Year (Reference)	Study Design	Enrollment Strategy	Selection Bias	Measurement Bias	Confounding	Overall Quality Rating	External Validity
McNaughton et al., 2013[17]	Prospective Cohort	Convenience sampling at four hospital EDs.	Moderate. Patients had lower education levels, chronic kidney disease, or abnormal Hemoglobin measurements based on Table 1.	Moderate. Standardized subjective measures of numeracy and evaluation for recidivism, but no verification with objective measure. No masking. Possibility of evaluator bias.	Small. Disease severity and acute presentation may have slightly confounded subjective numeracy and recidivism.	Fair	Poor. Generalizability limited by convenience sampling and ED physician availability to consent to study. Patients screened for limited symptoms not specific to AHF.
Abdel-Kader et al., 2010[18]	Prospective Cohort	Voluntary enrollment	Moderate. 269 initially consented, but 82 (30%) withdrew from study or excluded from analysis due to missing data	Small. Standardized objective numeracy and cognitive function assessments. Authors did not correct for duration of diagnosis of CKD, only duration of follow-up. Misclassification of kidney transplant status of participants on lists at other centers may bias results.	Moderate. Kidney transplant utilization likely partially confounded by employment status, income level, and insurance status.	Fair	Fair. Although excluded participants had similar demographic characteristics to study population, 30% exclusion may affect results. Single-site enrollment may also limit generalizability to cohorts of CKD patients treated at non-academic medical centers.
Marden et al., 2012[19]	Cross-sectional	Patients contacted after being randomized using random number generator in Excel.	Moderate. Patients recruited by mail following randomization. No description of those who declined to participate.	Small. Standardized objective numeracy, literacy, and HbA_{1C} measurements.	Small. Authors adjusted for disease duration, education, and demographic factor using multiple logistic models. No breakdown of participant characteristics by numeracy levels, though.	Good	Fair. Recruitment restricted to referral patients in endocrine clinics, and may represent disease severity or motivation for health care different from broader population.

Table 5 (continued): **Quality Assessment of Included Studies**

Authors, Year (Reference)	Study Design	Enrollment Strategy	Selection Bias	Measurement Bias	Confounding	Overall Quality Rating	External Validity
Pulgarón et al., 2014[20]	Cross-sectional	Voluntary enrollment	Moderate. No table provided of participant characteristics by numeracy levels.	Small. Standardized objective numeracy and self-efficacy measurements. Timeframe of HbA_{1C} measurements not provided.	Moderate Without providing numeracy group characteristics, it is difficult to assess for confounding. Variable insulin regimens and duration of diagnosis may confound HbA_{1C} measurements by affect disease severity or child and parent diabetes knowledge.	Fair	Fair. Convenience sampling limits generalizability. Compared to normative means, parent literacy and numeracy scores were significantly higher than representative population.

Figure 1: Flowchart of Identification and Inclusion of Relevant Studies



Numeracy Level and Completeness of Home Blood Pressure Measurement Reporting

Abstract

Self-measurement of blood pressure (BP) at home (home blood pressure monitoring) is valuable in diagnosing and managing hypertension and predicts risks of cardiovascular events and end-organ damage independent of office BP. However, its use is limited by patient effort and understanding. Numeracy (ability with handling numbers) may be an important contributor to such understanding, but its association with quality of home BP monitoring has not been examined. In this study, we examined the association of numeracy level with the completeness of reported home BP measurements.

We analyzed data from 420 adults 30 years and older participating in a four week BP measurement study. Each participant was loaned an Omron-705CP automatic home monitor with appropriate size cuff and asked to complete triplicate home BP measurements twice daily for 5 consecutive days during week 1 and week 3. We asked participants to record their readings on a pre-printed form. Proper use of the device was carefully explained and demonstrated by study personnel prior to acquisition of home BP measurements. During one of the study visits, we also asked participants to complete a previously validated 3-item numeracy assessment. Participants were considered to have adequate numeracy level if they provided correct responses to ≥2 items. We report total percentage of home BP readings completed as well as percent of participants reporting at least 85% of completed readings compared by numeracy level.

The mean age of participants was 48±12 years. Slightly more than half were female. Nearly three-fourths were white, and 21% were black. Most (73%) were college graduates. A total of 409 participants completed the numeracy assessment. Numeracy level was adequate

(score of 2 or 3) in 69% and low (0 or 1) in 31%. Those with adequate numeracy reported completing 96.2% of total home BP readings while those with low numeracy level reported 93.7% (P=0.009). At least 85% of readings were reported by 95% of participants in the adequate numeracy group compared to 88% in the low numeracy group (P=0.018).

Higher numeracy level is associated with more complete reporting of home BP readings, although the difference is small. Whether higher numeracy is associated with more accurate readings is an area of future research.

Introduction

Hypertension is well known to increase risk of cardiovascular disease (CVD) and stroke-related morbidity and mortality.[1–3] It is highly prevalent in the United States, and accumulates $51 million annually in health-related costs. Between 2003 and 2010, nearly 70 million Americans had hypertension, and among those, only 53.5% had it under control.[4] Appropriate identification and treatment of high blood pressure (BP) is an important public health issue as it may reduce the overall attributable risk of hypertension to other related comorbidities and mortalities.

Traditionally, clinicians diagnose and manage hypertension using BP measurements performed in the office setting. Self-measured BP, or home blood pressure monitoring (HBPM), is a useful strategy for providing clinicians with patient's out-of-office measurements of BP. Furthermore, HBPM predicts risks of cardiovascular events and end-organ damage independent of office BP.[5–7] With HBPM, the patient uses a portable device in the home setting to ideally record two sets of BP measurements during a day for consecutive days. However, its use is limited by patient effort and understanding.

Health literacy is the ability by which an individual can attain, process, and understand health information to make educated health decisions.[8] Numeracy, a component of overall health literacy, is the set of skills required for understanding and managing numerical health information.[9] Low numeracy is associated with fewer employment opportunities, reduced job growth, lower socioeconomic status, low literacy, and a poor home-learning environment.[10–12] Numeracy skills interfere with the understanding of risk perception, manipulation of numerical health information, self-management of chronic disease, and medical decision-making.[11] Low numeracy may be an important contributor to understanding patient health-related skills and outcomes by affecting the way patients process numerical information or the patient's ability to successfully complete health-related tasks in and out of the medical setting.[11–13] Numeracy level has been shown to vary even in highly educated and literate populations,[9,10] and since HBPM requires patients to measure and record BP values with time, numeracy level may be relevant to the successful completion of HBPM than health literacy alone. To our knowledge, the association of numeracy with quality and completeness of home BP monitoring has not been examined.

The purpose of this study is to investigate the relationship between numeracy level and completeness of home blood pressure reporting, and identify factors that mediate this possible relationship with a specific focus on demographic and socioeconomic characteristics.

Methods

Overall Design and Study Participants

For this cross-sectional study, we recruited 420 participants from twelve primary care clinics that participate with a University of North Carolina-led Research Consortium and via flyers posted in a clinical research center in central North Carolina between October 2010 and June 2013. Participants had to be at least 30 years of age, with most recent clinic systolic BP between 120 and 149 mmHg and diastolic BP between 80 to 95 mmHg, able to read and speak English, and able to attend study visits. We enrolled participants 30 years and older since they would potentially have elevated BPs that may lead to meaningful clinical outcomes or among whom would have absolute cardiovascular risk high enough to justify risk-reducing therapies. We excluded patients who were pregnant, had persistent atrial fibrillation or other arrhythmias, known heart disease including coronary artery disease, had a history of dementia or cognitive disorders, diagnosed with diabetes, took anti-hypertensive medications, and had systolic BP ≥ 160 mmHg or ≤ 110 mmHg and diastolic BP ≥ 100 mmHg or ≤ 70 mmHg. This study was approved by the University of North Carolina Institutional Review Board (IRB), and informed consent was obtained from each participant. The study complied with all aspects of the Health Insurance Portability and Accountability Act (HIPAA).

Health Literacy and Numeracy Assessment

We assessed participant health literacy and numeracy using the Rapid Estimate of Adult Literacy in Medicine–Short Form (REALM-SF)[14] and the 3-item standardized numeracy measure.[15] Each of these measurement tools has been previously validated and widely reported. Participant literacy scores were determined by the pronunciation of and time to read medical words (i.e. Menopause, Antibiotics, Exercise, Jaundice, Rectal, Anemia, and Behavior). A score of 0 corresponded with a third grade reading level or below, while a score of 7 corresponded with at least high school education and an ability to read most patient education materials.[14] Participant numeracy scores were calculated by answering three questions that assessed basic familiarity with probability, ability to convert a percentage into a proportion, and ability to convert a proportion back into a percentage.[15] Higher numeracy scores correspond with greater accuracy in interpreting numerical information and applying risk reduction.[15] These measurements were conducted following initial research office BP measurements as to avoid the possibility of influencing BP. They were also conducted on separate visits to minimize questionnaire burden. Using the 3-item standardized numeracy scale, we defined –Adequate Numeracy” as a score of 2 or 3 and –Low Numeracy” as a score of 0 or 1.

Office Blood Pressure Measurements

We obtained three research office BP measurements from the non-dominant arm with the participant seated and feet on the floor. We used an automatic oscillometric monitor to record measurements at one-minute intervals using an appropriate cuff size after an initial 5 minutes of rest to minimize variability in measurements.[16]

Home Blood Pressure Monitoring

We asked participants to perform out-of-office BP measurements in between office visits during two nonconsecutive weeks. We used the Omron 705 CP, an independently validated automatic monitor, for all home BP measurements.[17,18] Participants wore the BP cuff on the non-dominant arm with the proper cuff size determined by upper arm circumference. If the participant's arm circumference was too large and could not be accommodated by the available BP cuffs, he or she was provided with a Braun Vital Scans Plus wrist BP monitor to obtain home measurements.[19] After an in-office test measurement demonstrated adequate fit and comfort and participants were observed using the monitor, participants returned home with the correct cuff size and the home BP monitor. Each participant was given standardized oral and written instructions on how to the use the BP device. Participants were instructed that following five minutes of initial rest, they were to take home BP measurements that consisted of three seated measurements in the morning and evening at one-minute intervals for five consecutive days.[20,21] For every measurement, participants were asked to record the date, time, and systolic and diastolic BP readings onto a pre-printed form. Although participants received education on how to use the home BP monitor, teach back education or any further quality control methods to assure that HBPM is being performed accurately were not performed so as to understand how HBPM is actually practiced by people in the identification and management of hypertension. Home BP readings were stored in the device memory (up to a maximum of 28 most recent readings) as well. ―Completeness” of home BP measurements was calculated as the percentage of total number of recorded measurements by the participant over the two week period that participants performed HBPM. Thus, a participant who reported 60 systolic and 60 diastolic BPs over 2 weeks would have 100% completeness

$$\left(\frac{2\ measures\ (\text{1SBP + 1DBP) x 3 iterations x twice a day x 5 days x 2 measurement periods}}{\text{120 total possible measurements}}\right).$$

Other Measures

We collected information on race, ethnicity, marital status, education, health status, employment status, and household income.

Statistical Analysis

We used an analysis of covariance (ANCOVA) to assess the relationship of numeracy level on completeness of HBPM. In an initial model we adjusted for several potential confounders with numeracy level as the exposure and mean percentage of home BP recordings complete as the outcome. We excluded education level from the model because we theorized it has a significant role in the causal pathway between numeracy and reporting of HBPM. We used Pearson's chi-square and Goodman and Kruskal's gamma assessments to determine how effectively education level correlates with numeracy scores and to confirm our theorized relationship between the two variables. In our final adjusted model, we omitted covariates that had relatively equal distribution among those with adequate and low numeracy and covariates that did not have a meaningful effect on adjusted home BP reporting percentages (i.e. statistically not significant or clinical difference less than 0.05%) by numeracy level. Covariates in the final model included gender, race, marital status, health status, income level, and literacy level. We also assessed the correlation between health literacy and numeracy scores, and analyzed the relationship between health literacy scores and completion of HBPM reporting using simple linear regression. The differences in completed HBPM reporting by low health literacy (score of 5 or less) and high health literacy (score 6 or 7) were compared post hoc using Student's t-test. A post hoc logistic regression model was used with the outcome of $\geq$ 85% vs. < 85% of completeness of home BP reporting. We also assessed the difference in reported numerical home BP values between numeracy groups. We compared the outcomes mentioned above between participants with low numeracy level to those with adequate numeracy level using the two-sample Student's t-test for continuous variables or Chi-square for categorical variables. All statistical analyses were performed using Stata 13 (StataCorp LP, College Station, Texas).

Power Estimation

This study sample of 420 participants was available as part of a larger BP measurement study. To detect a minimum difference in completed BP reporting percentage of 5% between numeracy groups with a minimum numeracy group size of 120 and an alpha level of 0.05, we estimated the statistical power to be 0.8036.

Results

Characteristics of Sample

Eleven participants did not perform the numeracy assessment and thus were not included in the analysis. A total of 409 participants performed both HBPM and completed the numeracy level assessment (99.5%). The mean age of all participants was 47.9 years (Table 1). In this study population, 31% had low numeracy. One hundred out of 126 (79%) were female in the low numeracy group compared to 128 out of 283 (45%) in the adequate numeracy group. The proportion of whites in the low numeracy group was lower than in the adequate numeracy group (56 vs. 83%). The distribution in education levels was lower in the low numeracy group, with more college graduates among those with adequate numeracy level (51 vs. 84%). The mean research office BP was 125/78 mmHg (±34/32 mmHg) among those with low numeracy level and 129/81 mmHg (±25/23 mmHg) among those with adequate numeracy level.

Numeracy, Education Level, and Health Literacy Scores

There was a strong correlation between education levels and participant numeracy scores (Goodman and Kruskal's $\gamma = 0.63$; Pearson's $\chi^2 = 92.6$, $p<0.001$). Given this correlation, we did not include education in our model as it may serve as a causal factor between numeracy and HBPM. The distribution of education levels among participants is shown in Appendix Table 1. The correlation between literacy scores and numeracy scores was small to moderate (Goodman and Kruskal's $\gamma = 0.39$; Pearson's $\chi^2 = 28.3$, $p=0.001$).

Home Blood Pressure Reporting

The home blood pressure reporting averages are shown in Table 2. The unadjusted mean completeness of HBPM reporting among those with low numeracy level was 93.7% vs. 96.2% among the adequate numeracy group. After adjusting for gender, race, marital status, health status, income level, and literacy level, the difference in mean completeness of HBPM reporting between both groups was 93.6% vs. 96.2% (p=0.02). There was no relationship between completeness of HBPM reporting and health literacy scores (r=0.0002, p=0.8), and when stratified by low vs. high literacy scores, completion rates between both groups was not significant and unexpected (99 vs. 95%, p=0.09).

Participants completing a minimum of 85% of reported HBPM are shown in Table 3. Of those with low numeracy level, 88.1% completed at least 85% of HBPM reporting compared to 94.7% in the adequate numeracy level group (p=0.018), with an odds ratio of 2.41 (95% CI: 1.14, 5.11; Table 4).

Reported morning home BPs were 128/80 mmHg (±10/7 mmHg) among those with adequate numeracy vs. 129/80 mmHg (±11/11 mmHg) among those with low numeracy (p=0.5/0.6; Table 5). Home BPs reported in the evening were 130/80 mmHg (±10/8 mmHg) in the adequate numeracy group vs. 131/81 mmHg (±11/8 mmHg) in the comparison group (p=0.7/0.1).

Discussion

In this cross-sectional study, we examined how a sample of adults who were not on BP medications performed on a numeracy assessment and home BP reporting. Participants with lower numeracy scores completed home BP reporting less often than those with higher numeracy scores, which held true after adjusting for gender, race, marital status, health status, income level, and literacy level. One-third of our participants exhibited low numeracy despite having overall high literacy scores and education levels, which is consistent with other studies characterizing numeracy deficits in educated populations.[9,10] Although the difference in completed home BP reporting by numeracy level was 3%, there was no difference in blood pressure in low and high numeracy groups. This must be interpreted in the context of our sample in which college graduates comprised 51% and 84% in the low and adequate numeracy groups, respectively. These rates of educational attainment among the numeracy groups are significantly higher than compared to the general United States population, which recently reached an all-time high in college attainment at 34% among people aged 25-29 years.[22] The difference in home BP completion rates by numeracy level may in fact be substantially higher in a more representative US population given the overall lower education distribution.

Low health literacy has been associated with poorer ability to take medications appropriately, more difficulty interpreting health messages, reduced use of some preventive health services, increased emergency department visits and hospitalizations, and increased mortality among older populations.[23,24] Health literacy has also been shown to play a role in increased prevalence of hypertension and reduced hypertension-related knowledge.[25–27] Within our study population, we found no clear relationship between health literacy scores and completion of home BP reporting. Although differences in health literacy scores were statistically significant between the numeracy groups, both groups averaged at or above a high school reading level, minimizing the likelihood that a clinical difference in participant ability to read the health education materials explains the difference in home BP reporting.

Numeracy has more recently been studied alongside literacy as a set of essential skills that may play a role in the patient's understanding of health risks, knowledge, and medical decision-making.[9,11,13] Although most studies have assessed numeracy in the context of oral and written communication, evidence on the relationship between numeracy and the patient's ability to perform health-related tasks is insufficient.[23] Studies report barriers to successful HBPM completion include failure of recognized benefits, lack of knowledge of cuff use, time required for monitoring, forgetfulness, lack of personal assistance, and misunderstanding of how to report.[28,29] We hypothesize that patients with low numeracy may also have a fear of working with numbers, rather than reading off numbers for recording, and that low numeracy may serve as an additional barrier to successful HBPM completion.

Incomplete reporting of HBPM potentially limits the accurate identification of uncontrolled or masked hypertension that would benefit from anti-hypertensive therapy,[5,30] limits monitoring therapy among treated uncontrolled patients to prevent secondary complications of chronic hypertension,[5–7] and may lead to misclassification and potential overtreatment among patients with acceptable out-of-office blood pressures. Since the successful use of HBPM in the identification and management of hypertension has shown to facilitate a reduction in systolic and diastolic BPs to a clinically small but significant amount compared to clinic BP measurements alone,[31] addressing barriers such as numeracy level may improve HBPM adherence and appropriate classification of patients with borderline high blood pressures.

Our study has several limitations. By restricting inclusion to participants with their most recent clinic BPs in the borderline high ranges, we possibly negated any measurable difference in reported home BPs by numeracy level that could have been identified in a population with a uniform distribution of clinic BPs. HBPM was also performed over two separate weeks, and participants could have gained knowledge and skills when performing the health-related task during the first week that may have influenced completion rates during the second week (Appendix Table 2). Our study is also limited by its generalizability. Participants were recruited from primary care clinics that participate in a research consortium, and the education on HBPM use in these clinics may have been more intense and thorough than compared to other health care practices. Also, by participating in this research study about BP, participants may have been more motivated to complete home BP measurements. Furthermore, our study population consisting of those with borderline high BPs may report BPs for reasons different than for those who have hypertension and are taking anti-hypertensive medications.[32,33] Thus, the difference in BP completion rates by numeracy level among a more representative sample of primary care patients might in fact be greater. With regards to our numeracy assessment, we administered a 3-item widely-used measure to categorize our study population into low and adequate numeracy groups. The outcome of home BP measurement completion may differ by use of other assessment tools and numeracy level stratifications.

To our knowledge, this is the first study to report that higher numeracy level is associated with more complete reporting of home blood pressures. Since nearly one-third of participants from this relatively highly educated study population had low numeracy, screening for low numeracy may serve as an important role in the successful completion of HBPM among a broader US population. Given the differences in demographic characteristics between our numeracy groups, numeracy level may also play a role in disparities among race, marital status, health status, and household income level. Numeracy may also serve as a predictor of poorer completion of other health-related skills involving numerical information, and addressing low numeracy may help overcome similar barriers that also affect completion of HBPM.

We believe further studies are required to examine the relationship between numeracy level and the quality of home blood pressure monitoring in order to assess whether numeracy level is associated with accuracy of reporting and other health outcomes. Studies on numeracy may also demonstrate similar trends in the context of other numerical parameters, such as cholesterol, blood glucose, glycosylated hemoglobin (A1C), and CVD risk.

References

1. Lewington S, Clarke R, Qizilbash N, et al. Prospective Studies Collaboration, Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies. *Lancet*. 2002;360(9349):1903–13.

2. Pastor-Barriuso R, Banegas JR, Damián J, Appel LJ, Guallar E. Systolic Blood Pressure, Diastolic Blood Pressure, and Pulse Pressure: An Evaluation of Their Joint Effect on Mortality. *Annals of Internal Medicine*. 2003;139(9):731–9.

3. Law MR, Morris JK, Wald NJ. Use of blood pressure lowering drugs in the prevention of cardiovascular disease : meta-analysis of 147 randomised epidemiological studies. *British Medical Journal*. 2009;338(b1665):1–19.

4. CDC: Centers for Disease Control and Prevention. Awareness and Treatment of Uncontrolled Hypertension Among Adults — United States, 2003–2010. *Morbidity and Mortality Weekly Report (MMWR)*. 2012;61(35):703–709. Available at: http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6135a3.htm.

5. Hodgkinson J, Mant J, Martin U, et al. Relative effectiveness of clinic and home blood pressure monitoring compared with ambulatory blood pressure monitoring in diagnosis of hypertension: systematic review. *British Medical Journal*. 2011;342(d3621):1–17.

6. Tsunoda S, Kawano Y, Horio T, Okuda N, Takishita S. Relationship between home blood pressure and longitudinal changes in target organ damage in treated hypertensive patients. *Hypertension Research*. 2002;25(2):167–73.

7. Mulè G, Caimi G, Cottone S, et al. Value of home blood pressures as predictor of target organ damage in mild arterial hypertension. *Journal of Cardiovascular Risk*. 2002;9(2):123–9.

8. Nielsen-bohlman L, Panzer AM, Kindig DA. Health Literacy A Prescription to End Confusion. *Institute of Medicine of the National Acadmies*. 2004:1–41.

9. Rothman RL, Montori VM, Cherrington A, Pignone MP. Perspective: The Role of Numeracy in

Health Care. *Journal of Health Communication*. 2008;13(6):583–95.

10. Lipkus IM, Samsa G, Rimer BK. General Performance on a Numeracy Scale among Highly Educated Samples. *Medical Decision Making*. 2001;21(1):37–44.

11. Reyna VF, Nelson WL, Han PK, Dieckmann NF. How numeracy influences risk comprehension and medical decision making. *Psychological Bulletin*. 2009;135(6):943–73.

12. Ciampa PJ, Osborn CY, Peterson NB, Rothman RL. Patient Numeracy, Perceptions of Provider Communication and Colorectal Cancer Screening Utilization. *Journal of Health Communication*. 2010;15(Suppl 3):157–168.

13. Chen Y, Feeley TH. Numeracy, Information Seeking, and Self-Efficacy in Managing Health: An Analysis Using the 2007 Health Information National Trends Survey (HINTS). *Health communication*. 2013;(February 2014):37–41.

14. Arozullah AM, Yarnold PR, Bennett CL, et al. Development and Validation of a Short-Form, Rapid Estimate of Adult Literacy in Medicine. *Medical Care*. 2007;45(11):1026–33.

15. Schwartz LM, Woloshin S, Black WC, Welch HG. The role of numeracy in understanding the benefit of screening mammography. *Annals of Internal Medicine*. 1997;127(11):966–72.

16. O'Brien E, Pickering T, Asmar R, et al. O'Brien 2002.pdf. *Blood Pressure Monitoring*. 2002;7(1):3–17.

17. Artigao L, Llavador J, Puras A, et al. [Evaluation and validation of Omron Hem 705 CP and Hem 706/711 monitors for self-measurement of blood pressure]. *Aten Primaria*. 2000;25(2):96–102.

18. Iglesias Bonilla P, Mayoral Sánchez E, Lapetra Peralta J, et al. [Validation of two systems of self-measurement of blood pressure, the OMRON HEM-705 CP and OMRON M1 (HEM 422C2-E) models]. *Aten Primaria*. 2002;30(1):22–28.

19. Nolly H, Osso P, Nolly A, et al. Self-measurement of blood pressure : validation of the Braun

BP VitalScan Plus 1650 monitor according to the European Society of Hypertension International Protocol. *Blood pressure monitoring*. 2008;13(2):101–6.

20. Verberk WJ, Kroon A a, Kessels AGH, de Leeuw PW. Home Blood Pressure Measurement: A Systematic Review. *Journal of the American College of Cardiology*. 2005;46(5):743–51.

21. Verberk WJ, Kroon A a, Kessels AGH, et al. The optimal scheme of self blood pressure measurement as determined from ambulatory blood pressure recordings. *Journal of Hypertension*. 2006;24(8):1541–8.

22. U.S. Department of Education NC for ES. *The Condition of Education: Educational Attainment*. 2014:1. Available at: http://nces.ed.gov/programs/coe/indicator_caa.asp.

23. Berkman ND, Sheridan SL, Donahue KE, et al. Health Literacy Interventions and Outcomes: An Updated Systematic Review. *Evidence report/technology assessment*. 2011;(199):1–941.

24. Bostock S, Steptoe A. Association between low functional health literacy and mortality in older adults: longitudinal cohort study. *British Medical Journal*. 2012;344(e1602):1–10.

25. Pandit AU, Tang JW, Bailey SC, et al. Education, literacy, and health: Mediating effects on hypertension knowledge and control. *Patient Education and Counseling*. 2009;75(3):381–5.

26. Shibuya A, Inoue R, Ohkubo T, et al. The relation between health literacy, hypertension knowledge, and blood pressure among middle-aged Japanese adults. *Blood pressure monitoring*. 2011;16(5):224–30.

27. Gazmararian J a, Williams MV, Peel J, Baker DW. Health literacy and knowledge of chronic disease. *Patient Education and Counseling*. 2003;51(3):267–75.

28. Huff LS, Zittleman L, DeAlleaume L, et al. What Keeps Patients from Adhering to a Home Blood Pressure Program? *Journal of the American Board of Family Medicine : JABFM*. 2011;24(4):370–9.

29. Tan NC, Khin LW, Pagi R. Home blood-pressure monitoring among hypertensive patients in

an Asian population. *Journal of Human Hypertension*. 2005;19(7):559–64.

30. Pierdomenico SD, Cuccurullo F. Prognostic Value of White-Coat and Masked Hypertension Diagnosed by Ambulatory Monitoring in Initially Untreated Subjects: An Updated Meta-Analysis. *American Journal of Hypertension*. 2011;24(1):52–8.

31. Agarwal R, Bills JE, Hecht TJW, Light RP. Role of Home Blood Pressure Monitoring in Overcoming Therapeutic Inertia and Improving Hypertension Control: A Systematic Review and Meta-Analysis. *Hypertension*. 2011;57(1):29–38.

32. Viera AJ, Cohen LW, Mitchell CM, Sloane PD. Use of Home Blood Pressure Monitoring by Hypertensive Patients in Primary Care: Survey of a Practice-Based Research Network Cohort. *Journal of Clinical Hypertension*. 2008;10(4):280–6.

33. Viera AJ, Cohen LW, Mitchell CM, Sloane PD. How and why do patients use home blood pressure monitors? *Blood Pressure Monitoring*. 2008;13(3):133–7.

Tables and Figures

Table 1: Study Participant Characteristics by Numeracy Level

Demographics	Total (N = 409)	Numeracy Level: Low (0-1) (N = 126)	Numeracy Level: Adequate (2-3) (N = 283)	p-value[1]
Age in years, mean (SD)	47.9 (12.0)	47.9 (11.7)	47.9 (12.1)	0.99
Female, n (%)	228 (56)	100 (79)	128 (45)	<0.001
Race, n (%)				<0.001
White	306 (75)	71 (56)	235 (83)	<0.001
Black	87 (21)	51 (40)	36 (13)	<0.001
Asian	11 (3)	2 (2)	9 (3)	0.36
Other	5 (1)	2 (2)	3 (1)	0.65
Ethnicity, n (%)				
Hispanic	16 (4)	8 (6)	8 (3)	0.09
Non-Hispanic	393 (96)	118 (94)	275 (97)	
Marital Status, n (%)				0.002
Married	237 (58)	57 (45)	180 (64)	0.001
Widowed	9 (2)	6 (5)	3 (1)	0.018
Living with partner	30 (7)	15 (12)	15 (5)	0.018
Separated/Divorced	73 (18)	27 (21)	46 (16)	0.2
Never Married	60 (15)	21 (17)	39 (14)	0.4
Education, n (%)				<0.001
Some high school	5 (1)	4 (3)	1 (0)	0.017
High school grad	24 (6)	17 (13)	7 (2)	<0.001
Some college	79 (19)	41 (33)	38 (13)	<0.001
College Grad	301 (74)	64 (51)	237 (84)	<0.001
Health, n (%)				<0.001
Excellent	79 (19)	19 (15)	60 (21)	0.15
Very Good	198 (48)	49 (39)	149 (53)	0.010
Good	109 (27)	44 (35)	65 (23)	0.012
Fair	22 (5)	13 (10)	9 (3)	0.003
Poor	1 (0)	1 (0)	0 (0)	0.13
Employed, n (%)	321 (78)	92 (73)	229 (81)	0.073
Household Income, n (%)				<0.001
<$15,000	25 (6)	14 (11)	11 (4)	0.005
$15,000-19,999	9 (2)	6 (5)	3 (1)	0.018
$20,000-24,999	15 (4)	7 (6)	8 (3)	0.17
$25,000-29,999	17 (4)	7 (6)	10 (4)	0.34
$30,000-34,999	18 (4)	3 (2)	15 (5)	0.19
$35,000-39,999	18 (4)	12 (10)	6 (2)	0.001
$40,000-49,999	29 (7)	12 (10)	17 (6)	0.19
$50,000-79,999	94 (23)	38 (30)	56 (20)	0.019
$80,000-99,999	51 (13)	13 (10)	38 (13)	0.39
≥$100,000	132 (32)	13 (10)	119 (42)	<0.001
Literacy Score, mean (SD)	6.87 (0.46)	6.76 (0.68)	6.92 (0.32)	0.001
Clinic Blood Pressure in mmHg, mean (SD)	128/80 (28.5/25.9)	125/78 (34.1/31.7)	129/81 (25.5/22.8)	0.2 0.3

[1]p-value calculated using Chi-squared test for categorical variables and t-test for continuous variables.

Table 2: Home BP Completeness by Numeracy Level

	Numeracy Level		p-value
	Low (0-1) (N=126)	Adequate (2-3) (N=283)	
Mean HBPM, % (SE)[1]	93.7 (0.008)	96.2 (0.005)	0.009
Mean HBPM, % (SE)[2]	93.6 (0.009)	96.2 (0.005)	0.015
Mean HBPM, % (SE)[3]	93.6 (0.009)	96.2 (0.005)	0.020

[1]Unadjusted using t-test
[2]Adjusted for all potential confounders (excluding education level) using linear regression
[3]Adjusted for gender, race, marital status, health status, income level, and literacy level using linear regression

Table 3: 85% or Greater Home BP reporting by Numeracy Level

	Numeracy Level		p-value
	Low (0-1) (N=126)	Adequate (2-3) (N=283)	
≥85% Reporting, %[1]	88.1	94.7	0.018
≥85% Reporting, % (SE)[2]	91.4 (32.0)	95.2 (28.1)	0.115

[1]p-value calculated using Chi-Squared test
[2]p-value calculated using logistic regression

Table 4: Odds Ratios between Numeracy Level and ≥85% Completion

	Odds Ratio [95% CI]
Unadjusted[1]: Adequate / Low Numeracy	2.41 [1.14 ,5.11]
Adjusted[2]: Adequate / Low Numeracy	2.10 [0.79, 5.54]

[1]Unadjusted calculated using logistic regression
[2]Adjusted for gender, race, marital status, health status, income level, and literacy level using logistic regression

Table 5: Reported Home Blood Pressures by Numeracy Level

Demographics	Total (N = 409)	Numeracy Level		p-value[1] (SBP/DBP)
		Low (0-1) (N = 126)	Adequate (2-3) (N = 283)	
Morning BPs in mmHg, mean (SD)	128/80 (11/9)	129/80 (11/11)	128/80 (10/7)	0.5/0.6
Evening BPs in mmHg, mean (SD)	130/80 (11/8)	131/81 (11/8)	130/80 (10/8)	0.7/0.1
Week 1				
Morning BPs in mmHg, mean (SD)	129/80 (11/8)	129/81 (12/8)	128/80 (11/7)	0.5/0.2
Evening BPs in mmHg, mean (SD)	130/80 (11/8)	131/81 (12/8)	130/79 (11/8)	0.4/0.1
Week 2				
Morning BPs in mmHg, mean (SD)	128/80 (11/12)	129/80 (12/18)	128/80 (11/8)	0.6/0.9
Evening BPs in mmHg, mean (SD)	130/80 (11/8)	130/81 (11/8)	130/80 (11/8)	0.9/0.1

[1]p-value calculated using t-test; SBP, systolic blood pressure; DBP, diastolic blood pressure.

Acknowledgements

I would like to express my sincere gratitude to Dr. Anthony Viera and Dr. Stacey Sheridan for their continuous and extensive support of my master's research, comprehensive teaching, patience, and critical reading of my master's paper. My gratitude also goes to Laura Tuttle and Dr. Feng-Chang Lin who both provided me support in the methods and statistical analysis of this paper. I would also like to thank Emily Olsson and Kristin Stankevitz for their assistance with this project. This study was supported by Grant R01 HL098604 from the National Heart Lung and Blood Institute, with additional support provided through grant UL1 RR025747 from the National Institutes of Health.

Appendix

Appendix Table 1: Numeracy Level and Education Level

Demographics	Total (N = 409)	Numeracy Score			
		0 (N = 35)	1 (N = 91)	2 (N = 137)	3 (N = 146)
Education, n (%)					
Some high school	5 (1)	3 (9)	1 (1)	1 (1)	0 (0)
High school grad	24 (6)	9 (26)	8 (9)	6 (4)	1 (1)
Some college	79 (19)	13 (37)	28 (31)	28 (20)	10 (7)
College Grad	301 (74)	10 (28)	54 (59)	102 (74)	135 (92)
Pearson's χ^2	92.6[1]	54.4	10.0	0.9	27.3
Goodman and Kruskal's γ	0.6339	--	--	--	--

[1]p<0.001

Appendix Table 2: Completeness of HBPM for Weeks 1 and 2 by Numeracy Level

	Numeracy Level		p-value[1]
	Low (0-1) (N=126)	Adequate (2-3) (N=283)	
Mean Week 1 HBPM, % (SE)	90.8 (0.016)	94.7 (0.005)	0.0031
Mean Week 2 HBPM, % (SE)	96.6 (0.008)	97.6 (0.004)	0.29
Difference in HBPM[2], % (SE)	5.8 (0.016)	2.8 (0.005)	0.016
Total Mean HBPM[3], % (SE)	94.4 (0.007)	95.9 (0.004)	0.079

[1]Unadusted using t-test
[2]Difference in completeness of HBPM between Week 2 and Week 1
[3]Adjusted for gender, race, marital status, health status, income level, literacy level, and difference in blood pressure reporting between weeks 1 and 2