Mediators of the association between health literacy and asthma outcomes in African-American adults

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Abstract

African-Americans share a disproportionate burden of asthma and are more likely to have low health literacy. While the relationship between low health literacy and adverse health outcomes has been established, the mediating factors are unclear. The purpose of this study was to determine if self-efficacy and asthma knowledge mediate the relationship between health literacy and asthma outcomes. This cross-sectional study was a sub study of a larger clinical trial. Both numeracy and print literacy skills were assessed. Primary outcomes were asthma control and asthma related quality of life. Mediating factors examined were asthma self-efficacy and asthma self-management knowledge. Bivariate analysis was conducted to compare participants across health literacy levels, and bootstrapping multiple mediator analysis was used to examine self-efficacy and asthma knowledge as mediators. Bivariate analysis indicated that adequate numeracy but not adequate print literacy was significantly associated with increased quality of life and asthma control. Mediation analysis found that print literacy was not associated with asthma outcomes, and self-efficacy and knowledge did not mediate the relationship. Numeracy was associated with quality of life, and this relationship was partially mediated by self-efficacy and knowledge. Numeracy was not associated with asthma control. Results indicate that numeracy, but not print literacy, is associated with asthma outcomes. Self-efficacy and asthma knowledge are not primary mediators between health literacy and asthma outcomes and are not recommended as primary interventions points. Future research should examine other mediators in addition to self-efficacy and asthma knowledge and the role of numeracy in asthma self-management.

Key Words: Numeracy, Mediation Analysis, Health Literacy, Quality of Life, Asthma Control

Introduction

Approximately 25 million adults in the United States have asthma (Akinbami, Moorman, & Liu, 2011). African-Americans have increased asthma morbidity and mortality compared to non-Hispanic Whites (Akinbami et al., 2011), and are also more likely to have low health literacy (Nielsen-Bohlman, Panzer, & Kindig, 2004). Asthma disparities seen among African-Americans are due to a host of factors at both the individual and systemic level (Silver & Lang, 2012). Health literacy has been identified as one of many factors that contributes to asthma disparities seen among African-Americans (Canino, McQuaid, & Rand, 2009).

The Institute of Medicine (IOM) defines health literacy as "the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions" (Nielsen-Bohlman et al., 2004, p.2). The three major dimensions of health literacy are print, oral, and numeracy. Print literacy refers to the ability to read and comprehend written materials, and oral literacy encompasses speaking and listening skills (Baker 2006). Numeracy is defined as "the degree to which individuals have the capacity to access, process, interpret, communicate, and act on numerical, quantitative, graphical, bio statistical, and probabilistic health information needed to make effective health decisions (Golbeck, Ahlers-Schmidt, Paschal, & Dismuke, 2005)."

While the majority of health literacy research has been focused on print literacy, numeracy has been identified as a distinct domain of health literacy with an independent effect on health outcomes (Apter et al., 2009; Osborn, Cavanaugh, Wallston, & Rothman, 2010; Thai & George, 2010). The lack of accurate and reliable tools for measuring oral literacy has also contributed to the focus on print literacy (Nielsen-Bohlman et al., 2004). However, adequacy in all domains of health literacy is required to navigate the health care system, follow directions, communicate with providers, and make informed decisions regarding health (Diette & Rand, 2007).

Previous research has shown that low health literacy is associated with decreased asthma knowledge, poorer medication adherence, and poorer asthma outcomes resulting in increased burden for individuals, families, and the health care system. The few researchers

focusing on numeracy and asthma outcomes have found that low numeracy was associated with an increased number of hospitalizations and emergency department visits and a decreased asthma related quality of life (Apter et al., 2006; Apter et al., 2009; Apter et al., 2013).

Conceptual models explaining the relationship between health literacy and health outcomes indicate that the relationship is complex and individual, health care system, and environmental factors are involved (Nielsen-Bohlman et al., 2004; Baker, 2006; Paasche-Orlow & Wolf, 2007). The proposed framework for the current study (Figure 1) is a simplified version of the Baker (2006) model that focuses on individual capacity. A person's health literacy is influenced by a combination of their individual capacity and the complexity of messages they receive from the health care system. In this framework, health literacy is then one of many factors that lead to self-efficacy, knowledge, and behavior change and ultimately affects health outcomes.

Figure 1 *Proposed framework for the current study*

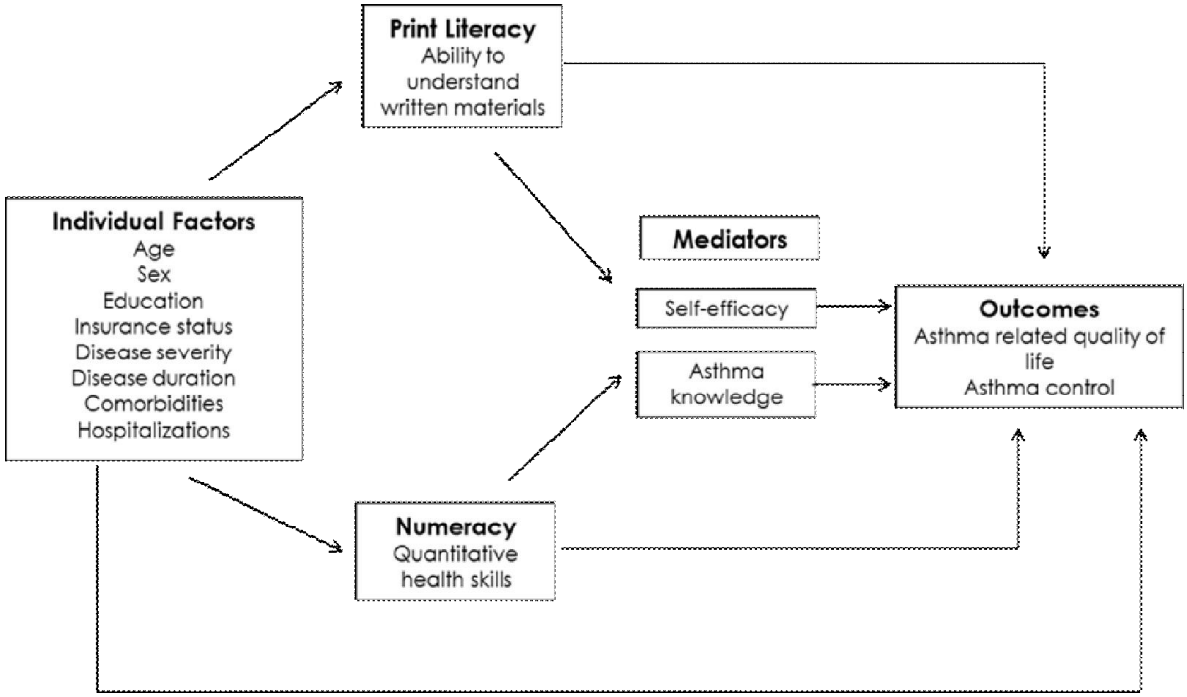

Figure 1 simplified version of the Baker (2006) model

The causal relationship between health literacy and health outcomes has not been well established, but there are a variety of possible mediating factors including self-efficacy, disease and self-management knowledge, and compliance (Berkman, Sheridan, Donahue, Halpern, & Crotty, 2011). While all of the aforementioned factors are at the individual level, non-individual factors such as social support and social environment may also link health literacy and health outcomes (Lee, Arozullah, & Cho, 2004). The mechanisms linking health literacy and health outcomes are unclear (Johnson, Baur, & Meissner, 2011), and there has been limited exploration of the mediating factors between health literacy and asthma outcomes (Rosas-Salazar, Apter, Canino, & Celedón, 2012). This study aimed to determine if self-efficacy and asthma knowledge mediated the relationship between health literacy (e.g. print literacy and numeracy) and health outcomes among African-American adults with asthma. Identifying mediating factors will aid in the development of evidence-based interventions that mitigate the effect of low health literacy on health outcomes. We hypothesized that (a) individuals with limited numeracy and low print literacy would have poorer asthma outcomes compared to individuals with adequate print literacy and numeracy, and (b) the relationship between health literacy and asthma outcomes would be mediated by self-efficacy and asthma knowledge.

Methods

This study was a sub-study of the BELT: Blacks and Exacerbations on LABA vs. Tiotropium study (R01 HS19408-01). BELT was a multi-site, randomized study that compared the effectiveness of two medications, long acting beta agonists (LABA)/inhaled corticosteroids (ICS) vs. tiotropium/ICS in African-American patients with asthma. The study enrolled African-Americans between 18-

75 years old with moderate to severe asthma. Participants were followed between 6 to 18 months, completed three to five follow-up visits, and answered monthly written survey evaluations of asthma control and quality of life.

In addition to being a sub-study of a larger clinical trial, this investigation was the quantitative phase of a mixed methods study. The results of the qualitative phase have been previously reported (Melton, Graff, Holmes, Brown, & Bailey, 2014). Data were collected via cross-sectional surveys. Participants who participated in the sub-study answered an additional set of questionnaires that measured numeracy, print literacy, self-efficacy, and asthma knowledge. Sub-study questionnaires were then matched with outcome data from the corresponding BELT visit. For example, if a participant completed health literacy surveys at their first visit, outcome data collected at the first visit was used for sub-study. An effort was made to collect data at either visit one (baseline) or visit two (one month) of the BELT study to reduce the possibility of having improved asthma outcomes due to study participation.

Sample and Setting

The data were collected at primary care clinics in Memphis, TN; Decatur, Georgia; Miami, Florida; and Kansas City, Missouri. Since all patients enrolled in the BELT study were eligible for the sub-study, inclusion and exclusion criteria were identical to those for the overall BELT study. This study was approved by the Institutional Review Boards of a The University of Tennessee Health Science Center.

Independent Variables

Print literacy was assessed using one of the three brief screening questions developed by Chew, Bradley, and Boyko (2004). The three questions were: "How often do you have someone help you read hospital materials?"; "How confident are you filling out medical forms by yourself?"; "How often do you have problems learning about your medical condition because of difficulty understanding written information?" Questions were scored on a 5-point Likert scale. Previous literature has demonstrated that a single question is adequate for detecting inadequate literacy (Chew et al., 2004; Powers, Trinh, & Bosworth, 2010). Based on the population of interest, the question "How confident are you filling out medical forms by yourself?" was used as the single item screening question (Wallace et al., 2006). The screening question was dichotomized into adequate or inadequate literacy using the previously determined "somewhat" response as the threshold.

The Newest Vital Sign (NVS) was used to measure numeracy (Weiss et al., 2005). The NVS consists of a nutrition label and six accompanying questions. Each question is worth one point, and scores can range from zero to six. Each question is worth one point, and scores can range from zero to six. A score of one or zero indicates a high likelihood (50% or more) of limited literacy. A score of two or three indicates the possibility of limited literacy, and a score of four to six almost always indicates adequate literacy. The NVS scores were dichotomized into either adequate or possibility of limited numeracy. Scores ranging from zero to three were classified as possibility of limited numeracy, and scores between four and six were classified as adequate numeracy.

Chew et al. (2004) question and the NVS were chosen because they were developed for use in clinical settings and avoid invoking feelings of shame and embarrassment about having low health literacy (Shah, West, Bremmeyr, & Savoy-Moor, 2010; Vangeest, Welch, & Weiner, 2010).

Mediating Variables

Self-efficacy was measured using the Asthma Self-Efficacy Scale (ASE) developed by Apter et al. (2006). The questionnaire is comprised of 14 questions using a 5-point Likert scale and is specific to circumstances around taking inhaled corticosteroids. The range of ASE scores is 14-70 with higher scores indicating greater self-efficacy. The total ASE score was used. The ASE alpha coefficient was of 0.81 in an earlier study (Apter et al., 2006) and 0.63 in the current study.

Asthma knowledge was measured using the Asthma Self-Management Questionnaire (Schaffer & Yarandi, 2007). The questionnaire is comprised of 24 true-false items and the total score is the percentage of correct responses. The Cronbach's alpha was 0.69 in an earlier study (Schaffer & Yarandi, 2007) and 0.61 in the current study.

Outcome Variables

Asthma quality of life was measured using the standardized version of the Asthma Quality of Life scale (AQLQ-S) (Juniper, Buist, Cox, Ferrie, & King, 1999). The AQLQ-S is comprised of 32 questions and four domains (i.e., activity limitations, symptoms, emotional function, and exposure to environmental stimuli). Item responses are based on 7-point Likert scale with higher scores indicating better quality of life. The overall mean of the AQLQ-S was calculated with higher scores indicating better asthma related quality of life.

Asthma control was measured using a shortened, six item version of the Asthma Control Questionnaire (ACQ) (Juniper, O'Byrne, Guyatt, Ferrie, & King, 1999; Juniper, Svensson, Mörk, & Ståhl, 2005). Items are scored from 0 to7. The mean of the responses to the six items was calculated with higher scores indicating poorer asthma control. Juniper et al. (2006) recommend 0.75 as the cut-point for well controlled asthma and 1.50 as the cut-point for inadequately controlled asthma.

Covariates

Covariates included age, sex, education, insurance status, forced expiratory volume (% FEV1), disease duration, number of asthma related hospitalizations in the last 12 months, and number of asthma related emergency department visits in the last 12 months, and number of comorbidities. All but disease severity were self-reported.

Data Analysis

Descriptive statistics (i.e. means, standard deviations, frequencies) of the demographic variables and health literacy levels were calculated. Bivariate associations between health literacy/numeracy, covariates, and asthma outcomes were tested using t-tests, $\chi 2$ test,

Fisher's Exact test, and Wilcoxon-Mann-Whitney tests. Because sub-study data were collected at different times throughout the follow-up period, assessment of intrinsic bias was undertaken by determining if the length of time in the main study influenced asthma outcomes. There was concern that individuals who were in the study for a longer period of time would have improved asthma outcomes compared to individuals who were in the study for shorter periods of time

The Preacher and Hayes (2008) recommended method of bootstrapping multiple mediator analysis with bias corrected confidence intervals was used. This method was chosen because it was appropriate for the small sample size, had the greatest power compared to other methods, did not require normality of the data, allowed the calculation of asymmetrical confidence intervals, and has more favorable type 1 error rates (Briggs, 2006; Preacher & Hayes, 2008; Williams & MacKinnon, 2008). Both total and specific indirect effects were examined using 5,000 bootstrap samples to calculate 95% bias corrected confidence intervals. Four main models were run, and all models included both asthma knowledge and self-efficacy as mediators. The analysis was completed using a SAS macro developed by Preacher and Hayes (2008). A total of four multiple mediator models were run. In model 1, print literacy was the independent variable and asthma control was the dependent variable. In model 2, print literacy was the independent variable and asthma quality of life was the dependent variable. In model 3, numeracy was the independent variable and asthma control was the dependent variable. In model 4, numeracy was the independent variable and asthma quality of life was the dependent variable. All models included both self-efficacy and asthma knowledge as mediators and controlled for age, sex, education, insurance status, %FEV 1, number of years with diagnosed asthma, number of comorbidities, number of hospitalizations in the last 12 months, and number of emergency department visits in the last 12 months. All covariates were included in the analysis regardless of being significantly associated in bivariate analysis because these covariates have been found to be significantly associated with print literacy and numeracy in previous research (Kutner, Greenberg, Jin, Paulsen, & White, 2006).

Post-Hoc Power Analysis

Previous studies using the data analysis methods described above typically did not perform or report power analyses (Buffardi & Campbell, 2008; Danaher, Smolkowski, Seeley, & Severson, 2008; Day, Hart, Wanklyn, McCay, MacPherson, & Burnier, 2013; Lynch, Johnson, Kable, Carroll, & Coles, 2011; Molloy, Randall, Wilkman, Perkins-Porras, Messerli-Bürhy, & Steptoe, 2012; Parisi et al., 2012; Wittman, Arce, & Santisteban, 2008), but relied on previously documented power that was determined through simulation studies (Briggs, 2006; Williams & MacKinnon, 2008). Thoemmes, MacKinnon, and Reiser (2010) recommend using Monte Carlo methods (Muthén & Muthén, 2002) for power analysis in multiple mediator models; this method was used to perform post hoc analysis in this study.

The alpha significance level was set at .05; all tests were two tailed. A post-hoc power analysis for each model was done to determine the power of detecting mediating effects.

Results

Sample Characteristics

Characteristics of the participants are presented in Table 1. Based on % FEV1 (M = 73.3, SD = 18.61) and ACQ (M = 2.11, SD = 1.21) scores, participants had moderate, poorly controlled asthma on average. The sample comprised 99 African American individuals between 18 and 75 years of age (M=46, SD = 11.37) and comprised more women (72%) than men (28%). A majority of participants had a high school education (31%) or some college (32%) and had health insurance through Medicare or Medicaid. On average, participants had been diagnosed with asthma for 22 (SD = 14.48) years and had at least one comorbidity (M= 1.11, SD= 1.03). In the last 12 months, participants reported one (M= 1.26, SD= 2.49) asthma related emergency room visit and less than one (M= 0.28, SD= 0.78) asthma related hospitalization.

Table 1 *Sample Characteristics*

Characteristics	M ± SD or n (%)
Age, years	46± 11.37
Male	28 (28)
Female	71 (72)
Education, n (%)	
< High school	28 (28.3)
High school	31 (31.3)
Some College	32(32.3)
College Graduate	8 (8.1)
Insurance, n (%)	
Private Insurance	10 (10.1)
Public Insurance	62 (62.6)
Uninsured	27 (27.3)

FEV1%	73.3 ±18.61
Disease duration, years	22± 14.48
Comorbidities	1.11± 1.03
Hospitalizations	0.28 ± 0.78
ED visits	1.26 ±2.49
ASE	52.9 ± 8.58
Asthma Knowledge	72.18± 11.76
ACQ	2.11 ± 1.21
AQLQ-S	3.86± 1.3
Print Literacy, n (%)	
Adequate	70 (71)
Low	29 (29)
Numeracy, n (%)	
Adequate	29 (29)
Limited	70 (71)

Note. ACQ: Asthma Control Questionnaire; ASE: Asthma Self-efficacy Scale; Asthma Knowledge: Asthma Self-Management Knowledge Questionnaire; AQLQ-S: Standardized Asthma Quality of Life Questionnaire; ED: emergency department; FEV1%: percentage of forced expiratory volume in one second

Bivariate associations between health literacy (print literacy and numeracy) and demographic, mediating and outcome variables are shown in Table 2.

Table 2 *Bivariate associations between health literacy and demographic, mediating, and outcome variables*

	Print Literacy			Numeracy		
Characteristics	Adequate	Low	p-Value	Adequate	Limited	p-Value
N (%)	70(71)	29(29)		29(29)	70(71)	
Ageb	45.62± 11.29	46.69±11.71	0.67	43.3±12.45	47.02±10.79	0.14
Sexa			0.55			0.56
Male	21(75)	7(25)		7 (25)	21 (75)	
Female	49(69)	22(31)		22(31)	49(69)	
Educationa			0.17			<0.001
< High school	17(61)	11(39)		4(14)	24(86)	
High school	21(68)	10(32)		5(16)	26(84)	
Some College	24(75)	8(25)		14(44)	18(56)	
College Graduate	8(100)	0(0)		6(75)	2(25)	
Insurancea			0.63			0.30
Private Insurance	7(70)	3(30)		5 (50)	5(50)	
Public Insurance	42(68)	20(32)		16(26)	46(74)	
Uninsured	21(78)	6(22)		8(30)	19(70)	
%FEV1b	74.14±18.32	71.28±19.48	0.49	74.24±16.13	72.91±19.64	0.75
Disease duration(years)b	21.69±14.45	22.69±14.78	0.75	19.52±13.34	23±14.90	0.28
Comorbiditiesb	1.00±0.99	1.37±1.08	0.10	0.76±0.69	1.26±1.11	0.008
Hospitalizationsb	0.21±0.74	0.44±0.87	0.18	0	0.4±0.90	<0.001
ED visitsb	1.3±2.75	1.17±1.75	0.78	0.86±1.66	1.43±2.78	0.21
ASEb	54.13±8.65	49.79±7.71	0.02	56±8.39	51.56±8.37	0.02
Asthma Knowledgeb	73.02± 11.64	70.15±12.01	0.27	76.33±11.03	70.45±11.7	0.02
ACQb	2.02±1.27	2.32±1.05	0.26	1.77±1.07	2.25±1.24	0.07
AQLQ-Sc	3.94 ±1.33	3.68 ±1.20	0.25	4.54±1.33	3.58±1.18	0.001

Note. ACQ: Asthma Control Questionnaire; ASE: Asthma Self-efficacy Scale; Asthma Knowledge: Asthma Self-Management Knowledge Questionnaire; AQLQ-S: Standardized Asthma Quality of Life Questionnaire; ED: emergency department; FEV1%: percentage of forced expiratory volume in one second. Age, sex, education, insurance status, disease duration, and number of comorbidities were all self-reported. Hospitalizations and ED visits are number of self-reported visits in the last 12 months. Asthma knowledge is scored as percent of correct answers. Private insurance includes employer sponsored, individual plans, or insurance through a spouse's or parent's employer. Public insurance includes Medicaid and Medicare. [a]Chi-square, Fisher's Exact if cell count <5; [b]Independent t-tests; [c]Wilcoxon Mann-Whitney

Print Literacy

More participants had adequate (71%) print literacy than low (29%) print literacy. Participants with adequate print-related health literacy had higher ASE scores compared to participants with low print-related health literacy (p=0.02) indicating that adequate print literacy was associated with increased self-efficacy. There were no observed differences between participants with adequate print-related health literacy and those with low print-related health literacy across age, sex, education, %FEV 1, number of years with diagnosed asthma, number of comorbidities, number of hospitalizations in the last 12 months, number of emergency department visits in the last 12 months, Asthma Knowledge Questionnaire scores, ACQ scores, or overall AQLQ-S scores.

Numeracy

Fewer participants had adequate numeracy (29%) compared to those with limited numeracy (71%). More education was associated (p = < 0.001) with adequate numeracy. Participants with adequate numeracy had fewer comorbidities (p= 0.008), fewer hospitalizations in the last 12 months (p= <0.001), and higher ASE scores (p= 0.02), and higher Asthma Self-Management Questionnaire scores (p= 0.02) compared to individuals with limited numeracy. Participants with adequate numeracy had lower ACQ scores compared to participants with limited numeracy (p = 0.07). Although this association was not statistically significant, the difference in scores is clinically relevant (Juniper, Svensson, Mörk, & Ståhl, 2005). Lastly, participants with adequate numeracy had higher AQLQ-S scores compared to compared to participants with limited numeracy (p= 0.001). There were no observed differences between participants with adequate numeracy and limited numeracy across age, sex, insurance status, %FEV 1, number of years diagnosed with asthma, and number of emergency department visits in the last 12 months.

Intrinsic Bias

The current study was a sub-study of a larger study with a follow up period from 6 to 18 months. Sub-study data were collected at different times throughout the follow up period. Because participants were enrolled in a larger study, they may have been more likely to take medications as prescribed due to follow-up visits and frequent interactions with study staff.

Eighty percent of sub-study data was collected during the first month of being enrolled in the BELT study at BELT visit 1 or BELT visit 2. Participants who completed the sub-study during BELT visit 1 or BELT visit 2 had significantly better asthma control as indicated by lower ACQ scores (p= 0.01) compared with other participants. Individuals who completed the sub-study at their 6 month BELT visit had significantly lower ACQ scores (p = < .0001) than individuals who completed the sub-study at any other time period. There were no differences in AQLQ-S scores across sub-study completion times (p = 0.05). Based on this analysis, time of visit was controlled for in the mediation analyses with ACQ as the outcome variable.

Mediation Analysis

Figure 2 displays the associations between print literacy and asthma control (Model 1). The total effect of print literacy on asthma control was 0.39 (p = 0.13) indicating no difference in asthma control based on print literacy. The direct effect of print literacy on asthma control was 0.35 (p = 0.17) indicating no difference in asthma control resulting from print literacy's influence on self-efficacy and asthma knowledge. The model had an adjusted R^2 of 0.20 (p = 0.001) indicating that the print literacy, self-efficacy, and asthma knowledge explained 20% of the variance in asthma control.

The indirect effects for Model 1 were not significant. Although the significant direct effect indicated partial mediation, significance tests for the specific indirect effects were not significant.

Figure 2 *Associations among print literacy, self-efficacy, asthma knowledge, and asthma control*

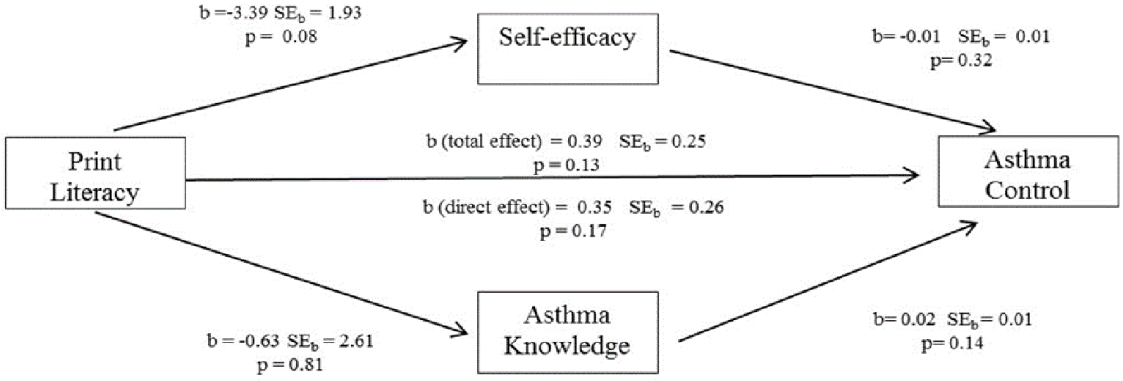

Figure 2. b: unstandardized path coefficient ;SE: standard error. Results of mediation analysis model showing associations among print literacy, the proposed mediating variables (self-efficacy and asthma knowledge) and asthma control. Unstandardized path coefficients, standard errors, and p-values are reported. The total effect is the effect of print literacy on asthma control. The direct effect is the effect of print literacy on asthma control when accounting for self-efficacy and asthma knowledge.

Figure 3 displays the relationship between print literacy and asthma related quality of life (Model 2). The total effect of print literacy on quality of life was -0.21(p = 0.47) indicating that print literacy was not

associated with quality of life. The direct effect of print literacy on quality of life was -0.16 (p = 0.59) indicating no difference in quality of life resulting from print literacy's influence on self-efficacy and asthma knowledge. Neither the indirect effects nor the overall model was not significant with an adjusted R^2 of 0.04 (p = 0.18) for Model 2. Print literacy was not associated with quality of life and that association was not mediated by self-efficacy or asthma knowledge.

Figure 3 *Associations among print literacy, self-efficacy, asthma knowledge, and asthma related quality of life*

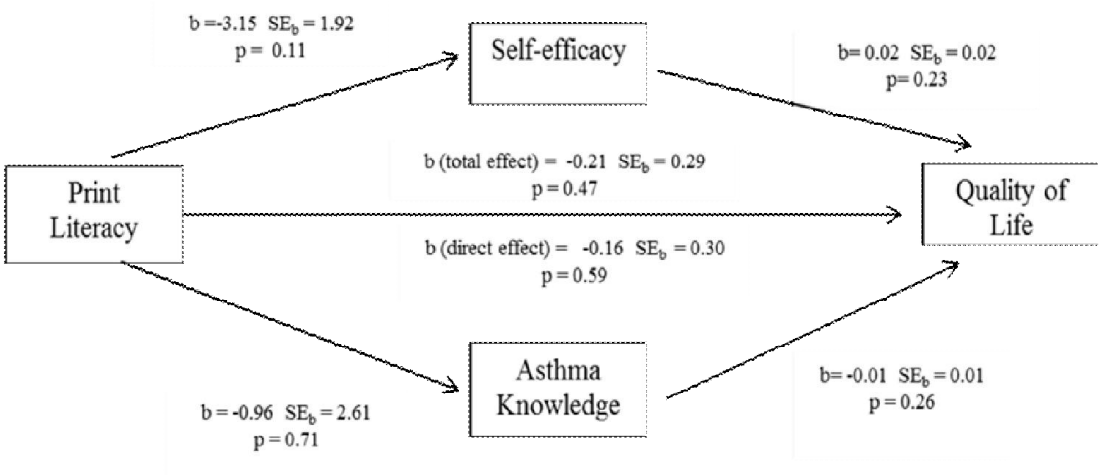

Figure 3. b: unstandardized path coefficients ;SE: standard error. Results of mediation analysis model showing associations among print literacy, the proposed mediating variables (self-efficacy and asthma knowledge) and asthma related quality of life. Unstandardized path coefficients, standard errors, and p-values are reported. The total effect is the effect of print literacy on quality of life. The direct effect is the effect of print literacy on quality of life when accounting for self-efficacy and asthma knowledge.

Figure 4 displays the association between numeracy and asthma control (Model 3). The total effect of numeracy on asthma control was 0.50 (p= 0.07) indicating no difference in asthma control based on numeracy. The direct effect of numeracy on asthma control was 0.50 (p = 0.08) indicating no difference in asthma control resulting from numeracy's influence on self-efficacy and asthma knowledge. The model had an adjusted R^2 of 0.21 (p = 0.001) indicating that numeracy, self-efficacy, and asthma knowledge explained 21% of the variance in asthma control. The indirect effects for Model 3 were not significant.

Figure 4 *Associations among numeracy, self-efficacy, asthma knowledge, and asthma control*

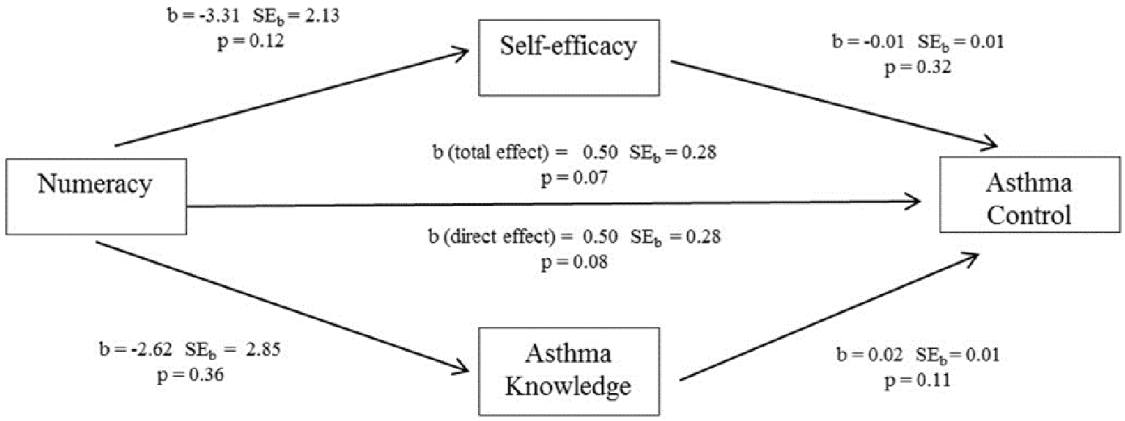

Figure 4. b: unstandardized path coefficient ;SE: standard error. Results of mediation analysis model showing associations among numeracy, the proposed mediating variables (self-efficacy and asthma knowledge) and asthma control. Unstandardized path coefficients, standard errors, and p-values are reported. The total effect is the effect of numeracy on asthma control. The direct effect is the effect of numeracy on asthma control when accounting for self-efficacy and asthma knowledge.

Figure 5 displays the association betweennumeracy and asthma related quality of life (Model 4). The total effect of numeracy on asthma quality of life was -0.99 (p= 0.002) indicating a significant one point difference in asthma quality of life based on numeracy (i.e. adequate numeracy associated with higher AQLQ-S scores). The direct effect of numeracy on asthma quality of life was -0.98 (p= 0.0002) indicating a difference in asthma quality of life resulting from numeracy's influence on self-efficacy and asthma knowledge. Individuals with adequate numeracy had better asthma related quality of life compared to individuals with limited numeracy, and this was partially mediated by self-efficacy and asthma knowledge. However the effect of these mediators is likely small due to the small size of the indirect effect coefficients. Model 4 was significant with an adjusted R^2 of 0.14 (p = 0.01) indicating that numeracy, self-efficacy, and asthma knowledge explained 14% of the variance in asthma related quality of life. The indirect effects for Model 4 were not significant.

Figure 5 *Associations among numeracy, self-efficacy, asthma knowledge, and quality of life*

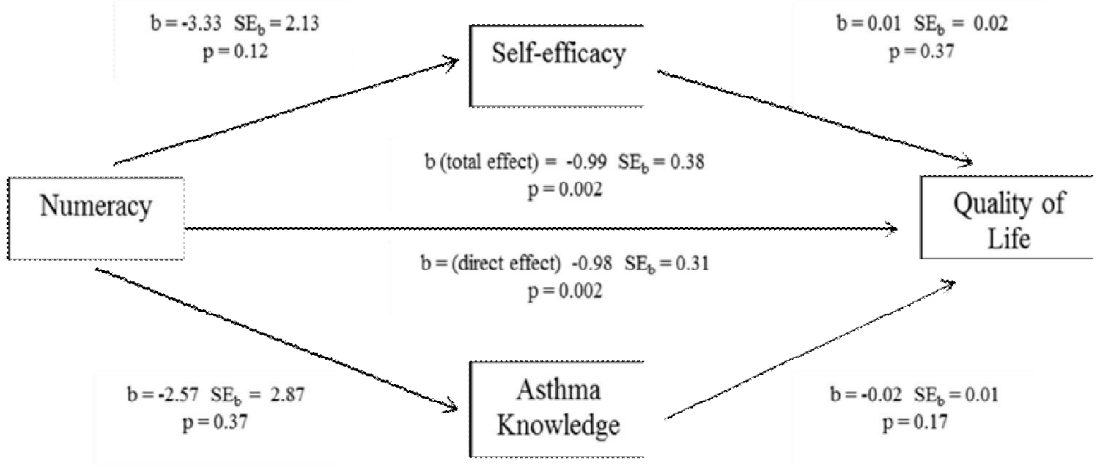

Figure 5. b= unstandardized path coefficients; SE: standard error. Results of mediation analysis model showing associations among numeracy, the proposed mediating variables (self-efficacy and asthma knowledge) and asthma related quality of life. Unstandardized path coefficients, standard errors, and p-values are reported. The total effect is the effect of numeracy on quality of life. The direct effect is the effect of numeracy on quality of life when accounting for self-efficacy and asthma knowledge.

Post-Hoc Power Analysis

Table 3 displays the results of the power analysis. Overall, there was low power to detect a mediating effect for both the combined effect of self-efficacy and asthma knowledge as well as the singular effects of self-efficacy and asthma knowledge. Interestingly, Model 2 was the only model with low power to detect a total effect.

Table 3 *Power analysis results*

Parameter	Model 1	Model 2	Model 3	Model 4
Total effect	0.998	0.28	0.80	0.96
Direct effect	0.64	0.09	0.23	0.72
Total mediated effect	0.06	0.06	0.06	0.05
Self-efficacy	0.06	0.07	0.06	0.0004
Asthma knowledge	0.02	0.04	0.003	0.06

Note. The total effect is the effect of health literacy on asthma outcomes. The direct effect is the effect of health literacy on asthma outcomes when accounting for self-efficacy and asthma knowledge. The total mediated effect is the combination of self-efficacy and asthma knowledge as mediators. Self-efficacy is the mediating effect of self-efficacy alone. Asthma knowledge is the mediating effect of asthma knowledge alone.

Discussion

This study found that low print literacy was associated with decreased self-efficacy, but was not associated with decreased asthma knowledge, quality of life, or an increased number emergency department visits or hospitalizations. Conversely, low numeracy was associated with decreased quality of life, asthma control, asthma knowledge, and an increased number of asthma-related hospitalizations. The findings of this study partially

support our hypotheses. Limited numeracy but not low print literacy was associated with poorer asthma outcomes. Additionally, self-efficacy and asthma knowledge only partially mediated the association between numeracy and asthma related quality of life.

The lack of association between print literacy and asthma outcomes is inconsistent with previous literature (Apter et al., 2006; Gazmararian, Williams, Peel, & Baker, 2003; Manusco & Rincon, 2006; Williams, Baker, Honig, Lee, & Nowlan, 1998) and reasons for the lack of association are unclear and merit further investigation. However, the present study supports previous findings of Williams et al. (1998) that low print literacy is associated with decreased self-efficacy.

Apter et al. (2013) found that after adjusting for age, sex, and race, high numeracy was associated with better asthma related quality of life, and high print literacy was associated with better asthma control and asthma related quality of life. While we found no association between print literacy and asthma control and quality of life, we did observe an association between high numeracy and quality of life as well. The findings of this study provide further evidence for the independent association of numeracy on asthma outcomes (Apter et al., 2006; Apter et al., 2009, Apter et al., 2013).

Apter et al. (2009) examined the relationship between numeracy and quality of life and found that self-efficacy partially mediated the relationship. In addition, Osborn et al. (2010) found that self-efficacy mediated the relationship between glycemic control and numeracy and health literacy skills, but numeracy had a stronger association with self-efficacy than health literacy. The current study found that numeracy was associated with asthma-related quality of life but not asthma control, and this relationship was partially mediated by self-efficacy and asthma knowledge. These findings support the previous literature showing that self-efficacy does partially mediate the relationship between numeracy and health outcomes. It is unclear why numeracy but not print literacy was associated with asthma outcomes. The greater impact of numeracy on asthma outcomes may also be related to how print literacy and numeracy were measured in this study.

Numeracy was measured using the NVS. The NVS is a more objective analysis than the single item print literacy screening question, and may have represented objective literacy; whereas, the print literacy measurement was a subjective assessment. Differences in associations with outcomes may in reality be differences between objective health literacy versus subjective health literacy. The quantitative burden of managing asthma should be assessed to better determine how numeracy affects asthma outcomes, and if it indeed it is more important for asthma self-management than print literacy.

Conclusions/Key Findings

While self-efficacy and asthma knowledge are important for disease management, findings from this study do not suggest increasing self-efficacy and asthma knowledge as primary intervention points for low health literacy interventions. African-Americans are more likely to have low health literacy and have greater difficulty communicating with their providers. The high prevalence of low health literacy among patients in this study should serve as a reminder to health care providers to use plain language during medical encounters, encourage patients to ask questions, and make sure that patients understand their treatment plans before they leave the office. It is important to note that this study presented health literacy from the individual perspective, yet health literacy skills are utilized within a social context that is influenced by larger structures. Health literacy is one of many factors that effects asthma outcomes. Environment, access to care, and other social determinants of health independently influence health outcomes as well as health literacy.

International Implications

The majority of published health literacy research has come from the United States (Pleasant, 2013). Therefore, it is difficult to apply these results to other countries, particularly in countries where the health literacy levels of the population are unknown. Health literacy is a function of not only individual capacity but of the demands that the health system places on consumers. This study serves as an example of research that can be conducted to develop conceptual models of health literacy, and exploratory studies of health literacy in various countries with diverse populations to move the field of health literacy research forward.

Limitations

Limitations of this study include the sample size, power, and the cross-sectional design. The participants were 99 urban, African-Americans living in the southeastern United States. Generalizations to other racial/ethnic groups, all African-Americans, and other regions of the country should be made with caution. Secondly, the study may have had low power to detect a second mediated effect. The estimates from the Monte Carlo approach power analysis were much lower than simulation study estimates previously reported by Briggs (2006). For multiple mediator models with a sample size of 100, power to detect the total indirect effect ranged from 0.825-0.958. Power to detect the first indirect effect ranged from 0917-0.9537, and power to detect a second indirect effect ranged from 0.171-0.532. Briggs (2006) simulated multiple populations with varying path coefficients and found that the BCa confidence intervals were the most powerful. It is unclear why the Monte Carlo results were significantly lower than the estimates by Briggs (2006). In addition to low power, the tools used to measure the mediating effects (i.e. ASE, AQLQ-S) had low coefficients and may have contributed to the low power to detect a mediating effect as well.

This study used a cross-sectional design. Health literacy, self-efficacy, and knowledge change over time, and a cross-sectional analysis captures only a snapshot in time. The results of this study have no bearing on the association between the observed variables over time. Also, mediation analysis is only testing associations

between variables. Therefore, the results do not implicate a causal relationship between health literacy and asthma outcomes.

Lastly, the high prevalence of low health literacy coupled with the use of self-administered questionnaires may have been problematic. Participants may not have understood the questions they were being asked or may have misinterpreted questions. However, a researcher was always present to help participants complete the questionnaires.

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Declaration of Interest

All ethical local regulations have been fully accomplished and this manuscript has not been submitted to another journal.

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