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Linking Numeracy and Asthma-related Quality of Life

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Abstract

Objective—To examine the correlation of numerical skills used in patients' self-management of asthma with asthma-related quality of life (AQOL).

Methods—Adults with moderate-severe asthma completed the Asthma Numeracy Questionnaire (ANQ), assessments of reading comprehension and self-efficacy, and the mini-Asthma Quality of Life Questionnaire (miniAQLQ). The numeracy-AQOL relationship was evaluated in the context of potential confounders (demographic variables) and mediators (e.g. income and self-efficacy), using tests of correlation then multivariable models to assess for confounders and mediators.

Results—80 adults with moderate or severe asthma were evaluated. Mean ANQ score was 2.3 ± 1.2 (range 0–4). ANQ was correlated with miniAQLQ ($\rho=0.24$, $p=0.03$). This association associated with AQOL (age, Latino ethnicity). The ANQ-miniAQLQ association was mediated by household income; the correlation was reduced by 81% when adjusting for income ($\rho=0.05$, $p=0.65$). In contrast, self-efficacy less strongly mediated this association; the correlation was reduced by 26% when controlled for self-efficacy ($\rho=0.20$, $p=0.80$).

Conclusion—Numerical skills needed for asthma self-management influence AQOL primarily through their impact on income and, to a lesser extent, on self-efficacy.

Practice Implications—Adults with asthma will benefit from self-management instructions employing the simplest mathematical constructs whose understanding is confirmed by clinicians.

Keywords

asthma; health literacy; numeracy; self-efficacy; quality of life; health disparity

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1. Introduction

The ability of patients to self-manage chronic diseases like asthma should be reflected in their quality of life.¹ Poor reading skill in the health context, one element of health literacy, is associated with less successful self-management of chronic diseases including asthma.^{1, 2} A less well-studied component of general and health literacy which also contributes to self-care is numeracy. Numeracy encompasses the numerical knowledge needed to understand and act upon directions and recommendations given by health care providers.³⁻⁶ This numerical knowledge includes skills such as arithmetic and use of percentage as well as higher-level concepts like estimation, problem-solving, error in measurement, probability, and risk--concepts used in asthma management.^{5, 7-11} Unfortunately, low numeracy is prevalent in the United States; 22% of American adults possess no more than the most simple and concrete quantitative skills and another 33% have only basic quantitative skills.^{12, 13} The impact of such low numeracy on quality of life in asthmatic patients has not yet been evaluated. What is certain, though, is that low literacy is associated with poorer health and contributes to health disparities, in general;^{2, 14, 15} and poor reading comprehension is associated with poorer quality of life in asthmatic adults.¹⁶

Recently, we validated and administered a brief questionnaire derived from numerical concepts advocated in national guidelines for the management of asthma⁹⁻¹¹ and discovered that asthmatic adults with low numeracy, but not necessarily poor reading comprehension, were more likely to have had a hospitalization or an ED visit for asthma.⁸ This suggested that facility with numerical concepts could influence the ability to self-manage asthma. We also previously found that asthma-related quality of life (AQOL) was lower in African Americans, Latinos, those with low household income, and those with less formal education.¹⁷ Socio-demographic factors were highly correlated with each other and the mechanisms potentially linking socio-demographics and health outcomes were not clear. Despite the results from our numeracy questionnaire suggesting an association between numeracy and asthma health status, the possible linkages between numeracy and a variety of socio-demographic factors made the evaluation of this previous study difficult. Therefore, in the present study we set out to achieve a better understanding of the mechanisms by which low numeracy could lead to poorer health outcomes in asthma.

Poor numerical skills are likely to influence AQOL through multiple pathways as depicted in our conceptual framework in Figure 1. For the current analysis we focus on assessing the contribution of two potential mediators of a link between low numeracy and AQOL: 1) self-efficacy for asthma management and 2) income. Specifically we postulate that poor numerical skills are associated with a lower asthma-related quality of life and that self-efficacy and income contribute to this association through mediation. Limited self-efficacy has been associated with lower asthma-related quality of life.¹⁸ We hypothesize that income is also a mediator of AQOL rather than simply a confounder whose effects should be controlled, because we conceptualize low numeracy limiting earning power (household income), thus reducing AQOL. We also hypothesize that poor numeracy limits the ability to understand self-management concepts, obtain health-care, pay for medications, etc.

2. Methods

2.1. Sample

Participants were recruited from practices serving urban low-income adults living in neighborhoods with high rates of asthma morbidity. These adults were beginning a randomized controlled trial of a behavioral intervention to maintain or improve medication adherence to an inhaled steroid regimen. This cross-sectional study presents baseline data prior to randomization.

Adults with moderate or severe asthma^{9, 10} who were prescribed an inhaled steroid were recruited from urban Philadelphia practices of the University of Pennsylvania Health System, Philadelphia Veterans Administration Medical Center, Woodland Avenue Health Center, and the Comprehensive Health Center at Episcopal Hospital. These practices provide either primary or asthma specialty care. All patients with currently scheduled appointments in these participating practices were screened for eligibility; and if found to be eligible, they were asked to participate. Adults were eligible if their record indicated asthma in the problem list or physician notes and if they had a current prescription for an inhaled steroid. Also required was evidence of reversible airways obstruction: an FEV1 percent predicted (FEV1ppd) less than 80% and either an increase in FEV1 of 200 ml and at least 12% after administration of a bronchodilator or of 200 ml and 15% with asthma treatment over the last 3 years.⁹

2.2 Procedures

Approval for this research was obtained from the Institutional Review Boards of the University of Pennsylvania and the Philadelphia Veterans Administration Medical Center. After providing informed consent, participants were interviewed to determine socio-demographics, asthma history, health literacy, self-efficacy, and quality of life. Spirometry was performed according to standard procedures.¹⁹

2.3 Health literacy

Specific numerical skills used in asthma self-management were assessed with the Asthma Numeracy Questionnaire (ANQ), a 4-item questionnaire of numerical concepts (arithmetic and percentage) adapted from standard asthma education (Figure 2).⁸ The 4th question represents a more complicated percentage concept that patients may be expected to understand and was included to enhance the discriminatory power of the tool. The ANQ is read aloud to participants who view a written copy, thus making reading comprehension unnecessary. The ANQ is available in English and Spanish and was administered in participants' primary language. The score is the number correct and ranges from 0 to 4.

Reading ability was tested using a general test, the Short Test of Functional Health Literacy in Adults (S-TOFHLA).²⁰ S-TOFHLA was chosen for comparison with the ANQ because of its brevity (Takers are timed for 7 minutes.), frequency of use, and availability in English and Spanish. The raw score of the S-TOFHLA is the sum of correct responses and ranges from 0 to 36. This score is categorized to obtain a Functional Health Literacy Level: inadequate (raw score ≤ 16), marginal (raw score of 17 to 22), and adequate (raw score of 23–36).^{20, 21}

2.4 Quality of life

Disease-specific quality of life was measured using the Mini-Asthma Quality of Life Questionnaire (MiniAQLQ).^{22, 23} Items were read to the participant while the participant looked at the written questionnaire. The 15-items of MiniAQLQ are each scored on a scale ranging from 1 (maximum impairment) to 7 (no impairment). The mean of the 15 responses is the score for the overall questionnaire and also for each of its domains. There are 4 domains: symptoms, activity limitations, emotional function, and environmental stimuli.

We administered the SF-12, a 12-item generic survey, derived from the SF-36.²⁴⁻²⁶ The SF-12 provides physical (PCS) and mental component summary (MCS) scores.

2.5 Self-efficacy

Self-efficacy, a concept formulated by Bandura,²⁷⁻²⁹ refers to a person's confidence that the behaviors required in a particular situation can be accomplished. Self-efficacy is a specific rather than a global characteristic of the individual and needs to be conceptualized and

measured *in terms of* the specific barriers that prevent accomplishment of the behavior.²⁷⁻³⁰ This 14-item 5-point Likert scale questionnaire (See Appendix), developed because no other relevant validated tools were available, addresses specific situational barriers to taking inhaled corticosteroids, an essential activity for self-management of all but the mildest asthma.³¹ Initial validation of a 12-item version showed good content validity and consistency.^{32, 33} Subsequently, two related items were added, at the suggestion of Cynthia S. Rand, PhD, and the 14-item questionnaire was found to have an alpha of 0.81.³¹ Because the questionnaire score correlated well with electronically measured adherence ($\rho=0.34$, $p=0.004$), this questionnaire was thought to reflect the strength of patient understanding of self-management as provided by patient-clinician communication.³¹ The score is the sum of items, with higher score indicating greater-self-efficacy.

2.6 Data analysis

Descriptive statistics were obtained on all variables using STATA 9.0 (Stata Corporation, College Station, Tex). Univariable correlation models, using nonparametric tests, assessed the literacy-quality of life association in the context of a set of potential confounders and mediators. Confounders (demographic variables) were defined to be variables that conceptually impacted both numeracy and quality of life. Mediators were considered to be variables conceptually influenced by numeracy but still impacting on quality of life, e.g. household income and self-efficacy. The primary exposure or treatment variables were literacy variables (Figure 1).

We based our analyses on Spearman Correlations due to the lack of normality of the outcomes. Because our analyses were based on correlations, we chose the following strategy from MacKinnon et al^{34, 35} for each confounder and then each mediator.³⁶ The identification of confounders involved the assessment of the pairwise relationships among the miniAQLQ, numeracy scores, and the confounder. We followed the same strategy for selecting the mediators, but also adjusting all mediation correlations for the selected confounders. If the resulting AQLQ-numeracy correlation adjusting for both the significant confounders and mediators was not significant and was 15% less than the AQLQ-numeracy correlation adjusting for the significant confounders only, we concluded mediation was demonstrated.

We repeated this analysis testing the association of MiniAQLQ with reading comprehension (S-TOFHLA) instead of ANQ. As a sensitivity analyses we examined the correlation of ANQ and S-TOFHLA with SF-12 results. We expected ANQ, which involves specific numerical concepts related to asthma management would not be related to SF-12 components although the general assessment of reading comprehension might.

3. Results

Eighty participants were mostly African American, female, and living in households with low incomes (Table 1). In the 12 months prior to assessment, almost half had an ED visit and more than a quarter had been hospitalized for asthma. Mean miniAQLQ score was lower and more variable than in the population of symptomatic asthmatics in which this measure was validated (4.0 ± 1.4 , compared with 5.4 ± 0.8) (Table 2).²²

Both literacy measures revealed suboptimal scores among the participants. With respect to the ANQ, 7 participants (8.8%) did not respond to any of the items correctly and only 16 (20%) answered all 4 items correctly. The mean S-TOFHLA score was only in the middle of the adequate range (Table 2).

On univariable analysis numeracy was associated with asthma-specific quality of life ($\rho=0.24$, $p=0.03$). Of the domains of the miniAQLQ, this relationship was most significant for activity limitation. Univariable associations of potential confounders and mediators found Latino

ethnicity, educational attainment, household income, and self-efficacy associated with miniAQLQ (Table 3).

The association between miniAQLQ and ANQ was sustained ($p=0.27$, $p=0.02$) when controlling for potential confounders significantly associated with asthma-related quality of life (age and Latino ethnicity). Adjusting for numeracy reduced the association of Latino ethnicity 6% ($p=-0.29$, $p=0.0009$), income 17% ($p=0.34$, $p=0.002$), and self-efficacy 10% ($p=0.27$, $p=0.02$) (Tables 3 and 4). Furthermore, the ANQ-miniAQLQ association was clearly mediated by household income with an 81% reduction in the correlation when adjusting for income ($p=0.05$, $p=0.66$), but only partially mediated by self-efficacy with a 26% reduction in the correlation when controlling for self-efficacy ($p=0.20$, $p=0.08$) (Table 5).

On univariable analysis S-TOFHLA was not associated with asthma specific quality of life ($p=0.13$). Neither ANQ nor S-TOFHLA functional health literacy level were correlated with PCS or MCS ($p>0.11$).

4. Discussion and Conclusion

4.1. Discussion

Low numerical skills specific to a health-related task, self-management of asthma, were associated with reduced health-specific quality of life in this population of mostly poor, minority patients with high asthma morbidity. As expected, numeracy was most closely associated with the activities and symptom domains of the quality of life measure, further supporting the overall finding. Such associations were sustained with the adjustment for potential confounders of quality of life including race and age. In addition, these associations were accounted for in part by the mediating factors self-efficacy and family income (See Figure 1).

Adjusting for numeracy reduced the associations of Latino ethnicity, lower household income, and lower self-efficacy with lower quality of life. This indicates that health disparities are linked to numeracy and, could arise at least in part from limited formal educational opportunities frequently faced by vulnerable populations. For clinicians, our findings indicate the need to ensure patients' comprehension of numeracy concepts used in their medical care.

Although numerical skills can be difficult to separate from reading skills, this analysis is noteworthy in that it suggests numeracy is important and distinct from reading comprehension. The ANQ was read to participants in their primary language and thus, while understanding of the ANQ required aural literacy, it did not require reading comprehension. The S-TOFHLA did not offer a wide range of scores and 4 participants were unable to take it.

The relationship with quality of life and educational attainment has been previously described.¹⁷ The identification of specific mechanisms by which poor educational attainment, such as low numeracy, leads to poorer quality of life can aid in devising improved care interventions. The current analysis supports the concept of health literacy as a framework for understanding how poor literacy skills relate to poor health outcomes. In this framework low numerical skill in patients creates obstacles to the implementation of medical recommendations. Rather than a fixed risk factor (low educational attainment), low health literacy is potentially modifiable and its effect can be attenuated.^{3, 8} Approaches to reduce the obstacles to health created by low literacy include supplementing instructions with careful formatting of written instructions combined with oral explanations, simple graphs (e.g. bar graphs no more than 2–3 bars), pictures, or anecdotes.^{6, 37–44} Interventions for chronic disease management which make use of strategies that reduce print literacy obstacles have improved adherence and reduced the frequency of disease exacerbations in other settings. A disease management program for

patients with congestive heart failure and poor medical adherence which made use of non-text based visual aids was very effective in overcoming numerical obstacles to medical adherence.^{45, 46} It is reasonable to expect that similar approaches to asthma care will have similar benefits. In fact, a recent Cochrane review found that symptom-based action plans were as effective as those based on pulmonary function monitoring by peak flow meters which require some numeracy skill.⁴⁷

As indicated in the conceptual model (Figure 1), our results suggest the importance of literacy, especially numerical skills, acquired in formal education, as a determinant of health by influencing income, the ability to obtain a job, healthy living conditions, and access to health care. Supporting this model we also found partial mediation of the relationship between numeracy and AQOL by self-efficacy. In previous studies of patients with asthma of similar demographics and severity, we found self-efficacy associated with better adherence³¹ and also with better asthma-related quality of life,¹⁷ supporting our model. Nevertheless, our model is clearly incomplete; the causal pathway linking education to health is complex and beyond the scope of this current analysis.

Our study has several limitations. First, the sample size is relatively small. Nevertheless, a relationship between numeracy and asthma-related quality of life was observed. The small size limits somewhat the generalizability of the conclusions to patients with milder or more severe asthma, other demographics, and other diseases. Nevertheless, we were able to recruit a sample of highly vulnerable patients according to asthma severity and demographic risk factors. The two literacy measures, ANQ and S-TOFHLA, are tailored towards identifying individuals with very limited literacy. Less limited literacy may also detract from asthma quality of life, but is not measurable with the literacy tools we employed. However, populations at greatest risk for very low literacy are also those with greatest disparities in chronic diseases including asthma.^{1, 48} Another limitation is that the ANQ involves only a few of the many important numerical tasks used in conveying health information.^{5, 7-11} Nevertheless, our task was to construct a brief tool of basic relevant numerical and health-related concepts specifically used during asthma self-management, a disease with effective therapy and modifiable risk factors that reduce morbidity.³² Finally, this study is limited by its cross-sectional design so that explanatory relationships must be interpreted without the benefit of temporal associations. Despite these limitations, these findings provide important and clinically relevant information regarding the care of patients with asthma generally.

4.2. Conclusion

Numerical skills specific to asthma self-management influence AQOL through their impact on income and on self-efficacy.

4.3 Practice implications

Clinicians must be cognizant of the numerical concepts embedded in self-management instructions. Since low numeracy is widespread and is not easily recognized in patients, and when identified can be embarrassing to patients, we do not recommend screening for this characteristic. Instead, we recommend universal precautions and assume all patients have low numeracy.^{49, 50} The interventions that would benefit adults with low numeracy, e.g., clear health communication approaches, are also beneficial to communication with adults with higher numeracy. That is, for all patients, the use of the simplest mathematical constructs and streamlining information --removing unnecessary mathematical information-- is likely helpful.^{44, 51-53} Whenever possible, make use of relevant examples to illustrate the instructions and explanations.³ Discussions should be interactive and practitioners should confirm comprehension with techniques such as the “teach back” method in which the patients are asked to give the provider a summary of the key instructions.^{3, 6, 50, 52, 54, 49, 50} Framing

instructions with illustrative anecdotes, pictures, graphs, or tables --accompanied by brief, carefully formatted instructions-- is helpful.^{6, 37, 38, 55, 56}

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Appendix. Self-Efficacy and Situational Barrier Survey Questionnaire

1. I have a hard time doing what my doctor tells me to do.
2. I will remember to take all of my [ICS* name] even when my family takes lots of time.
3. I will refill my prescription so I will not run out of my [ICS name].
4. I forget to take my [ICS name] when I am feeling fine.
5. I will remember to take my [ICS name] even when I am away from home.
6. I forget to take my [ICS name] when my spirits are very low.
7. I forget to take my [ICS name] when my schedule is very, very busy.
8. My doctor's opinion means more than my friends' or family's opinion.
9. If I did not think my [ICS name] was working, I would not take it.
10. I will remember to take my [ICS name] even if I were not sure I was taking the medicine properly.
11. I will remember to take my [ICS name] as prescribed because I understand their importance.
12. I am not sure I can learn to use the inhaler correctly.
13. I have found that there is very little I can do to stop an asthma attack from getting worse.**
14. I am sure that I can take [ICS name] exactly the way my doctor said to.**

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*ICS = inhaled corticosteroid

** courtesy of Cynthia Rand, PhD

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Figure 1. Conceptual model postulating how numeracy could influence asthma-related quality of life

We hypothesize that numerical skills are associated with asthma-related quality of life and that this relationship is in part mediated by income and self-efficacy. That is, poor numerical skills limit income, educational opportunities, access to jobs with health insurance, access to low-allergen housing, and the acquisition of further numerical skills used in asthma self-management. Numerical concepts are embedded in self-management instructions, as depicted here for asthma. In our model, confounders are demographic variables that conceptually impact numeracy and quality of life. Mediators are variables conceptually influenced by numeracy and impact on quality of life.

Here are some examples of statements or questions patients might hear in a doctor's office.

1. Your doctor asks you to take 30 mg of prednisone every day for a week. The pharmacist gives you a bottle of 5 mg tablets
How many pills should you take each day?
☐☐
2. If a patient has a 1% chance of developing osteoporosis or bone loss:
that means
 - a. Out of 1000 patients, one will develop bone loss
 - b. Out of 100 patients, one will develop bone loss
 - c. Out of 10 patients, one will develop bone loss
 - d. Out of 5 patients, one will develop bone loss
 - e. The patient will develop bone loss
 - f. The patient will never develop bone loss
3. You have a peak flow meter. Your Danger or Red Zone is 50% of your best reading. Your best reading is 400 L/min.
What is your Danger Zone?
☐☐☐ L/min or less
4. You are told the Green Zone (the OK zone) is a reading between 80% and 100% of your best reading. Your Worry Zone is between 50% and 80% of your best reading. Your best reading is 400 L/min. When are your readings in the Worry Zone?
 - a. Between 300 and 400 L/min
 - b. Between 200 and 320 L/min
 - c. Between 200 and 300 L/min
 - d. Between 240 and 320 L/min
 - e. Between 100 and 300 L/min

Figure 2.
Asthma Numeracy Questionnaire

Table 1

Sociodemographics and asthma characteristics of 80 adults with moderate or severe asthma.

Demographics	
Age [*]	47 ± 13
Female	55 (69%)
Race	
Black	52 (65%)
White	15 (19%)
Other	8 (10%)
Missing	5 (6%)
Ethnicity: Hispanic/Latino	9 (11%)
Spanish as primary language	3 (4%)
High school graduate	69 (86%)
Household income < \$30,000/year	53 (66%)
Disease severity	
FEV1 ^{*†}	66 ± 17
# with at least one ED visit for asthma in past year	39 (49%)
# hospitalized in past year for asthma	21 (26%)

* mean ± standard deviation

† percent predicted

Table 2
Asthma-related quality of life, health literacy, and self-efficacy scores among 80 patients with moderate or severe asthma.

Health Literacy	
Asthma Numeracy Questionnaire*	
Overall score	2.3 ± 1.2
Number of subjects answering each item correctly:	
Item 1 (arithmetic word problem)	64 (80%)
Item 2 (simple percent, risk)	37 (46%)
Item 3 (simple percent, peak flow meter)	57 (71%)
Item 4 (interpretation of percent for peak flow meter)	29 (36%)
Short Test of Functional Health Literacy in Adults	
Raw Score*	29 ± 9
Number of patients whose literacy was**	
Inadequate (Score 0 – 16)	7 (9%)
Marginal (Score 17 – 22)	6 (8%)
Adequate (Score 23 – 36)	65 (81%)
Self-efficacy (Range: 14 – 70)	53 ± 7
MiniAQLQ	
Overall mean score*	4.0 ± 1.4
Domains	
Symptoms*	4.0 ± 1.6
Activity limitations*	4.4 ± 1.6
Emotional function*	4.0 ± 1.9
Environmental stimuli*	3.9 ± 1.6

* mean ± standard deviation

** 4 participants did not take S-TOFHLA: 2 participants declined to take the test; two additional participants were blind.

Table 3

Univariable correlations between asthma-related numeracy and potential confounders and mediators with asthma-related quality of life

Variable	Spearman correlation	
	Association ρ	p-value
Age	0.16	0.15
Sex	-0.17	0.14
Latino	-0.32	0.004
African American	-0.21	0.06
Educational attainment	0.25	0.03
Household income	0.41	0.0002
Self-efficacy	0.30	0.008
Numeracy	0.24	0.03
Association of numeracy with miniAQLQ domains		
Symptoms	0.22	0.05
Activity limitations	0.31	0.005
Emotional function	0.19	0.10
Environmental stimuli	0.17	0.12
Functional reading comprehension level	0.22	0.05

Table 4

Association between asthma-related quality of life and each potential confounder and mediator, adjusting for numeracy

Confounder	Spearman correlation	
	Association ρ	p-value
Age	0.25	0.03
Female	-0.15	0.20
Latino	-0.29	0.009
African American	-0.16	0.16
educational attainment	0.15	0.18
household income	0.34	0.002
self-efficacy	0.27	0.02