Abstract

Parent Asthma Numeracy Skill: Examining Associations with Child Asthma Outcomes and Parent Illness Representations

Introduction. Poor asthma outcomes are often due to misjudgment of asthma severity and management, the responsibility for which is often assumed by parents. The construct of asthma numeracy measures individuals' ability to use mathematics to complete activities related to asthma self-care (ex. medication dosing/adherence). This study aimed to understand the associations between parent asthma numeracy and: asthma management, asthma control, and parent asthma illness representations. **Methods.** 236 Latinx and Black children diagnosed with asthma, ages 10-17 years old, and their parents participated in this cross-sectional study. They were recruited from asthma/pediatric clinics and emergency departments within the Bronx, NY. The Asthma Numeracy Questionnaire measured parent asthma numeracy skill. Doser devices monitored child ICS adherence and Quick-Relief medication use. Self-report of asthma-related sick and ED visits indicated acute health care utilization. Child/Asthma Control Tests measured self-report of asthma control, %FEV1 indicated pulmonary function, and the Asthma Illness Representations Scale measured parent beliefs aligned with the professional model of asthma. **Results.** In unadjusted analyses parent asthma numeracy was associated with ICS Adherence (R^2_{change}=0.04, p=0.045) and ED visits (OR=0.74, 95% CI [0.59,0.93], p=0.01). In adjusted analyses parent asthma numeracy was significantly associated with parent asthma illness representations (R^2_{change}=0.05, p<0.001) but not with child ICS adherence (R^2_{change} =0.008, p = 0.83), QR use (OR=1.004, 95% CI [0.76,1.32]) ED visits (OR=0.798, 95% CI [0.63,1.02]), sick visits (OR=0.87, 95% CI [0.67,1.14]), self-reported asthma control

(OR=0.99, 95% CI [0.79,1.23]), or pulmonary function (R^2_{change}=0.0, p=0.82). Exploratory analyses revealed child age was a moderator in the relationship between parent asthma numeracy and child QR use. **Conclusion.** As hypothesized, greater parent asthma numeracy skill was significantly associated with parents having views of asthma more closely aligned with the professional model of asthma management. This study also revealed a trend regarding greater parent asthma numeracy being associated with decreased likelihood of child ED visits. These findings are unique and may be suggestive of the clinical utility of the ANQ as a screening tool for illness representations. It provides a basis for clinical interventions to address the construct of asthma numeracy with the goal of improving child asthma management and clinical outcomes.

Parent Asthma Numeracy Skill: Examining Associations with Child Asthma Outcomes and Parent Illness Representations

by

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Chapter I: Introduction

Background and Significance

Asthma is a chronic respiratory disorder characterized by airway: inflammation, obstruction, and hyper-responsiveness (Maslan & Mims, 2014). It is often referred to as an epidemic due to its steadily increasing prevalence worldwide over the past few decades (Sears, 2014). Asthma triggers lead to asthma symptoms and are fairly common; they can include exposure to allergens, exercise, chemical irritants, dust, and pollution (Vernon, Wiklund, Bell, Dale, & Chapman, 2012). Once exposed to such triggers, individuals with asthma experience symptoms such as coughing, wheezing, shortness of breath, and chest tightness. More severe symptoms are indicative of an asthma attack, which can lead to death if untreated. Asthma affects over 300 million people and contributes to over 250,000 deaths annually (Baïz & Annesi-Maesano, 2012). There has been a continued increase in pediatric asthma (Akinbami, Simon, & Rossen, 2016), with the highest prevalence in children 10-17 years old (American Lung Association, 2012). The increasing rates of asthma prevalence and morbidity, particularly in children, warrant further research within the field.

Asthma Disparities

Asthma prevalence varies by many factors, including: age, race and ethnicity, and geographic location. Though asthma is a condition that can impact individuals of any age, its prevalence in children (Ferrante & La Grutta, 2018) and ethnic minority individuals (Akinbami & Schoendorf, 2002) is steadily increasing. Racial disparities in asthma also exist, particularly between Black and White children, with the former having a higher prevalence (Akinbami et al., 2016). Latinx and Black children generally have the highest prevalence of asthma, and among Latinx populations, Puerto Ricans have the highest prevalence while

Mexicans have the lowest (Lara, Akinbami, Flores, & Morgenstern, 2006). Geographically, pediatric asthma has the highest prevalence in New York City (NYC), and specifically in the Bronx. Children in the Bronx have the highest rates of asthma related hospitalizations, emergency department (ED) visits, mortality (Garg, Karpati, Leighton, Perrin, & Shah, 2003), and exposure to risk factors (Warman, Silver, & Wood, 2009). Asthma also contributes to more emergency room visits and hospitalizations than any other condition in New York City (Corburn, Osleeb, & Porter, 2006). Disparities related to asthma prevalence warrant further research within the populations that experience asthma related consequences to a greater extent.

Asthma Management and Asthma Control

Mortality in asthma patients is often due to misjudgment of both asthma severity and asthma management (A. Johnson, Nunn, Somner, Stableforth, & Stewart, 1984). In order to manage symptoms, children with asthma are often prescribed two different types of medications: those taken as needed, such as Quick-Relief (QR) and those taken daily, such as Inhaled Corticosteroids (ICS). Increased use of QR medications is often indicative of poor asthma management, as its use suggests an increase in the frequency of asthma symptoms (Sullivan et al., 2013). In order to combat the use of QR medications, controller (ICS) medications are prescribed; these preventative medications are taken daily, regardless of the presence of asthma symptoms. Poor adherence to ICS medications is fairly common in children with asthma (Makhinova, Barner, Richards, & Rascati, 2015; Wu et al., 2015); less than 50% of prescribed doses are taken (Arcoleo et al., 2019; Walders, Kopel, Koinis-Mitchell, & McQuaid, 2005). This poor adherence contributes to asthma morbidity, which can also be defined by the increased need for QR medication use, greater Emergency

Department (ED) visits, and greater hospitalizations or health care utilization (HCU) (Arcoleo et al., 2019; Fritz & Overholser, 1989). In conjunction, rates of QR use, ICS adherence, and HCU, provide a greater framework within which to assess general asthma management.

Alternatively, asthma control can be assessed through subjective measures of self-report by children with asthma, and objective measures designed to evaluate the severity of airway inflammation (Bateman, 2001). The Asthma Control Test (ACT) is a self-report assessment which measures the presence of asthma related symptomology in individuals 12 years old and up (Liu et al., 2007), and the Childhood Asthma Control Test (C-ACT) measures this in children that are under 12 years old (Nathan et al., 2004). These measures assess the construct of subjective asthma control. Objective asthma control can be assessed through values representing pulmonary function provided after a breathing test. One such value, the percentage of Forced Expiratory Volume exhaled in 1 second (%FEV1) has been previously associated with asthma control (Banks, 2002; Fuhlbrigge et al., 2001). In conjunction, these subjective and objective measures provide data to assess general asthma control.

Asthma Numeracy

Health literacy involves the ability to interpret health-related information and make decisions based on this interpretation, in a manner that conveys appropriate understanding. Previous studies have shown that adults with lower literacy have poorer knowledge of asthma, display poorer techniques in using metered-dose-inhaler medications (Williams, Baker, Honig, Lee, & Nowlan, 1998), have poorer understanding of asthma treatments, and have lower confidence in their ability to manage their asthma (Morrison, Glick, & Yin, 2019). Lower health literacy in parents has been associated with a decreased ability to utilize asthma action plans to respond to a child's asthma exacerbation (Brigham, Goldenberg, Stolfi, Mueller, & Forbis, 2016). Lower literacy has also been associated with higher rates of emergency department visits and higher rates of hospitalizations in adults with asthma; it presents as a barrier to effective asthma management (Thai & George, 2010).

Health numeracy expands upon the concept of literacy, and encompasses an individual's ability to access, interpret, and communicate numerical or quantitative health information in order to make an effective health decision (Golbeck, Ahlers-Schmidt, Paschal, & Dismuke, 2005). Numeracy incorporates the ability to comprehend and utilize numerical information to change health behaviors, which can then influence asthma treatment and outcomes, as seen in the model (Figure 1) by Reyna, Nelson, Han, and Dieckmann (2009).

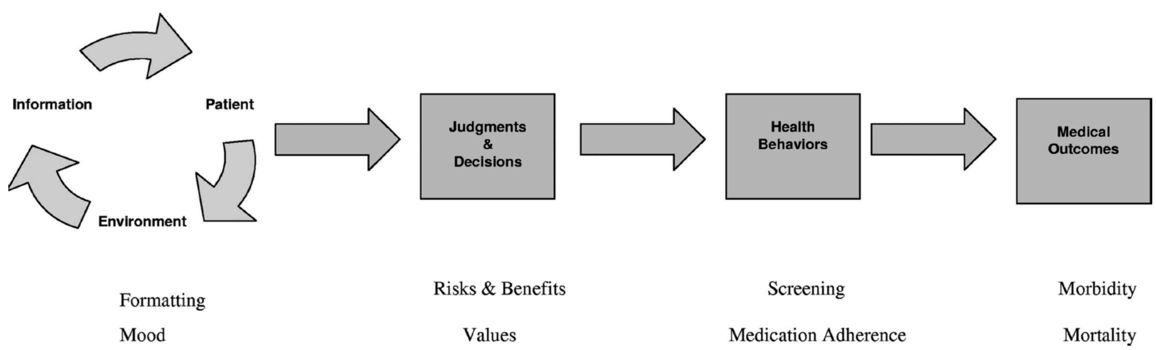


Figure 1. A causal framework for effects of numeracy on risk reduction and medical outcomes.

The latter part of the definition of numeracy entails a functional component that involves accurate processing and concurrent application of math skills in order to complete a task (Rothman, Montori, Cherrington, & Pignone, 2008). These math skills may be basic, computational, analytical, or statistical in nature, and involve the ability to understand and utilize numbers (Golbeck et al., 2005). Even adults with higher levels of education have difficulty with numeracy questionnaires (I. M. Lipkus, Samsa, & Rimer, 2001), which can become concerning for those with health conditions, since numeracy can affect decision making and behavior change related to health management (Isaac M. Lipkus & Peters, 2009).

The model by Reyna, Nelson, Han, and Dieckmann (2009) breaks down how the understanding of numerical medical information can influence health decisions. Numeracy impacts an individual's assessment of the risks and benefits of treatment options, appropriate estimation of the risk presented by the illness, and the subsequent value placed on managing the illness. These judgements then translate to an individual's health behaviors regarding management, use of health care, and treatment adherence. All of these factors then impact medical outcomes. While more research is needed regarding the long-term consequences of numeracy on illness morbidity and mortality, the model highlights the role numeracy may play in these outcomes.

Relative to asthma, numeracy can be quite important. Asthma numeracy measures individuals' ability to use mathematics in order to complete activities related to asthma self-care. This can include medication management through dosing and adherence, interpretation of quantitative data, and perception of the severity of one's asthma. Pulmonary breathing tests yield quantitative values, such as peak flow values, to express the level of asthma functioning. It is critical to interpret these values correctly, in order to identify the level of asthma control they represent. Being able to correctly identify how well controlled asthma is will influence which asthma medication is needed at that time, QR or controller. Asthma treatment also requires proficiency with arithmetic in order to administer proper doses of the necessary medications (Andrea J. Apter et al., 2006). A study of 351 Puerto Rican children diagnosed with asthma, showed that low parent asthma numeracy was associated with increased emergency department visits and increased hospitalizations in children (Rosas-Salazar et al., 2013).

In previous studies of non-asthma diseases, lower numeracy has been associated with a lower ability to comprehend and utilize health related information (Peters, Hibbard, Slovic, & Dieckmann, 2007). Relative to breast cancer management, lower levels of numeracy were associated with a poorer understanding of the risk of developing the disease and the benefits of preventative mammogram screenings (Schwartz, Woloshin, Black, & Welch, 1997). Lower health numeracy has also consistently been associated with poorer clinical outcomes for diseases such as diabetes. These outcomes include: self-reported experience of complications, self-efficacy, and decision making (Al Sayah, Majumdar, Williams, Robertson, & Johnson, 2013). Low diabetes-related numeracy has also been significantly associated with poorer diabetes control as indicated by glycemic index values (Marden et al., 2012; Osborn, Cavanaugh, Wallston, White, & Rothman, 2009).

Relative to asthma, greater asthma numeracy in adults has been associated with better asthma control, better adherence, and greater quality of life, related to their own asthma (A. J. Apter et al., 2013). In a prospective cohort study of 284 adults with moderate to severe asthma, the association between baseline asthma-related numeracy and asthma self-management, control, and quality of life were examined. Asthma numeracy was measured by the Asthma Numeracy Questionnaire (ANQ) and analyzed as a continuous variable, self-management was measured by ICS adherence via electronic devices, asthma control was measured by the Asthma Control Questionnaire, and asthma-related quality of life was measured by the Mini-Asthma Quality of Life Questionnaire. In unadjusted analyses, higher numeracy was associated with better ICS adherence, asthma control, and asthma-related quality of life, while the latter was the only variable with this association in the adjusted analyses (A. J. Apter et al., 2013). Less is known about the association between asthma numeracy in parents and asthma control and management in their children.

However, some research has been done regarding parent literacy and numeracy in relation to their child's asthma; in one study, the association between health literacy in parents and asthma control in their children over 2 years old was analyzed for 246 participants in a prospective study (Krishnan, Rohman, & Dozor, 2016). In this study, health literacy and numeracy were measured in conjunction by the Short Assessment of Health Literacy and Newest Vital Signs questionnaires. Asthma control was measured by the Asthma Control Test (ACT) or Child Asthma Control Test (C-ACT). Multivariate analyses accounted for health insurance and age. The study results indicated that parents with lower health literacy were less likely to have their children's asthma be categorized as well controlled, than parents who had health literacy scores in the normal range. Less is known about this relationship with parent asthma numeracy alone. Greater research is warranted in this area.

Asthma Illness Representations

Illness Representations refer to an individual's understanding of the nature, cause, symptoms, and treatment of an illness (Diefenbach & Leventhal, 1996). This understanding of one's illness is based on self-perception and can be understood through the five main components of the Common Sense Model (Leventhal, Brissette, & Leventhal, 2003): identity with the illness, causal beliefs regarding the illness, timeline-related beliefs regarding acuteness or chronicity of the illness, beliefs regarding the ability to control or cure the illness, and consequences of the illness on various aspects of the individual's life (Petrie &

Weinman, 2006). Illness representations are important to assess, as they can influence how an individual chooses to participate in treatment and illness management (Petrie & Weinman, 2006).

Asthma Illness Representations encompass an individual's asthma-related beliefs and can often highlight differences in the understanding of asthma between patients and health care providers (HCPs). Beliefs held by HCPs incorporate varying uses of quick-relief and controller medications based on the severity of asthma symptoms, in order to achieve optimal control for the chronic condition of asthma; this represents the professional model of asthma illness representations. The professional model of asthma views the illness as chronic and present even during times when symptoms are controlled; it stresses the importance of daily ICS use (K. Sidora-Arcoleo, Feldman, Serebrisky, & Spray, 2010a; US Department of Health and Human Services, 2011). The lay person model of asthma illness representations is often held by the patient or family and incorporates the belief that asthma is episodic, unpredictable, and not easily controlled (Yoos et al., 2007). Disparities in asthma illness representations between the professional and lay models may contribute to adverse asthma outcomes and are important to evaluate.

Parents often assume high levels of responsibility for managing their child's asthma (McQuaid et al., 2001; Yoos et al., 2007), therefore parent asthma illness representations are important to assess. Parent illness representations can be assessed through the self-report measure, the Asthma Illness Representation Scale (AIRS), which provides information regarding risks for, and barriers to, asthma medication use (K. Sidora-Arcoleo et al., 2010a). In a cross-sectional study of 228 parents of 5-12 year old children diagnosed with asthma, the impact of parent illness representation on child medication regimen was analyzed (Yoos et al., 2007). Parent beliefs were measured by the Asthma Illness Representation Scale and medication regimen was measured by a structured assessment of asthma severity and control. Results indicated that parent asthma illness representations that were congruent with the professional model of asthma, were associated with better child medication management with both quick-relief use and controller adherence (Yoos et al., 2007). However, little is known about the relationship between parent's illness representations and parent asthma numeracy.

Components of both the lay model and professional model of asthma incorporate factors which are evaluated in the construct of asthma numeracy. Numeracy incorporates the ability to comprehend and utilize numerical information to change health behaviors, which can then influence asthma treatment and outcomes (Reyna et al., 2009). Relative to asthma, this includes interpreting peak flow values, managing medications, and understanding risk factors (Andrea J. Apter et al., 2006). Those individuals whose beliefs align with the professional model of asthma may have a better understanding of numeracy and thus: the proper doses for controller medications, interpretation of asthma control based on peak flow readings, and the risk of developing medication-related side effects. This may be due to their belief that asthma is chronic yet controllable, while those who believe asthma is episodic and unpredictable (lay person model), may have difficulty with the consideration of the importance of the numbers in the above concepts.

The comprehension of health information impacts whether an individual's beliefs align with the lay or professional model of asthma, which can then influence asthma outcomes. Just as greater asthma numeracy has been associated with better asthma outcomes (A. J. Apter et al., 2013), alignment with the professional model of asthma, rather than the lay model, has been associated with better asthma outcomes in terms of greater controller medication use and lower acute health care utilization (K. Sidora-Arcoleo et al., 2010a). However, despite having similarly compelling associations with asthma outcomes, the association between parent asthma illness representations and parent asthma numeracy has not previously been examined and warrants further research.

Specific Aims and Hypotheses

The current study aimed to understand the associations between parent asthma numeracy and: asthma management, asthma control, and parent asthma illness representations. If the proposed hypotheses below are supported, new strategies and interventions for asthma management can be implemented to improve parent asthma numeracy, parent asthma illness representations, and asthma management and control in children.

Specific Aim 1: Examined the association between parent asthma numeracy skill (ANQ) and children's asthma management as measured by Inhaled Corticosteroid (ICS) adherence, quick-relief medication use, and health care utilization (sick visits, ED visits)

Hypothesis 1a: Greater parent asthma numeracy skill will be associated with greater ICS adherence

Hypothesis 1b: Greater parent asthma numeracy skill will be associated with lower quick-relief medication use

Hypothesis 1c: Greater parent asthma numeracy skill will be associated with less frequent asthma related sick visits and ED visits

Specific Aim 2: Examined the association between parent asthma numeracy skill (ANQ) and children's asthma control as measured by the Asthma Control Test (ACT/C-ACT) and pulmonary function (%FEV1)

Hypothesis 2a: Greater parent asthma numeracy skill will be associated with better asthma control.

Hypothesis 2b: Greater parent asthma numeracy skill will be associated with better pulmonary function.

Specific Aim 3: Examined the association between parent asthma numeracy skill (ANQ) and parents' illness representations about their child's asthma (AIRS)

Hypothesis 3a: Greater parent asthma numeracy skill will be associated with parents having views of asthma more closely aligned with the professional model of asthma management than the lay model.

Innovation and Significance

Parents often assume high levels of responsibility for managing their child's asthma, often greater than that of their children (McQuaid et al., 2021; McQuaid et al., 2001). Therefore, it is likely that parents' asthma numeracy is associated with their child's asthma management and asthma control. A study with a sample of 351 Puerto Rican children diagnosed with asthma, ages 6-14 years old, showed that low parent asthma numeracy was associated with increased emergency department visits and increased hospitalizations in children. Almost 30% of the parents had low numeracy, which increased the probability of ED visits by two-fold, compared to parents who did not have low asthma numeracy. The association between parent numeracy and lung functioning in this sample was not significant (Rosas-Salazar et al., 2013). The association of parent asthma numeracy and child asthma control in other populations has not been previously studied.

The association between parent asthma numeracy and other aspects of child asthma management have yet to be examined. The proposed aims attempted to provide greater knowledge regarding this relationship and to gain a greater understanding of parent illness representations. While both parent asthma illness representations and parent asthma numeracy have been associated with asthma outcomes through similar mechanisms, little is known about their association with one another; no studies to date have analyzed this relationship.

The aims of this study will add to the understanding of the association between parent asthma numeracy, asthma management, asthma control, and asthma illness representations. If the aims are achieved, they will further elucidate the impact of parent asthma numeracy on factors such as ICS medication adherence, QR medication use, HCU, objective asthma control, and a child's perceived asthma control. This is true for the target population of the study, the populations that are most commonly impacted by chronic asthma: Black and Latinx children in the Bronx. If the hypotheses are confirmed, new strategies and interventions for asthma management can be implemented to improve parent asthma numeracy, with the goal of improving asthma management and control in children and reframing asthma illness representations in parents. This can include addition of brief measures for assessing parent understanding of asthma and asthma medication doses, brief psychoeducation on quantitative information involved in asthma understanding, and assessment of level of responsibility for asthma management done during medical appointments. These changes may address the increasing asthma prevalence and morbidity in the most commonly affected populations.

Chapter II: Methods

Overview of Design

This study extracted data and outcome measures from Dr. Jonathan Feldman's R01-funded Childhood Asthma Perception Study (CAPS; R01:HL128260-01), in order to analyze the relationship between parent asthma numeracy and child asthma management (Specific Aim 1), parent asthma numeracy and child asthma control (Specific Aim 2), and parent asthma numeracy and parent asthma illness representations (Specific Aim 3) in Latinx and Black children ages 10-17 years old from the Bronx, NY. The parent study, CAPS, is ongoing and was approved by the Albert Einstein College of Medicine Institutional Review Board (IRB).

CAPS is a longitudinal RCT analyzing the efficacy of an intervention introduced at the second of its nine total sessions: baseline, randomization, mid-treatment, post-treatment, 1-month-follow-up, 3-month-follow-up, 6-month-follow-up, 9-month-follow-up, and 12-month-follow-up. The intervention involves psychoeducation, problem solving skills, and motivational interviewing with the goal of improving asthma symptom perception. The secondary analyses in the current study were conducted with data from the baseline and randomization sessions of the larger parent study, CAPS. This current cross-sectional study proposed analyzing data solely from the baseline and randomization sessions, before the parent study treatment is administered; no intervention effects are expected during this time frame. The time frame between the baseline and randomization sessions was at least 4 weeks. A cross-sectional design was best suited for this study.

General Procedures

The ANQ was administered at the randomization session. Devices to monitor QR use and ICS adherence were distributed at the baseline session, and these data were downloaded for the first time at the randomization session. HCU was measured by self-report of asthma-related sick visits and ED visits within the past year, at the baseline session. The ACT, C-ACT, and AIRS were administered, and %FEV1 was assessed, at the baseline session as well. Table 1 provides a summary of the time points at which data were collected.

Participant Population

Latinx and Black children, ages 10-17 years old were recruited for the study, with a parent or guardian; the two comprised a dyad for the duration of the study. The target sample size for CAPS was 260 dyads. For this study, data were collected for participants recruited by January 31st, 2020.

Inclusion Criteria

Children were 10-17 years old and must have been diagnosed with asthma by a health care provider (this was verified by Medical Chart Reviews), reported having breathing problems within the last 12 months, been prescribed a controller medication for their asthma within the past 12 months, have a parent who have self-reported Black or Latinx ethnicity, have self-reported Black or Latinx ethnicity, speak English or Spanish, and completed at least one outcome measure for asthma management and asthma control. The parents of these children must have completed the ANQ.

Exclusion Criteria

Participants were deemed ineligible if: parent reported significant cognitive disabilities during initial screening, the parent reported that child had a significant cognitive disability that would interfere with study participation, the child was unable to understand study procedures at baseline, the child was managing other severe respiratory concerns, child participated in an interventional asthma study within the last 12 months.

Clinical Sites and Setting

Participants were enrolled from primary and tertiary health care centers in the Bronx (NY). The recruitment sites included asthma clinics, pediatric clinics, and emergency departments within Jacobi Medical Center and Montefiore Medical Center. The Bronx consists of the highest rates of pediatric asthma in the nation as well as large Latinx and Black populations (Warman et al., 2009), making this city the ideal setting to recruit the current sample.

Recruitment, Screening, Incentives

Individuals were screened for eligibility at aforementioned clinical sites by trained research assistants and staff who completed an Eligibility Questionnaire, in either English or Spanish, with individuals interested in the study. The questionnaire was designed to account for inclusion and exclusion criteria and helped clarify eligibility. Recruitment was also conducted via phone calls. Physicians participating in the study signed letters which were mailed to their patients; the letters included study flyers with CAPS inclusion and exclusion criteria and study overview. Two-weeks after mailing out the letters, research assistants and staff called the patients to discuss their interest in participating in the study. Interested individuals were offered a financial incentive of $340 should they complete the entire study, with varying monetary amounts for each session. Relative to this study, the financial incentive was $40 ($30 for baseline and $10 for randomization). Demographic data were collected prior to enrollment, via the Eligibility Screening Form (ESF).

Informed Consent Procedure

During the Recruitment process informed consents, approved by the IRB, were signed to ensure proper explanation of study procedures and to allow the interested participants to share their medical information. At clinics, study staff distributed a written informed consent/assent, release of medical information form, and HIPAA authorization form to interested participants. Consent forms were signed by all parents and children 13 years or older and assent forms were signed by children under 13 years old. For phone recruitment, an oral consent with this information was read by the study staff and verbally agreed to by interested participants. After this initial recruitment, potential participants arrived to the baseline session, received an in-depth overview of the study, and were asked to sign the full written informed consent and assent documents to solidify their interest in participating in the study. In the consent documents, participants were informed that they were able to stop answering questions or drop out of the study at any time, and that their care would not be influenced by their decision to either enroll or drop out. Participants were provided with copies of these forms for their personal records should they have any questions.

Ethics

The parent study, CAPS, obtained and maintained approval from the Institutional Review Board of Albert Einstein College of Medicine, and is currently active. While the study involves working with children, a vulnerable population, all safety factors have been considered. During the Recruitment process informed consents and assents were signed by all participants to ensure proper explanation of study procedures and allow the interested participants to share their medical information.

Data Management

Patient confidentiality was ensured by assigning unique study identification numbers at baseline and utilizing those numbers to record data at all sessions. Physical data forms, such as for informed consent, were stored in locked cabinets. Virtual data were gathered from the Medialab computer software program which was used by study staff to administer questionnaires to participants. This was stored in private study folders on the Albert Einstein College of Medicine virtual private network (VPN). The virtual data were locked with passwords, with access only for study staff, and were backed up daily and reviewed by Dr. Jonathan Feldman. There were no breaches of confidentiality.

Measures

Demographics

Demographic information was collected through self-report on the Eligibility Screening Form that was distributed prior to participant enrollment. This questionnaire provided information on parent and child age, gender, and ethnicity, parent education, and household income.

Table 1. Primary and Secondary Measures

Measures	Construct	Completed by	Administration Timepoint
Primary			
Asthma Numeracy Questionnaire (ANQ)	Asthma Numeracy Skill	Parent	Randomization
Secondary			
Inhaled corticosteroid (ICS) Adherence	Asthma management: Adherence	Child	Randomization
Quick Relief (QR) Medication Use	Asthma management: QR Use	Child	Randomization
#Asthma related sick visits	Asthma management: Health Care Utilization (HCU) in past 12mos	Together*	Baseline
#ED visits	Asthma management: Health Care Utilization (HCU) in past 12mos	Together*	Baseline
Asthma Control Test and Child-Asthma control Test (ACT, C-ACT)	Asthma control: Subjective/Self-reported asthma control	Parent, Together*	Baseline
% Forced expiratory volume in 1 second (%FEV1)	Asthma control: objective Asthma control/pulmonary function	Child	Baseline
Asthma Illness Representations Scale (AIRS)	Asthma illness representations	Parent	Baseline

**Note: Together indicates that parent and child both worked together to complete this measure*

Parent Asthma Numeracy

The Asthma Numeracy Questionnaire (ANQ) was used to assess numeracy in adults (Andrea J. Apter et al., 2006). This brief, 4-item measure targeted the assessment of numeracy skills that are common to asthma management The ANQ asks participants to: conduct basic arithmetic to compute how many pills should be taken in a medication adherence scenario (one item), assess the risk of developing an illness through interpretation of statistics (one item), and assess appropriate symptom management through percentage calculations (two items). Please see Appendix A for this measure.

The ANQ offers both text and multiple-choice answer options, with scoring of 1 point for each correct answer and 0 points for each incorrect answer, for a total score range of 0-4. Greater scores indicate greater asthma numeracy. The ANQ has been validated in both English and Spanish (Andrea J. Apter et al., 2006). The measure's content validity was established based on asthma management guidelines from the National Asthma Education and Prevention Program (NAEPP). Convergent validity was established by comparing scores on the ANQ to established measures of functional health literacy (STOFHLA: Short Test of Functional Health Literacy; REALM: Rapid Estimate of Adult Literacy in Medicine). The ANQ's internal consistency and reliability were measured using Cronbach's alpha; the ANQ has moderate internal consistency ($\alpha = 0.57$) (Andrea J. Apter et al., 2006) for an adult population. The ANQ was administered at the randomization session in the appropriate language (English or Spanish).

Asthma Management

Controller and ICS Adherence. Adherence to controller or ICS medications was recorded objectively at the randomization session. At baseline, the participant's ICS medication was collected and fitted with appropriate devices to record adherence information. All Metered Dose Inhalers (MDI) were fitted into a SmartInhaler cartridge or doser device. Dosers are electronic devices which record the frequency of medication use in the past 30 days and Doser CT devices record these data for 45 days (Meditrack, Massachusetts, USA); these devices are considered to be more reliable for objectively monitoring medication use than self-report measures or pharmacy records (Jentzsch, Camargos, Colosimo, & Bousquet, 2009). SmartInhaler cartridges were used when doser devices would not fit on an MDI. They kept track of how often the child was using the medication and transferred this information to an online program for easy access by study staff. The cartridge lasted the duration of the study since it can store over 6,000 data points (Burgess, Wilson, Cooper, Sly, & Devadason, 2006). Doser and SmartInhaler data were combined. Data were processed as per standard cleaning procedures for adherence (Feldman et al., 2012), after which adherence was calculated as a percentage; this was the number of total doses taken by a child per day, divided by the number of prescribed doses for the child, times 100. Adherence was truncated down to 100% for instances in which children used their devices more than was recommended. For the purpose of this study, the results from the randomization session were used.

QR Medication Use. The use of QR medication was recorded objectively at the randomization session. At baseline, the participant's QR medication was collected and fitted with appropriate devices to record information pertaining to its use. All Metered Dose Inhalers (MDI) for QR medication were fitted with a Doser Device. This device recorded the frequency, per day, of a child's use of the medication. The Doser Device records data for a 30-day period and the Doser CT records data for a 45-day period; these devices were used based on availability. Days between baseline and randomization sessions (when these data were collected) varied for participants based on appointment dates. The assessment period for these analyses was dependent on the number of days doser data were available and recorded; all data points were used for the analyses. Overall QR use was calculated by the percent frequency of use by each participant. To calculate this value, study staff cleaned the data by determining the number of days each participant used the QR medication one or more times, dividing this by the number of days doser data was available for that session, and calculating this into a percent value. If the QR medication was used twice or more per week, which is more than 28.6%, based on NHLBI guidelines (NHLBI, 2007) this would indicate poorly controlled asthma. If a participant used their QR medication on 3 days of a 21-day time period, their frequency of use would be 3/21 or 14.3%, which would indicate well controlled asthma since this value is less than 28.6% use. This information was recorded in a doser database.

Health Care Utilization. HCU was defined as sick visits and emergency department visits related to asthma. This information was self-reported by the participants at baseline. To calculate the HCU for a participant, the frequency of sick visits and emergency department visits related to asthma within the past 12 months, was calculated individually (#sick visits in past 12mos; #ED visits in the past 12mos). The two measures were analyzed separately.

Asthma Control

Child Asthma Control. The Asthma Control Test (ACT) (Nathan et al., 2004) and Childhood-Asthma Control Test (C-ACT) (Liu et al., 2007) were used to measure if a child had poorly controlled or well controlled asthma. The ACT is a 5-item, self-report assessment which measures the presence of asthma related symptomology in individuals 12 years old and up. The C-ACT measures this construct in children that are 5-11 years old, through a 7-item measure that incorporates 4 responses from the child and 3 responses from both the parent and child. Both the ACT and C-ACT assess the role of asthma on a child's activities, symptom frequency, and sleep (Liu et al., 2007). The overall total score for the ACT and C-ACT was calculated for each participant. Higher scores on the measures were indicative of better control while lower scores were indicative or poor control. Scaled scores range from 0-

27 and a total score under 19 indicates poor asthma control (Liu et al., 2007). Scores were then divided based on this clinical cut-off and asthma was categorized as either well controlled or poorly controlled, for each participant. The ACT has good internal-consistency in patients with varying levels of asthma control ($\alpha = 0.84$) (Nathan et al., 2004) and the ACT and C-ACT are both reliable and valid in English (Liu et al., 2007; Nathan et al., 2004; Schatz et al., 2006) and Spanish (Vega et al., 2007). These measures were administered at the baseline session in the appropriate language (English or Spanish).

Pulmonary Function. Spirometry testing provided an objective measure of lung function and was conducted at the baseline session by trained study staff who adhered to ATS standards, which include race-specific correction values from the National Health and Nutrition Survey (NHANES III) (ATS, 1995), and used the KOKO program (Fuhlbrigge et al., 2001). At the end of appropriate administration of this breathing test, at least three forced expiratory breaths were recorded, which allowed the KOKO spirometer to calculate the percentage of Forced Expiratory Volume exhaled in 1 second (%FEV1). A higher %FEV1 value is associated with greater asthma control (Banks, 2002).

Parent Asthma Illness Representations

The Asthma Illness Representation Scale (AIRS) was used to measure parent asthma illness beliefs, and whether they were associated with the lay model or professional model (K. Sidora-Arcoleo et al., 2010a). The AIRS is a 37-item measure with five subscales assessing: knowledge of symptoms, facts about asthma, attitude towards medication use, emotional aspects of medication use, and treatment expectations. Scoring is conducted on a five-point Likert scale ranging from 1-strongly agree to 5-strongly disagree. Total scores were used for this measure; greater total scores indicate closer alignment with the professional model, rather than the lay model of asthma management. The measure has acceptable internal consistency (α = 0.82) in English and has been validated in both English (K. Sidora-Arcoleo et al., 2010a) and Spanish (K. Sidora-Arcoleo, Feldman, Serebrisky, & Spray, 2010b). The AIRS was administered at the baseline session in the appropriate language (English or Spanish).

Data Collection and Statistical Analyses

Power and Sample Size

G*Power 3.1 was used to estimate the size of the sample needed to produce accurate and reliable results. A power analysis was conducted for each aim and results indicated that the sample size needed would be 196 participants/dyads to meet the requirements for Aim 3, which requires the largest sample size.

Specific Aim 1.

Previous studies have shown that greater numeracy was associated with better adherence (p=.01) and asthma control (p=.005) in adults (A. J. Apter et al., 2013) and that lower parent numeracy was associated with increased ER and urgent care visits in children with asthma (aOR:1.7, 95% CI=1.03-2.7, p=.04) (Rosas-Salazar et al., 2013). Power analyses were conducted for this aim with medium effect size. The analysis was conducted for an F-test for linear multiple regression with fixed model, R2 from zero. The power analysis conducted was a priori to compute required sample size, given a set power and effect size. The power was set at 0.8, with a 0.05 alpha value, 2 predictors, and moderate effect size (f2=.15). The results indicated that the sample size needed would be 68 participants/dyads.

Specific Aim 2.

A previous study showed that greater numeracy was associated with better asthma control ($p=.005$) in adults (A. J. Apter et al., 2013). Power analyses were conducted for this aim using medium effect size. The analysis was conducted for an F-test for linear multiple regression with fixed model, R2 from zero. The power analysis conducted was a priori to compute required sample size, given a set power and effect size. The power was set at 0.8, with a 0.05 alpha value, 2 predictors, and moderate effect size ($f2=.15$) was chosen again to account for a previous study (Rosas-Salazar et al., 2013) indicating small to medium effect sizes based on odds ratio calculations (Chen, Cohen, & Chen, 2010). The results indicated that the sample size needed would be 68 participants/dyads.

Specific Aim 3.

The relationship between asthma numeracy and asthma illness representations has not been previously studied. However, in a study of older adults with asthma, lower health literacy was associated with the belief that asthma is episodic (OR: 1.84, 95% CI: 1.2-2.82) and can be cured (OR: 2.22, 95% CI: 1.29-3.82) (Federman et al., 2013). Lower HL was also associated with greater concern regarding medication use ($\beta = 0.92$, $p = .05$). Power analyses were conducted for this aim based on this effect size. The analysis was conducted for an F-test for linear multiple regression with fixed model, R2 from zero. The power analysis conducted was a priori to compute required sample size, given a set power and effect size. The power was set at 0.8, with a 0.05 alpha value, 2 predictors, and small effect size ($f2=.15$) was chosen. The results indicated that the sample size needed would be 196 participants/dyads.

Data Management and Preparation

The IBM SPSS Statistics 26.0 software was used to run the statistical analyses. In order to start the analyses, descriptive statistics were analyzed to provide information regarding the demographics of the participants. Means and standard deviations were calculated for parent and child age. Percent totals, per category, were calculated for parent and child gender and ethnicity, parent education, and household income. Then, frequencies and descriptive statistics were calculated for all study variables.

For the ANQ, an overall score was calculated for each participant ranging from values of 0-4, with greater values indicating greater numeracy. The ANQ was analyzed as a continuous variable, as was done in the most recent study by the authors who validated the measure (A. J. Apter et al., 2013). The study analyses focused on the association the ANQ had with the different measures reported in each hypothesis. For asthma management all three (ICS Adherence, QR medication use, HCU) variables were continuous. For asthma control, the subjective measure was categorical and dichotomous (ACT/C-ACT) and the objective measure was continuous (%FEV1). For asthma illness representations, the AIRS was also continuous, with greater scores indicating a closer alignment to the professional model. The data for each of the measures were also assessed for normality by skew and kurtosis values, and parametric testing was performed on appropriate data. Variables that were skewed and had elevated kurtosis were dichotomized.

It is important to address whether there was an additional variable (outside of the variables analyzed for each of the three hypotheses) that impacted associations. Covariate checks were performed to test associations between the outcome and demographic variables. If a variable was significantly associated with the outcome measure, it was considered a covariate. Parent-education level was tested as a potential covariate for all hypotheses since it may be associated with parent asthma numeracy (Andrea J. Apter et al., 2006; Rosas-Salazar et al., 2013) and parent asthma illness representations (K. Sidora-Arcoleo et al., 2010a). In previous studies of health conditions, greater numeracy has been associated with a greater understanding of an illness (Peters et al., 2007) and lower education level has been associated with lower health numeracy (T. V. Johnson et al., 2013). Household income was also tested as a potential covariate, as it has been associated with asthma numeracy score (Andrea J. Apter et al., 2006) and asthma illness representations aligning with the lay person model (K. Sidora-Arcoleo et al., 2010a). Demographic variables, such as parent ethnicity, child gender, and child age were also tested as potential covariates. It is important to note that parent role may be different as a function of age, as younger children tend to seek more help from their parents (McQuaid et al., 2021; McQuaid et al., 2001), the use of child age as a covariate may be warranted. The relationships between potential covariates and outcomes were analyzed to determine which variables would be covariates. Pearson correlations, Spearman's correlation, t-tests, ANOVAs, and chi-square tests were performed to assess the covariates and their significance. A hierarchical regression was used to determine if the covariates had significant predictive power. The predictor, asthma numeracy, was entered into either linear or logistic regressions, with the appropriate covariates. Additionally, hierarchical regressions were performed in exploratory analyses with the goal of assessing if there were associations with the interaction of parent asthma numeracy skill and child age on the main outcome variables. These analyses were included to account for differences with this interaction, as the age at which children are responsible for activities related to their asthma management and control varies in previous literature; some studies suggest children seek more help from parents

(McQuaid et al., 2001) while others suggest that children assume responsibility for activities such as ICS medication use in their early teenage years (Orrell-Valente, Jarlsberg, Hill, & Cabana, 2008). Exploratory analyses also included determining associations between parent asthma numeracy skill and the demographic variables.

Specific Aim 1

To examine the association between parent asthma numeracy skill (ANQ) and children's asthma management as measured by Inhaled Corticosteroid (ICS) adherence, quick-relief medication use, and health care utilization.

Hypothesis 1a: Greater parent asthma numeracy skill will be associated with greater ICS adherence. ICS adherence was measured as a percentage for participants; this was the number of total doses taken by a child per day, divided by the number of prescribed doses for the child, as determined by doser and SmartInhaler. Percent adherence, the dependent variable, is continuous so linear regressions were performed with any significant covariates at step 1 and predictor (ANQ) at step 2, with the outcome as adherence.

Hypothesis 1b: Greater parent asthma numeracy skill will be associated with lower QR medication use. QR medication use was calculated as percent frequency of QR use from baseline to randomization. As reported below, these data were asymmetrical so QR use was dichotomized based on clinical-cutoffs for frequency of use (NHLBI, 2007), as either poorly controlled or well controlled. Clinical cut-offs for QR data indicate that 2 or less days of puffs per week indicates well controlled asthma and more than 2 days of puffs per week indicates poorly controlled asthma (NHLBI, 2007). Thus the dependent variable became binary and logistic regression was performed with any significant covariates at step 1 and predictor (ANQ) at step 2, with the outcome as QR use.

Hypothesis 1c: Greater parent asthma numeracy skill will be associated with less frequent asthma related sick visits and ED visits. The frequency of sick visits and emergency department visits within the past 12 months was recorded at the baseline session. This provided a numerical value for each participant, for each of the two categories, which were analyzed separately. As reported below, the two outcomes were dichotomized, therefore two logistic regressions were performed with any significant covariates at step 1 and predictor (ANQ) at step 2, with the outcome as sick visits and ED visits. Greater parent asthma numeracy skill will be associated with less frequent asthma related sick visits and ED visits.

Specific Aim 2

To examine the association between parent asthma numeracy skill (ANQ) and children's asthma control as measured by the Asthma Control Test (ACT/C-ACT) and pulmonary function (%FEV1).

Hypothesis 2a: Greater parent asthma numeracy skill will be associated with better asthma control on the ACT/C-ACT. The total ACT/C-ACT value was recorded for each participant and the clinical cut-off score determined whether asthma was well controlled or poorly controlled; this was a binary/dichotomous variable. Since the dependent variable is dichotomous, a logistic regression was performed with any significant covariates at step 1 and predictor (ANQ) at step 2, for the outcome of subjective asthma control.

Hypothesis 2b: Greater parent asthma numeracy skill will be associated with better pulmonary function. The %FEV1 value was recorded for each participant; higher values indicate better control in this continuous variable. Since the dependent variable is continuous, hierarchical linear regression will be performed with any significant covariates at step 1 and predictor (ANQ) at step 2, with the outcome as pulmonary function.

Specific Aim 3

To examine the association between parent asthma numeracy skill (ANQ) and parents' illness representations about their child's asthma (AIRS)

Hypothesis 3a: Greater parent asthma numeracy skill will be associated with parents having views of asthma more closely aligned with the professional model of asthma than the lay model. The total AIRS score was recorded for each participant. This is a quantitative value, with a greater number representing greater alignment with the professional model. Since the dependent variable is continuous, hierarchical linear regression will be performed with any significant covariates at step 1 and predictor (ANQ) at step 2, with the outcome as asthma illness representations.

Chapter III: Results

Refusal Data

Analyses were completed to identify potential differences between individuals who were participants in the study and those who refused to participate. Refusal data for both mailing-related calls and in-person recruitment were recorded for the parent study, CAPS. Refusal data were available for 959 dyads that were screened to participate in the study. A majority of screened dyads refused to participate (64.4%). There were no significant differences in child age (t (882)= 0.48; p= 0. 61) between participants who enrolled in the study (M= 13.24, SD= 2.22) and those who refused to participate (N=13.50, SD= 2.23). There were no significant differences in child gender (χ^2=0.47, p=.49) between participants who enrolled in the study (55.9% male) and those who refused to participate (58.5% male). Screened dyads that refused to participate reported reasons of: lack of interest (68.7%), lack of time (19.4%), or other (13.9%). The other category included reasons such as psychosocial stressors or moving out of the state and having travel difficulty.

Participant Characteristics

A total of 236 parent-child dyads participated in this study. Please see Table 2 for participant characteristics. Parents were predominantly female (93.2%) and children were predominantly male (55.9%). The average age of parents was 43 years old (M= 42.69, SD= 8.05) and the average age of children was 13 years old (M= 13.24, SD= 2.22). Both parents (33.9%) and children (34.7%) predominantly identified as Puerto Rican. A majority of children at baseline had moderate-persistent asthma (45.3%). Relative to education, a majority of parents had at least a high school level of education (48.5%). For this sample, the household income was above $1000/month (64%) and most families were living below the poverty threshold (72%).

Table 2

Participant Characteristics

Variable	Total Sample (n=236)
Child Age (*M* (*SD*))	13.24 (2.22)
Parent Age (*M* (*SD*))	42.69 (8.05)
Child Gender (*N* (%))	
Female	104 (44.1)
Male	132 (55.9)
Parent Gender (*N* (%))	
Female	220 (93.2)
Male	16 (6.8)
Child Ethnicity (*N* (%))	
Puerto Rican	82 (34.7)
African American	75 (31.8)
Dominican	30 (12.7)
Other Latinx	36 (15.3)
Other	13 (5.5)
Parent Ethnicity (*N* (%))	
Puerto Rican	80 (33.9)

African American	56 (23.7)
Dominican	30 (12.7)
Other Latinx	41(17.4)
Other	29 (12.3)
Parent Education (*N* (%))	
Less than High School	67 (28.5)
High School	52 (22.0)
More than High School	62 (26.3)
College Graduate	36 (15.3)
Post-Graduate	18 (7.6)
Household Income, Complete (*N* (%))	
$500 or less/month	20 (8.5)
$501-750/month	23 (9.7)
$751-1000/month	42 (17.8)
$1001-1350/month	37 (15.7)
$1351-1500/month	16 (6.8)
$1501-2000/month	18 (7.6)
$2001-2500/month	25 (10.6)
$2501-3000/month	17 (7.2)
$3000 or more/month	38 (16.1)
Household Income, Binary (*N* (%))	
Below 1000/month	85 (36.0)
Above 1000/month	151 (64.0)

Poverty Status (*N* (%))	
Below the Poverty Line	170 (72.0)
Above the Poverty Line	66 (28.0)
Child Asthma Severity (*N* (%))	
Intermittent	14 (5.9)
Mild-persistent	40 (16.9)
Moderate-persistent	107 (45.3)
Severe-persistent	75(31.8)

*Note. "Other Latinx" category includes Mexican, Latinx Central American, Latinx South American, and "Other" category includes Jamaican, Black-Caribbean, and African.

Parent Asthma Numeracy Skill

All 236 participants completed the ANQ. A majority of parents scored a 2 on the ANQ (28.4%). Please see Figure 2 for the frequency of total ANQ scores. The mean of ANQ Total score was 1.68 (SD = 1.16). Values ranged from 0-4. The data were normally distributed since skew and kurtosis values were near 0, as seen in Table 3. The reliability for the ANQ was assessed by the Kuder Richardson 20 test due to the measure having dichotomized items (correct or incorrect) (Feldt, 1965), and was poor (KR = 0.48).

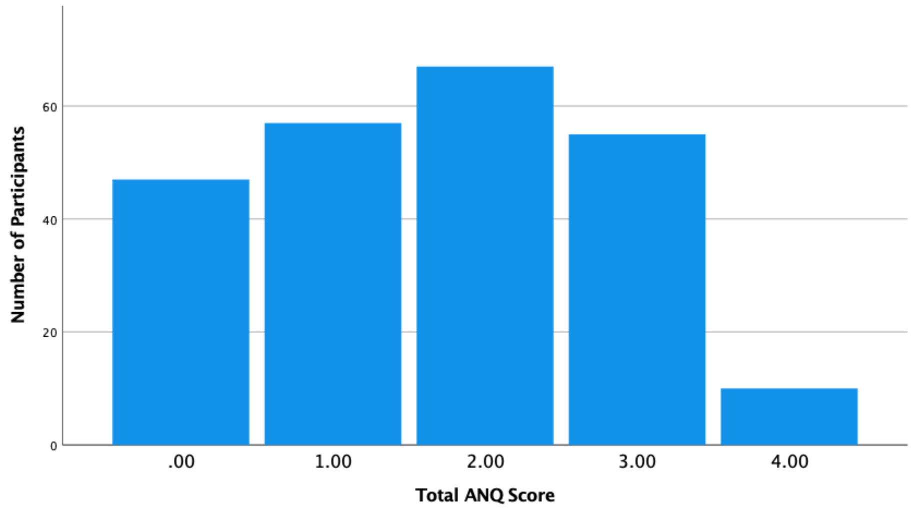
Table 3

Descriptive Statistics for the ANQ

Variable	*N*	Mean	*SD*	Min	Max	Kurtosis	Skewness
ANQ Total	236	1.68	±1.16	.00	4.00	-0.995	0.041

Figure 2

Frequency of Total ANQ Scores



ICS Adherence

A total of 101 participants had ICS data through Dosers. Missing data were due to participants not bringing back devices for download during the randomization session, participants losing devices, or device failure, for all other participants. The mean percent ICS adherence was 39.27 ($SD = 28.70$). The data were not skewed, as seen in Table 4 and Figure 3. ICS adherence was not associated with child age ($r=-0.12$, $p=0.25$), household income ($\rho=-0.05$, $p=0.64$), child gender ($t\ (99) =-1.44$, $p=0.29$), or parent ethnicity [$F(4, 96) = 0.68$, $p=0.55$]. However, ICS adherence was associated with parent education ($\rho=-0.22$, $p=0.03$); as parent education decreased, ICS adherence increased. Due to these findings, parent education was added as a covariate in the analyses for ICS Adherence.

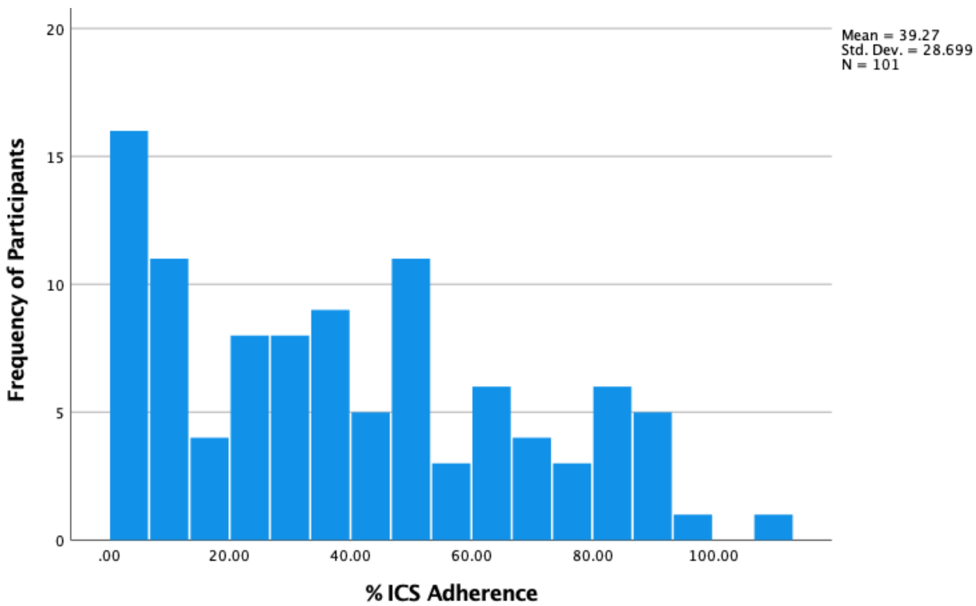
Table 4

Descriptive Statistics for % ICS Adherence

Variable	*N*	Mean	*SD*	Min	Max	Kurtosis	Skewness
ICS Adherence	101	39.27	±28.70	.00	106.67	-0.88	0.39

Figure 3

ICS Adherence Histogram



Quick Relief Medication Use

A total of 194 participants had QR use data through dosers. Missing data for the 42 participants were due to participants not bringing back devices for download during the randomization session, participants losing devices, or device failure. The mean percent frequency of QR use was 21.90 (SD = 24.84); this indicates that overall participants used their QR medication less than 22% of the time for which they had doser data available, which was less than 1.5 days per week. On average, participants did not have poorly controlled asthma because they did not typically use their QR medications more than 2 days per week.

Please see Table 5, which indicates the skew and kurtosis values were within acceptable range. The data were not normally distributed, because it was not symmetrical. Please see Figure 4 for the histogram of frequency of QR use. QR was dichotomized, as well controlled (72.16% of participants) or poorly controlled (27.84% of participants) based on clinical cut offs (using the medication more than 2 times/week indicated poor control), due to the asymmetry. In the covariate analyses with dichotomized variables, independent samples t-tests revealed there were no associations between QR medication use and child age (t (192)=-0.53, p=0.600), parent education (t (191)=-0.09, p=0.93), or household income (t (192)=0.67, p=0.51). Chi square tests revealed there were no associations between QR use and adult ethnicity (χ^2=6.59, p=0.16) or child gender (χ^2=0.06, p=0.81). No demographic variables were associated with this outcome measure therefore no covariates were entered into the model for QR analyses.

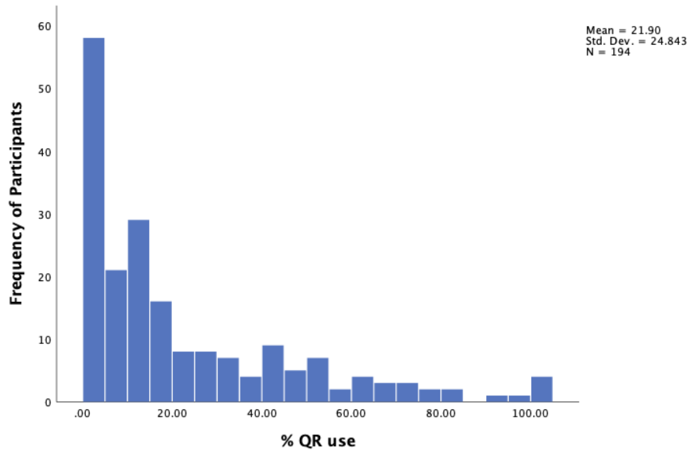
Table 5

Descriptive Statistics for Frequency of QR use

Variable	*N*	Mean	*SD*	Min	Max	Kurtosis	Skewness
%QR use	194	21.90	±24.84	.00	100.00	1.36	1.41

Figure 4

Percent Frequency of QR use Histogram



Acute Healthcare Utilization

Relevant to acute HCU data, 234 participants had self-reported frequency of ED visits and 235 participants had self-reported frequency of sick visits, in the past year. The mean frequency of ED visits was 1.87 (SD = 3.74) in the past year. The mean frequency of sick visits was 2.88 with a standard deviation of (SD = 5.19) in the past year. Please see Table 6, which indicated both ED visits and sick visits were positively skewed and had elevated kurtosis. Therefore, they were dichotomized as no visits or >0 visits due to the distribution. Please see Figure 5 for the distribution of ED visits and Figure 6 for the distribution of sick visits.

In the covariate analyses with dichotomized variables, independent samples t-tests revealed there were no associations between ED visits and parent education (t (231)=-0.30, p=0.76) or household income (t (232)=0.63, p=0.53). Chi-square tests revealed that ED visits were not associated with adult ethnicity (χ^2=6.36, p=0.17) or child gender (χ^2=0.11, p=0.74). However, there was an association between ED visits and child age (t (232)=-4.05, p<0.01), where younger kids had more visits.

In the covariate analyses with dichotomized variables, independent samples t-tests revealed there were no associations between sick visits and parent education (t (232)=0.52, p=0.61) or household income (t (233)=0.596, p=0.55). Chi-square tests revealed that sick visits were not associated with parent ethnicity (χ^2=8.00, p=0.09). However, there were associations between sicks visits related to child age (t (233)=-3.16, p=0.002) and child gender (χ^2=4.51, p=0.03).

Due to these findings, child age was added as a covariate in the analyses for HCU by ED visits and child age and child gender were added as covariates in the analyses for HCU by sick visits.

Table 6

Descriptive Statistics for HCU in the Past Year

Variable	*N*	Mean	*SD*	Min	Max	Kurtosis	Skewness
ED Visits	234	1.87	±3.74	.00	40.00	50.73	5.99
Sick Visits	235	2.88	±5.19	.00	48.00	35.99	5.19

Figure 5

ED Visits Histogram

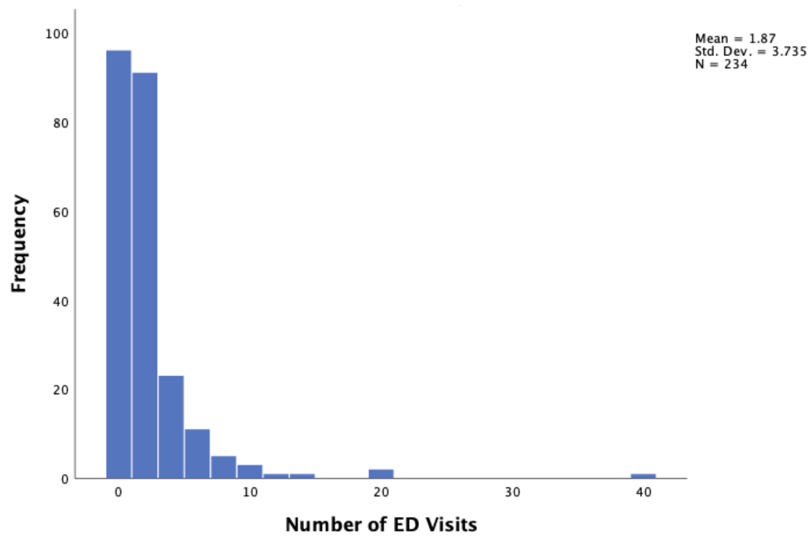
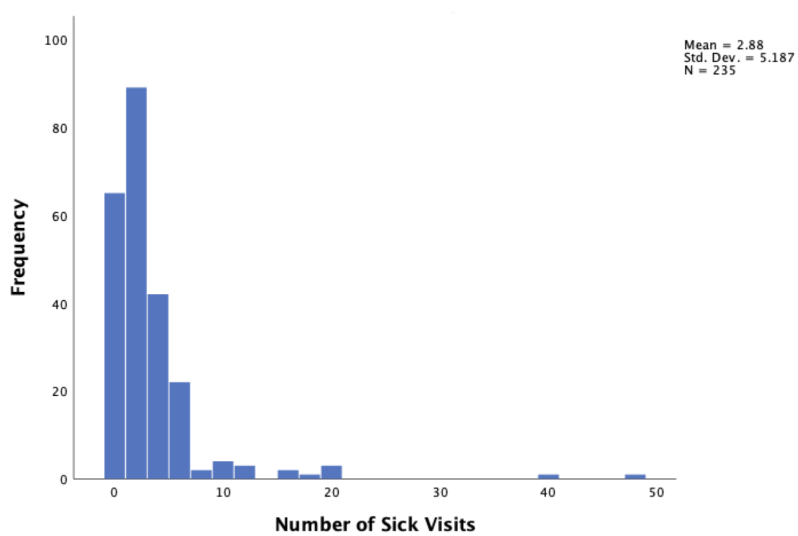


Figure 6

Sick Visits Histogram



Asthma Control Test / Child-Asthma Control Test

All 236 participants had data available for subjective asthma control, as measured by the ACT (n = 151) and C-ACT (n = 85). The reliability for ACT (α=0.797) and C-ACT (α=0.765) was assessed by Cronbach's alpha and both measures had acceptable reliability. The mean total score on the ACT was 18.99 (SD = 4.15). The mean total score on the C-ACT was 18.78 (SD = 4.85). The data were normally distributed, as seen in Table 7. Total ACT scores ranged from 6-25 and total C-ACT scores ranged from 4-26. Asthma control was dichotomized and overall, 117 (49.6%) participants had well controlled asthma and 119 (50.4%) participants had poorly controlled asthma.

In the covariate analyses with dichotomized variables of control, independent samples t-tests revealed there were no associations between asthma control and child age (t (234)=-1.22, p=0.22), parent education (t (233)=0.26, p=0.80), or household income (t (234)=-0.47, p=0.64). Chi-square tests revealed that there were no associations between asthma control and parent ethnicity (χ^2=5.54, p=0.24).

However, there were associations between child gender (χ^2=5.04, p=0.03). Male children (N = 74; 63.35%) were more likely to have well controlled asthma than female children (N = 43; 36.75%), and female children (N = 61; 51.26%) had significantly more instances of poorly controlled asthma than male children (N = 58; 48.74%). Due to these findings, child gender was added as a covariate in the analyses for subjective asthma control.

Table 7

Descriptive Statistics for Subjective Asthma Control

Variable	*N*	Mean	*SD*	Min	Max	Kurtosis	Skewness
ACT	151	18.99	±4.15	6.00	25.00	-0.05	0.09
C-ACT	85	18.78	±4.85	4.00	26.00	0.53	0.31
Dichotomized (Poor vs Well)	236	0.50	±0.50	0.00	1.00	-2.02	0.02

Pulmonary Function

A total of 233 participants had data available for the objective measure of asthma control, pulmonary function via %FEV1. The mean %FEV1 was 89.94 (SD = 14.01). The data were normally distributed, as seen in Table 8. Values for %FEV1 ranged from 45-126%, indicating variance in the pulmonary function in participants.

In the covariate analyses, pulmonary function was not associated with child age (r=0.11, p=0.09), parent education (ρ=0.02, p=0.82), household income (ρ=0.03, p=0.60), or child gender (t (231) = 0.16, p=0.87). ANOVA tests revealed that there were associations between groups for pulmonary function, based on parent ethnicity [F(4, 228) = 4.00, p=0.004]. Post hoc Tukey tests revealed that African American (M=87.48, SD=14.6) and Dominican (M=84.44, SD=14.6) parents had children with significantly lower pulmonary function compared to Other Latinx (96.18, SD=11.68) parents, whom had children with the highest pulmonary function, as seen in Figure 7. The findings in the covariate analyses for pulmonary function revealed associations with child ethnicity, which was added as a covariate to the analyses for pulmonary function.

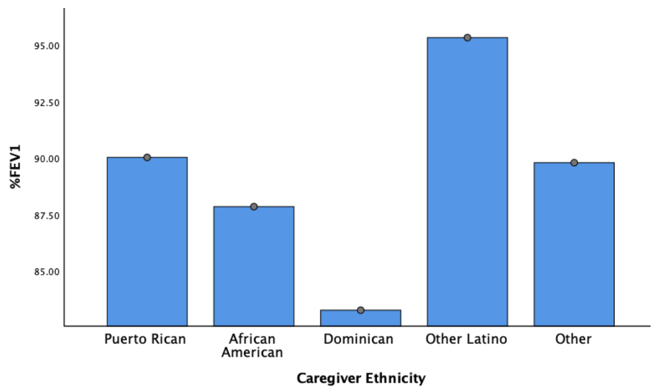
Table 8

Descriptive Statistics %FEV1

Variable	*N*	Mean	*SD*	Min	Max	Kurtosis	Skewness
%FEV1	233	89.94	±14.01	45.00	126.00	0.21	-0.17

Figure 7

Differences in %FEV1 by Parent Ethnicity



*Note. "Other Latinx" category includes Mexican, Latinx Central American, Latinx South American, and "Other" category includes Jamaican, Black-Caribbean, and African.

Asthma Illness Representations

All 236 participants had data available for parent asthma illness representations. The AIRS reliability (α=0.79) was assessed by Cronbach's alpha and was considered acceptable. The mean for AIRS Total score was 3.11 (SD = 0.31). The data were normally distributed, as seen in Table 9. Total scores ranged from 2.11 to 3.91, indicating variance in alignment of illness representations with the lay and professional models of asthma.

In the covariate analyses, Pearsons correlation revealed AIRS was not associated with child age (r=-0.03, p=0.61) and a t-test revealed AIRS was not associated with child gender (t (234) =-0.650, p=0.62).

Spearman's correlation revealed that parent education (ρ=0.32, p< 0.001) was significantly correlated with total AIRS score, with higher scores being associated with greater parent education. Spearman's correlation also revealed that household income (ρ=0.194, p= 0.003) was significantly correlated to total AIRS score; greater alignment with the professional model of asthma was associated with greater household income. ANOVA tests revealed that there were significant differences between groups, for total AIRS score, based on parent ethnicity [F(4, 231) = 3.36, p=0.01]. Post hoc Tukey tests Tukey revealed that Puerto Rican (M=3.06, SD=0.27) and Other Latinx (M=3.02, SD=0.31) parents had significantly lower scores on the AIRS compared to African American (M=3.21, SD=0.27) parents, as seen in Figure 8.

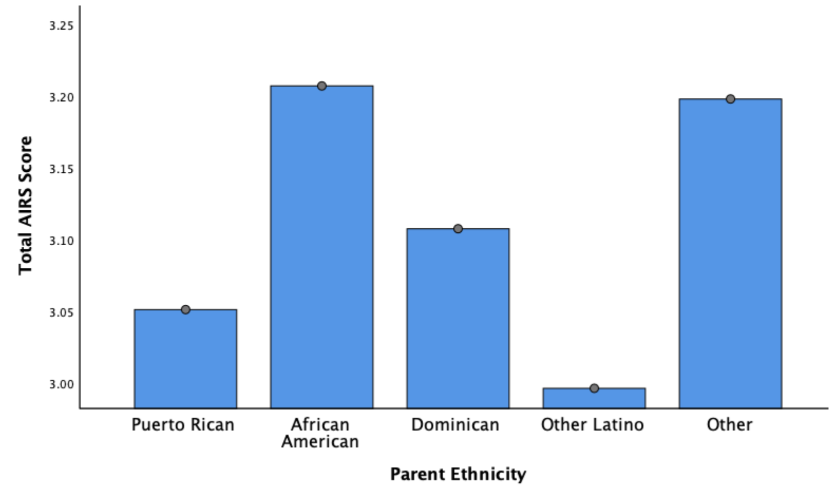
Table 9

Descriptive Statistics for the AIRS

Variable	*N*	Mean	*SD*	Min	Max	Kurtosis	Skewness
AIRS Total	236	3.11	±0.31	2.11	3.91	0.12	-0.19

Figure 8

Differences in AIRS score by Parent Ethnicity



*Note. "Other Latinx" category includes Mexican, Latinx Central American, Latinx South American, and "Other" category includes Jamaican, Black-Caribbean, and African.

Analyses by Aim

The associations between parent asthma numeracy and outcome measures were analyzed with and without adding covariates to the models. The adjusted analyses included only the covariates that were associated with each outcome measure, for each measure. The unadjusted analyses were conducted without these covariates. The QR medication use analyses did not require adjustments due to lack of covariates as determined from the above analyses.

Specific Aim 1

Associations between parent asthma numeracy skill and children's asthma management by ICS adherence, QR medication use, and health care utilization were examined.

Unadjusted Hypothesis 1a. Linear regression was used to test a model predicting ICS adherence. In the unadjusted analyses, the predictor ANQ was entered in the first step of the regression**.** Model 1 explained 4% of the variance (R = 0.20, F [1, 99] = 4.12, p = 0.045). Please see Table 10. Total ANQ score was associated with ICS Adherence (R^2_{change}=0.04, F

$_{change}$ [1, 99] =4.12, p=0.045); this negative relationship indicated an increase in ANQ was associated with lower ICS adherence. Parent asthma numeracy skill was associated with ICS adherence. The hypothesis was supported by the unadjusted analyses.

Table 10

Unadjusted Linear Regression Analysis for Association between ANQ and ICS Adherence

		Coefficient						
Step	Variable	*B*	*SEB*	β	*t*	*F*	R^2_{change}	*p*
1	(Constant)	48.00	5.14		9.33			<0.001
	ANQ	-5.13	2.53	-0.2	-2.03	4.12	0.04	0.045

[b] F_{change} (1, 99) = 4.12, p=0.045

Adjusted Hypothesis 1a. Linear regression was used to test a model predicting ICS adherence through adjusted analyses. Previous analyses revealed parent education was significantly associated with ICS adherence, so this was entered in the first step of the regression as a covariate. The model after step 1 explained 4.8% of the variance (R = 0.22, F [1, 96] = 4.83, p = 0.03). The predictor ANQ was added at step 2. The model after step 2 explained 5.6% of the variance (R = 0.24, F [2, 95] = 2.79, p = 0.07). The ANQ did not predict significant variance; there was a 0.8% change in the model from step 1 to step 2 (R^2_{change} =0.008, p = 0.83). Please see Table 11. Total ANQ score was not associated with ICS Adherence (R^2_{change}=0.008, F_{change} [1, 95] =0.77, p=0.38); parent asthma numeracy skill was not associated with child ICS medication adherence once parent education was controlled for. The hypothesis was not supported.

Table 11

Adjusted Linear Regression Analysis for Association between ANQ and ICS Adherence

		Coefficient							
Step	Variable	*B*	*SEB*	β	*t*	*semipartial r* r_{sp}	*F*	R^2_{change}	*P*
2[b]	(Constant)	54.97	7.99		6.89				<0.001
	Parent Edu	54.75	8.00		6.84				<0.001
	ANQ	-5.84	6.65	-0.09	-0.88	-0.09	2.79	0.008	0.38

[b] F_{change} (1, 95) = 0.77, p = 0.38

Hypothesis 1b. Logistic regression was used to test a model predicting QR medication use. Previous analyses revealed no covariates for percent frequency QR medication use, so in the first step of the regression the predictor ANQ was entered. The Omnibus test of model coefficients revealed that Model 1 was not significant (χ^2=0.001, p=0.98). The Nagelkerke statistic revealed that 0% of the variance in the QR use was explained by the predictor. Please see Table 12. Total ANQ score was not associated with QR medication use (OR=1.004, 95% CI [0.76,1.32]); parent asthma numeracy skill was not associated with QR use. The hypothesis was not supported.

Table 12

Logistic Regression Analysis for Association between ANQ and QR medication use

		Coefficient							
Step	Variable	*B*	*SE*	Wald	Df	Odds-Ratio	95% CI Lower	95% CI Upper	*p*
1	(Constant)	-0.96	0.28	11.75	1				<0.001
	ANQ	0.004	0.14	0.001	1	1.004	.76	1.32	0.98

Nagelkerke R^2=0.00

Unadjusted Hypothesis 1c. Logistic regressions were used to test models predicting acute HCU, through ED visits and sick visits individually.

ED Visits. In the unadjusted analyses, the predictor ANQ was entered in the first step of the regression**.** The Omnibus test of model coefficients revealed that Model 1 was significant (χ^2=6.79, p=0.009). The Nagelkerke statistic revealed that 4% of the variance in ED visit use was explained by the predictor. Please see Table 13. Total ANQ score was associated with ED visits (OR=0.74, 95% CI [0.59,0.93], p=0.01). This negative relationship indicates an increase in ANQ was associated with decreased likelihood of ED visits; parent asthma numeracy skill was associated with ED visits. The hypothesis was supported by the unadjusted analyses.

Table 13

Unadjusted Logistic Regression Analysis for Association between ANQ and HCU: ED Visits

		Coefficient							
Step	Variable	*B*	*SE*	Wald	Df	Odds-Ratio	95% CI Lower	95% CI Upper	*p*
1	(Constant)	0.88	0.246	12.81	1	2.41			<0.001
	ANQ	-0.30	0.118	6.59	1	0.74	0.59	0.93	0.01

Nagelkerke R^2=0.04

Sick Visits. In the unadjusted analyses, the predictor ANQ was entered in the first step of the regression**.** The Omnibus test of model coefficients revealed that Model 1 was not significant (χ^2=2.42, p=0.12). The Nagelkerke statistic revealed that 1.5% of the variance in sick visits was explained by the predictor. Please see Table 14. Total ANQ score was not associated with sick visits (OR=0.74, 95% CI [0.64,1.05], p=0.12); parent asthma numeracy skill was not associated with sick visits. The hypothesis was not supported by unadjusted analyses.

Table 14

Unadjusted Logistic Regression Analysis for Association between ANQ and HCU: Sick visits

		Coefficient							
Step	Variable	*B*	*SE*	Wald	Df	Odds-Ratio	95% CI Lower	95% CI Upper	*p*
1	(Constant)	1.30	0.27	23.07	1	3.68			<0.001
	ANQ	-0.20	0.13	2.39	1	0.74	0.64	1.05	0.12

Nagelkerke R^2=0.015

Adjusted Hypothesis 1c. Logistic regressions were used to test models predicting acute HCU, through ED visits and sick visits individually.

ED Visits. Previous analyses revealed child age was significantly associated with ED visits, so this was entered in the first step of the regression as a covariate. The Omnibus test of model coefficients revealed that Step 1 was significant (χ^2=15.56, p<0.001). The Nagelkerke statistic revealed that 8.7% of variance was explained by child age; older children were less likely to have ED visits. The predictor ANQ was added at step 2. The Omnibus test of model coefficients revealed through step 2, the addition of ANQ was not significant (χ^2=3.42, p=0.06). The Nagelkerke statistic revealed that 10.5% of variance was explained by the combination of age and ANQ, with the addition of ANQ changing the Nagelkerke R^2 by 1.8%. Please see Table 15. Analyses indicate a trend towards an increase in ANQ being associated with decreased likelihood of ED visits. However, Total ANQ score was not associated with ED visits (OR=0.798, 95% CI [0.63,1.02]); parent asthma numeracy skill was not associated with ED visits. The hypothesis was not supported.

Table 15

Adjusted Logistic Regression Analysis for Association between ANQ and HCU: ED Visits

		Coefficient							
Step	Variable	*B*	*SE*	Wald	df	Odds-Ratio	95% CI Lower	95% CI Upper	*p*
2	(Constant)	3.67	0.86	18.12	1	39.20			<0.001
	Child age	-0.22	0.06	11.70	1	0.803	0.71	0.91	<0.001
	ANQ	-0.23	0.12	3.38	1	0.798	0.63	1.01	.07

Nagelkerke R^2=0.105

Sick Visits. Previous analyses revealed child age and child gender were significantly associated with sick visits, so they were entered in the first step of the regression as covariates. The Omnibus test of model coefficients revealed that Model 1 was significant (χ^2=12.66, p=0.002). The Nagelkerke statistic revealed that 7.6% of variance was explained by child age and child gender. The predictor ANQ was added at step 2. The Omnibus test of model coefficients revealed through step 2, the addition of ANQ was not significant (χ^2=1.03, p=0.31). The Nagelkerke statistic revealed that 8.2% of variance was explained by the combination of child age, child gender, and ANQ, with the addition of ANQ changing the Nagelkerke R^2 by 0.6%. Please see Table 16. Total ANQ score was not associated with sick visits (OR=0.87, 95% CI [0.67,1.14]); parent asthma numeracy skill was not associated with sick visits after controlling for the effects of child age and gender. The hypothesis was not supported.

Table 16

Adjusted Logistic Regression Analysis for Association between ANQ and HCU: sick visits

		Coefficient							
Step	Variable	*B*	*SE*	Wald	df	Odds-Ratio	95% CI Lower	95% CI Upper	*p*
2	(Constant)	3.80	0.93	16.74	1	44.87			<0.001
	Child age	-0.17	0.07	6.45	1	0.84	0.73	0.96	0.01
	Child gender	-0.55	0.30	3.29	1	0.58	0.32	1.05	0.07
	ANQ	-0.14	0.13	1.02	1	0.87	0.67	1.14	0.31

Nagelkerke R^2=0.082

Specific Aim 2

Examined associations between parent asthma numeracy skill (ANQ) and children's asthma control as measured by the Asthma Control Test (ACT/C-ACT) and pulmonary function (%FEV1).

Unadjusted Hypothesis 2a. Logistic regressions were used to test models predicting self-reported asthma control. In the unadjusted analyses, the predictor ANQ was entered in the first step of the regression**.** The Omnibus test of model coefficients revealed that Model 1 was not significant (χ^2=0.002, p=.971). The Nagelkerke statistic revealed that 0% of the variance in asthma control was explained by the predictor. Please see Table 17. Total ANQ score was not associated with self-reported asthma control (OR=0.99, 95% CI [0.80,1.24]); parent asthma numeracy skill was not associated with self-reported asthma control. The hypothesis was not supported by the unadjusted analyses.

Table 17

Unadjusted Logistic Regression Analysis for Association between ANQ and Asthma Control

		Coefficient							
Step	Variable	*B*	*SE*	Wald	Df	Odds-Ratio	95% CI Lower	95% CI Upper	*p*
1	(Constant	-0.01	0.23	0.002	1	0.99			0.97
	ANQ	-0.004	0.11	0.001	1	0.996	0.80	1.24	0.97

Nagelkerke R^2=0.00

Adjusted Hypothesis 2a. Logistic regressions were used to test models predicting subjective asthma control. Previous analyses revealed child gender was associated with the binary categories poorly controlled and well controlled asthma; this was entered in the first step of the regression as a covariate. The Omnibus test of model coefficients revealed that the model at step 1 was significant (χ^2=5.06, p=0.025). The Nagelkerke statistic revealed that 2.8% of variance was explained by child gender. The predictor ANQ was added at step 2. The Omnibus test of model coefficients revealed through step 2, the addition of ANQ was not significant (χ^2=0.01, p=0.91). The Nagelkerke statistic revealed that 2.8% of variance was explained by the combination of child age and ANQ, with the addition of ANQ changing the Nagelkerke R^2 by 0%. Please see Table 18. Total ANQ score was not associated with self-reported asthma control (OR=0.99, 95% CI [0.79,1.23]); parent asthma numeracy skill was not associated with self-reported asthma control once child gender was controlled for. The hypothesis was not supported.

Table 18

Adjusted Logistic Regression Analysis for Association between ANQ and Asthma Control

		Coefficient							
Step	Variable	*B*	*SE*	Wald	df	Odds-Ratio	95% CI Lower	95% CI Upper	*p*
2	(Constant)	0.27	0.26	1.02	1	1.30			0.31
	Child gender	-0.59	0.27	5.01	1	0.55	0.33	0.93	0.03
	ANQ	-0.01	0.11	0.01	1	0.99	0.79	1.23	0.91

Nagelkerke R^2=0.028

Unadjusted Hypothesis 2b. Linear regression was used to test a model predicting pulmonary function. In the unadjusted analyses, the predictor ANQ was entered in the first step of the regression**.** Model 1 explained 2% of the variance (R = 0.04, F [1, 231] = 0.31, p = 0.58). Please see Table 19. Total ANQ score was not associated with child %FEV1 (R^2_{change}=0.001, F [1, 231] =3.2, p=0.82); parent asthma numeracy skill was not associated with child pulmonary function. The hypothesis was not supported by the unadjusted analyses.

Table 19

Unadjusted Linear Regression Analysis for Association between ANQ Pulmonary Function

		Coefficient						
Step	Variable	*B*	*SEB*	β	*t*	*F*	R^2_{change}	*p*
1	(Constant)	90.67	1.60		56.70			<0.001
	ANQ	-0.43	0.78	-0.04	-0.55	3.2	0.001	0.58

[b] F_{change} (1, 231) = 0.31, $p = 0.58$

Adjusted Hypothesis 2b. Linear regression was used to test a model predicting pulmonary function. Previous analyses revealed that parent ethnicity was associated with %FEV1, so this was entered in the first step of the regression as a covariate to control for its effect on pulmonary function. The model after step 1, parent ethnicity, explained 6.6% of the variance ($R = 0.26$, F [4, 228] = 4.00, $p = 0.004$). The predictor ANQ was added at step 2. The model after step 2 explained 6.6% of the variance ($R = 0.26$, F [5, 227] = 3.2 , $p =$ 0.008); the ANQ did not predict significant variability since there was a 0% change in the model from step 1 to step 2 (R^2_{change} =0.0, $p = 0.82$). Please see Table 20. Total ANQ score was not associated with child %FEV1 (R^2_{change}=0.0, F [5, 227] =3.2, p=0.82); parent asthma numeracy skill was not associated with child pulmonary function even after controlling for parent ethnicity. The hypothesis was not supported.

Table 20

Adjusted Linear Regression Analysis for Association between ANQ and Pulmonary Function

Step	Variable	Coefficient							
		B	*SEB*	β	*t*	*F*	R^2_{change}	*semipartial r* r_{sp}	*p*
2 [b]	(Constant)	87.80	2.28		38.53				<0.001
	Ethnicity[a]								
	PR	3.45	2.36	0.12	1.46			0.09	0.15
	Dominican	-3.15	3.05	-0.08	-1.03			-0.07	0.30
	Other Latinx	8.65	2.82	0.24	3.07			0.20	0.002
	Other	1.81	3.08	0.04	0.59			0.04	0.56
	ANQ	-0.17	0.77	-0.01	-0.22	3.2	0.0	-0.01	0.82

[a]Reference group is African American

[b] F_{change} (1, 227) = 0.05, $p = 0.82$

Specific Aim 3

Examined association between parent asthma numeracy skill (ANQ) and parents' illness representations about their child's asthma (AIRS).

Unadjusted Hypothesis 3a. Linear regression was used to test a model predicting asthma illness representation. In the unadjusted analyses, the predictor ANQ was entered in the first step of the regression**.** Model 1 explained 10.9% of the variance ($R = 0.330$, F [1, 234] = 28.6, $p<0.001$). Please see Table 21. ANQ total score was significantly associated with total AIRS score (R^2_{change}=0.109, F [1, 227] =28.6, p<0.001). The positive relationship indicated that as ANQ score increased, AIRS score increased, aligning closer to the professional model of asthma; parent asthma numeracy skill was associated with parent asthma illness representations. The hypothesis was supported by the unadjusted analyses.

Table 21

Unadjusted Linear Regression Analysis for Association between ANQ and Parent AIRS score

		Coefficient						
Step	Variable	*B*	*SEB*	β	*t*	*F*	R^2_{change}	*p*
1	(Constant)	2.96	0.03		87.37			<0.001
	ANQ	0.09	0.02	0.330	5.34	28.56	0.109	<0.001

[b] F_{change} (1, 234) = 28.56, p <0.001

Adjusted Hypothesis 3a. Linear regression was used to test a model predicting asthma illness representation. Previous analyses revealed that parent education, household income, and parent ethnicity were associated with the total AIRS score, so these were entered in the first step of the regression as covariates, to control for their effect on asthma illness representations.

The model after step 1, covariates explained 15% of the variance (R = 0.39, F [6, 228] = 6.71, p < 0.001). The predictor ANQ was added at step 2. The model after step 2 explained 20% of the variance (R = 0.45, F [1, 227] = 8.10, p < 0.001); this was significant and there was a 5% change in the model from step 1 to step 2 (R^2_{change} =0.05, p < 0.001). Please see Table 22. ANQ total score was significantly associated with total AIRS score (R^2_{change}=0.05, F_{change} [1, 227] =14.17, p<0.001). The positive relationship indicated that as ANQ score increased, AIRS score increased, aligning closer to the professional model of asthma; parent asthma numeracy skill was associated with parent asthma illness representations even after controlling for parent ethnicity, education and income. The hypothesis was supported.

Table 22

Adjusted Linear Regression Analysis for Association between ANQ and Parent AIRS score

		Coefficient							
Step	Variable	*B*	*SEB*	β	*t*	*F*	R^2_{change}	semipartial r r_{sp}	*p*
2 [b]	(Constant)	2.87	0.07		41.07				<0.001
	Parent education	0.03	0.01	0.25	3.67			0.24	<0.001
	Household Income	0.003	0.01	0.02	0.33			0.02	0.74
	Parent Ethnicity[a]								
	Puerto Rican	-0.12	0.05	-0.19	-2.51			-0.16	0.01
	Dominican	-0.10	0.06	-0.10	-1.50			-0.10	0.14
	Other Latinx	-0.09	0.06	-0.11	-1.38			-0.09	0.17
	Other	-0.01	0.06	-0.01	-0.20			-0.01	0.84
	ANQ	0.06	0.12	0.24	3.76	8.1	0.05	0.24	<0.001

[a] Reference group is African American

[b] F_{change} (1, 227) = 14.17, p <0.001

Exploratory Analyses

Interaction between Parent Numeracy and Child Age

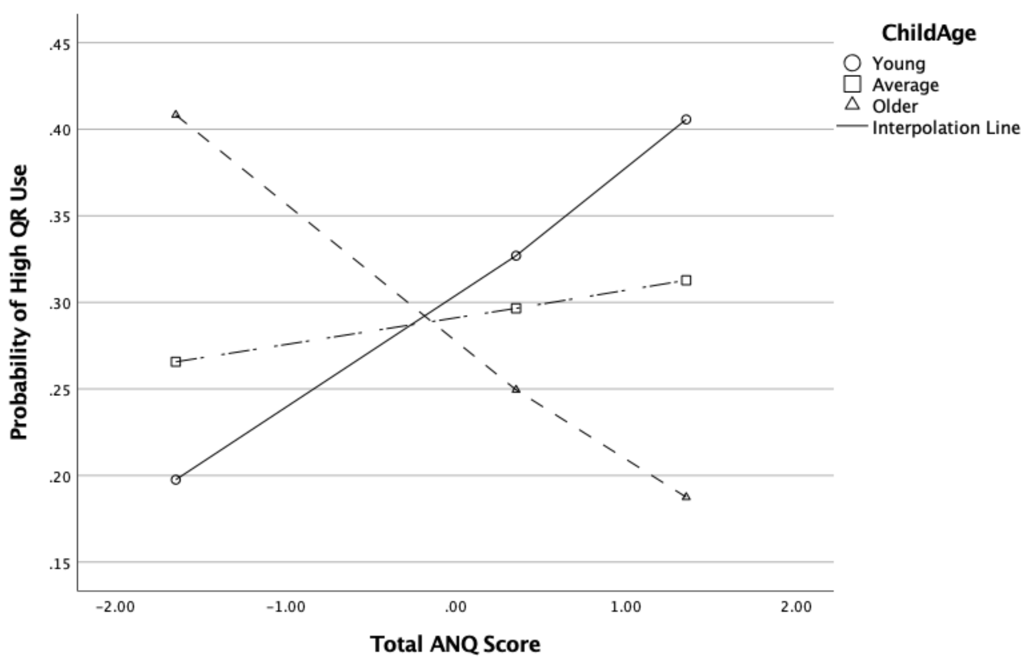
Exploratory analyses assessed if the interaction between child age and parent numeracy skill predicted any of the outcome variables. These associations with the interaction of parent asthma numeracy and child age were analyzed in the adjusted analyses which included only the covariates that were associated with each outcome measure, for each measure. Multiple linear and logistic regressions were used to test the moderating effect of age on the outcomes: ICS medication use, QR medication use, ER visits, sick visits, self-reported asthma control, pulmonary function, and AIRs. Covariates were entered into the first block, parent numeracy and child age were entered in the second block, and the interaction between parent numeracy and child age was entered into the last block of the model.

The models revealed that the interaction between parent numeracy skill and child age did significantly predict QR medication use (OR=0.874, 95% CI [0.77,0.99], p=0.048); this indicates the effect of parent numeracy on QR use was different for different age groups. Age was a moderator in the relationship between parent asthma numeracy and QR medication use. Figure 9 depicts how the probability of having higher QR use relates to each age group, as divided into younger, average, and older age children in this sample, which was measured by the 16^{th}, 50^{th}, and 84^{th} percentiles, respectively. As parent numeracy skill increased in younger children, those children's probability of using their QR medications more frequently increased. As parent numeracy skill decreased in older children, those children's probability of using their QR medications more frequently decreased. There was a stronger relationship between ANQ and QR use in older children (B=1.79, OR=5.97) than in younger children (B=0.31, OR=1.36).

The interaction between parent numeracy skill and child age did not predict significant variance for ICS adherence (R^2_{change}=0.00, F_{change} [1, 151] =0.66, p=0.798), ED visits (OR=1.02, 95% CI [0.91,1.14], p=0.712), sick visits (OR=0.91, 95% CI [0.81,1.01], p=0.12), self-reported asthma control (OR=0.997, 95% CI [0.87,1.08], p=0.55), child %FEV1 (R^2_{change}=0.001, F [1, 225] =1.26, p=0.723), or total AIRS score (R^2_{change}=0.007, F_{change} [1, 225] =1.87, p=0.173).

Figure 9

Probability of High QR Medication Use by Parent Numeracy Skill



Parent Numeracy and Demographic Variables

Exploratory analyses also assessed if parent asthma numeracy skill was significantly associated with demographic variables, or the potential covariates in the above models. Analyses revealed that total ANQ score was significantly associated with child age ($r=.211$, $p<0.001$), parent education ($r=0.256$, $p=<0.001$), and household income ($\rho=0.33$, <0.001). As child age, parent education level, and household income increased, the parent asthma numeracy skill increased as well. ANQ score was not significantly associated with parent ethnicity [$F(4, 236) = 0.689$, $p=0.60$] or child gender ($t\ (234) =0.51$, $p=0.53$).

Chapter IV: Discussion

Summary of Findings

This study aimed to understand the associations between parent asthma numeracy skill and child asthma management, child asthma control, and parent asthma illness representations. Associations between the total parent ANQ score and: child ICS adherence, child QR use, child HCU via number of ED visits and sick visits, child subjective asthma control via the ACT/C-ACT, child pulmonary function via %FEV1, and total parent AIRS score, were examined. Notably, the hypothesis (3a) regarding total parent ANQ scores' association with total parent AIRS score was supported. As hypothesized, parent asthma numeracy skill was associated with parent asthma illness representations. Greater parent asthma numeracy skill was associated with parent alignment of views of asthma with the professional model rather than the lay model, in both unadjusted and adjusted models. Additionally, both ED visits and ICS adherence were associated with ANQ score in unadjusted analyses. Greater parent asthma numeracy skill was associated with less frequent ED visits and lower adherence to ICS medications; however, adjusted analyses were not significant.

Covariate analyses indicated several significant associations between: (1) parent education and ICS adherence (2) child age and number of ED visits, (3) child age and gender and number of sick visits, (3) child gender and subjective asthma control, (5) parent ethnicity and child pulmonary function, and (6) parent education, household income, and parent ethnicity and parent asthma illness representations. These associations revealed that more educated parents were likely to have children with worse adherence, younger children were more likely to have ED visits, younger children and female children were more likely to have sick visits, male children were more likely to have better self-report asthma control, African American and Dominican parents were more likely to have children with lower pulmonary function compared to Other Latinx parents, and Puerto Rican and Other Latinx parents were more likely to have lower scores on the AIRS compared to African American parents. Exploratory analyses revealed that the interaction between parent numeracy skill and child age impacted QR medication use differently, depending on child age, and had a stronger relationship in older children. An increase in parent numeracy skill increased the probability of younger children using their QR medications more frequently, and a decrease in parent numeracy skill decreased the probability of older children using their QR medications frequently. Exploratory analyses also revealed significant associations between parent asthma numeracy skill and child age, parent education, and household income where an increase in these variables was associated with an increase in parent asthma numeracy skill.

The study analyses also revealed non-significant findings. Parent asthma numeracy skill was not found to be associated with ICS adherence, QR use, HCU, subjective asthma control, or pulmonary function in adjusted analyses. The sample on average had, low adherence (39.67%), good control based on QR medication use (72.16%), at least 1 ED visit in the past year (1.87), at least 2 sick visits (2.88) in the past year, poor self-reported asthma control (50%), good pulmonary function (89.9%), and beliefs more closely associated with the professional model of asthma (3.11 on AIRS). Additionally, covariate analyses indicated that QR medication use was not associated with the predictor (ANQ) or any demographic variables (child age, child gender, parent education, parent ethnicity, household income) in the study. Exploratory analyses revealed that the interaction between parent numeracy skill and child age did not significantly impact ICS adherence, HCU, subjective asthma control, pulmonary function, or total AIRS. They also revealed that parent asthma numeracy sill was not associated with parent ethnicity or child gender. However, these non-significant findings are important to understand.

Interpretation

Asthma Numeracy Questionnaire

In the current study, the ANQ was utilized to test numeracy skill in parents of children with asthma. The measure is short, with only four items, therefore the internal consistency value (KR=0.48) determined by the Kuder Richardson 20 test may not be reliable. This test was used because each item of the ANQ is scored as either correct or incorrect. However, the study regarding development of the ANQ measured the reliability by using Cronbach's alpha and suggested moderate internal consistency ($\alpha = 0.57$) (Andrea J. Apter et al., 2006). Additionally, the distribution of scores in the ANQ in this study sample showed that the largest percentage of participants scored a 2, the least percentage scored a perfect 4, and the mean score was 1.68 (SD=1.17). In a previous study of 284 participants, the mean score was slightly higher, at 2.3 (SD=1.2) (A. J. Apter et al., 2013). It is important to note, that the sample in this study was lower on asthma numeracy than the samples in previous studies. This may indicate poorer understanding and interpretation of quantitative information by parents regarding their child's asthma. It may be helpful to consider the relatively low asthma numeracy skill in this sample of Latinx and African American parents in the Bronx and ways to target improvement. Additionally, higher ANQ scores were associated with greater parent education, greater household income, and greater child age. With the latter, it is possible that the parents' understanding of asthma improved over time as the parents of older children may have had more experience managing asthma. It may be important to understand the directionality of these relationships and whether the findings hold true in a different population sample ; this would be an important area for future research. Clinically, the ANQ may be used to quickly determine a parent's baseline understanding of asthma numeracy and based on the score, improvement in numeracy skill can be targeted through quick interventions. During asthma related visits, health care providers can give feedback to parents regarding incorrect answers in order to optimize child-care. Providers can also assess which domain of asthma management the parent has difficulty with, based on the questions answered incorrectly (e.g., medication dosing, peak flow readings and pulmonary function) and provide psychoeducation in that area. It is also important to understand why this sample from the Bronx had low asthma numeracy scores, compared to the other studies that also had ethnic minority participants from urban cities; future research with this sample may provide more information on factors that may contribute to lower scores. Future research may also help determine if improved numeracy is associated with improved adherence or asthma outcomes. Additionally, the ANQ specifically measures asthma related numeracy. It is possible that a different construct measuring general numeracy, or health literacy, could have associations with asthma outcomes in children.

Factors to Consider Regarding Non-Significant Findings

The analyses in this study revealed several non-significant findings regarding the role of parent asthma numeracy skill. Several other studies have reported that greater numeracy was associated with better health outcomes (A. J. Apter et al., 2013) and lower numeracy was associated with poorer health outcomes (Al Sayah et al., 2013; A. J. Apter et al., 2013; Marden et al., 2012). However, these studies were conducted in adults and representative of self-management of illness. It is important to note, that in a study of Puerto Rican children diagnosed with asthma, similar non-significant findings existed; low parent asthma numeracy was not associated with steroid medication use or pulmonary function (Rosas-Salazar et al., 2013). The current study assessed the relationship of parent numeracy skill on child outcomes, which may indicate a different pathway of illness management that may explain the non-significant findings. It is possible that the role parent asthma numeracy plays on child outcomes is indirect. In future research it would be interesting to assess the impact child asthma numeracy has on asthma outcomes, which may be a more direct relationship. As previously mentioned, parent numeracy skill was measured specifically in the context of asthma. This may not be representative of general parent numeracy, which may have different associations with child asthma outcomes.

Additionally, the extent to which parents were responsible for managing their child's asthma in this study is unknown. While parents generally tend to take a large responsibility in managing children's asthma (McQuaid et al., 2001), child age may impact this relationship. One study showed that by age 7yo, children were responsible for 20% of the responsibility of taking their ICS medications, and by ages 11yo and 15yo, this changed to 50% and 75%, respectively (Orrell-Valente et al., 2008). A study of 14-18 year old African American adolescents revealed that caregivers often work towards supporting teenagers' independence in managing their own asthma (Gibson-Scipio & Krouse, 2013) while other studies revealed that adolescents and their parents tend to have divergent views regarding who is mostly responsible for asthma management (Heyduck, Bengel, Farin-Glattacker, & Glattacker, 2015) and children tend to take more responsibility for their asthma management during their transition to high school (McQuaid et al., 2021).

In the current study, participants were 10-17 years-old and the mean age of children was 13. It is possible that teenage children started to work towards taking greater responsibility for their own asthma management and control, which may have influenced the extent to which parent asthma numeracy skill impacted child asthma outcomes. Related to this, child age was associated with HCU which is suggestive of this influence. Younger children were more likely to utilize acute health care and may have had their parents' support in doing do. More broadly, there is limited research on the ANQ and only few studies have utilized this measure. However, the measure has elicited some interesting findings in previous literature therefore the current findings, including the null hypotheses, add important contributions to this sparse area of literature.

Parent Asthma Numeracy and Parent Asthma Illness Representations

Greater parent asthma numeracy skill was associated with parents having views of asthma more closely aligned with the professional model of asthma management than the lay model; this finding was significant. The mean for AIRS Total score was 3.11, and scores ranged from 2.11 to 3.91, indicating variance in parent illness representations. This mean score is consistent with the AIRS validation study which reported mean scores of 3.11 and 3.44 in its two sample groups (K. Sidora-Arcoleo et al., 2010a). Parent education, household income, and parent ethnicity were also significantly associated with total AIRS score, which is consistent with the validation study.

In the current study, parent asthma numeracy was positively associated with parent asthma illness representations in both adjusted and unadjusted analyses. This indicates that greater parent numeracy was associated with parents having asthma related beliefs that align closer to the professional model of asthma, which views asthma as chronic and stresses the importance of daily ICS use (K. Sidora-Arcoleo et al., 2010a; US Department of Health and Human Services, 2011). This finding is unique and has several important implications. Parents who are able to better understand quantitative information as it applies to asthma are also more likely to understand the nature of asthma and may therefore adhere to professional recommendations when treating their child's asthma. This is critical, since previous studies indicate poor treatment adherence in the domains of daily asthma medication use and acute healthcare utilization.

The significant association may also be suggestive of the clinical utility of the ANQ in identifying asthma illness representations, potentially as a screening tool. The ANQ is a short 4-item measure that can quickly be administered during asthma-related medical appointments, which makes it a convenient assessment tool. Health care providers may be able to quickly gauge a parent's overall understanding of asthma through the ANQ, and then provide tailored feedback. For those parents who have lower numeracy, extra time spent on psychoeducation regarding the nature and treatment of asthma may be useful, as these study findings suggest it is likely that these parents will have asthma illness representations more closely aligned with the lay person model of asthma. These two may be related variables that can be addressed together during medical visits. For those parents with higher numeracy, time during medical appointments can be focused on other important topics, such as understanding the child's role in their own asthma management.

The ANQ asked parents to conduct basic arithmetic to compute medication adherence, assess the risk of developing an illness, and assess appropriate symptom management. Therefore, low numeracy may explain poor understanding of both asthma management practices (e.g., ICS adherence) and symptom perception. This may be the pathway through which asthma numeracy is related to asthma illness representations. Additionally, since the relationship between asthma numeracy and asthma illness representations was positive, improvement in one concept may lead to improvement in the other. Interventions to target asthma numeracy in parents may improve their management of their child's asthma, via their general understanding of asthma-related beliefs.

The association between asthma numeracy and asthma illness representations is interesting, since it indicates that higher parent numeracy skill was associated with more accurate parent beliefs regarding asthma management via medication use. However, other non-significant findings indicated that asthma numeracy skill was not significantly associated with ICS adherence or QR use. Additionally, in unadjusted analyses greater parent numeracy skill was associated with lower ICS adherence. This is surprising since an alignment with the professional model of asthma indicates associations with better asthma outcomes, in terms of greater controller medication use and lower acute health care utilization (K. Sidora-Arcoleo et al., 2010a); this was not the case in the current study. The lack of a direct relationship on medication use in this study raises questions regarding the strength of the aforementioned relationships, their directionality, and the implications on child asthma management and control. Future research in this area is warranted.

In the current study, greater AIRS score was associated with greater parent education, and in the validation study, parents with greater education had reported higher total AIRS scores. Low parent education was also shown to have a significantly negative effect on parent illness representations in another study of children with asthma (Yoos et al., 2007). In the current study, greater AIRS scores were associated with greater household income, and in the validation study parents in poverty (as determined by type of health insurance used, which was indicative of federal poverty lines) had significantly lower AIRS scores than parents who were not in poverty. In the current study, Puerto Rican and Other Latinx parents had significantly lower scores on the AIRS compared to African American parents. In the validation study, Puerto Rican, Afro-Caribbean, and African American parents had lower scores compared to White parents. Additionally, African American parents had higher scores on a subscale regarding attitudes towards medication use, than did Afro-Caribbean parents (K. Sidora-Arcoleo et al., 2010a). Another study assessing the association of parent AIRS and sociodemographic characteristics reported significant differences in illness representation by ethnic groups, particularly between Puerto Rican, African American, and White caregivers (Kimberly Sidora-Arcoleo, Feldman, Serebrisky, & Spray, 2012). The associations between parent asthma numeracy skill and demographic variables are largely consistent with previous literature.

Parent Asthma Numeracy and Asthma Management

ICS Adherence. Parent asthma numeracy skill was associated with lower ICS adherence in unadjusted analyses. This result is inconsistent with past literature where greater asthma numeracy was associated with better ICS adherence (A. J. Apter et al., 2013). However, in the current study the association was not significant in adjusted analyses which accounted for parent education level. The previous study measured adult numeracy associations with their own asthma, rather than their children, therefore the nonsignificant result in this study may be explained by the aforementioned factors of parent impact on child illness management. Generally, the mean ICS adherence for participants in this study was less than 40%, which is consistent with previous literature regarding asthma medication adherence (Arcoleo et al., 2019; Walders et al., 2005). ICS adherence in this study was also associated with parent education, where greater parent education was associated with lower adherence. It is important to note that greater ANQ scores were associated with higher education level in the parents in this sample. This is interesting, as it exemplifies that parent education is not a good benchmark through which to assess child asthma management and warrants future research on how parent education levels may be associated with child medication responsibility, and how that translates to medication use. Parent education level in this sample was mostly at the high school graduate level (26.3%); close to 50% of the sample had less than a high school education while the other 50% had either graduated high school or pursued higher education. Additionally, ICS adherence data were only available for 101 of 236 participants, therefore the results may not be indicative of overall adherence within all the participants in the current study. Less than half the participants had data for this outcome measure. Overall, the results indicate that parent education may not be a good benchmark through which to assess child asthma management, but rather parent asthma related beliefs may be more informative.

QR Medication Use. Parent asthma numeracy skill was not associated with QR medication use in children. The data were available for 194 of 236 participants, which is a majority of the sample. Based on clinical cut-offs set by NHLBI guidelines, a majority of the participants (72.16%) in this study were not using QR medications at an elevated level that would reflect poor asthma control. However, exploratory analyses revealed that the interaction of parent asthma numeracy skill and child age was associated with QR medication use in children differently for younger and older children. This is important to consider, as children may have varying levels of responsibility for managing their medications based on age. The results indicated that a decrease in parent numeracy skill decreased the probability of older children using their QR medications frequently. Clinically, this may imply that if parents have lower numeracy skill, then their children are not likely to use QR any more frequently than if the parents had higher numeracy skills, if these children fall in an older age group. This is consistent with past literature that indicates children start to take more responsibility for their asthma in their teenage years (Gibson-Scipio & Krouse, 2013; Orrell-Valente et al., 2008) , as the parent's numeracy skills do not interfere with their QR medication use. The exploratory analyses also indicated that an increase in parent numeracy skill increased the probability of younger children using their QR medications more frequently, which may imply poorer asthma control. This is inconsistent with previous literature that indicates greater parent numeracy skill is associated with better child asthma control (A. J. Apter et al., 2013; Krishnan et al., 2016). When interpreting these findings, it is important to consider the aforementioned factor of the level of responsibility each child has for managing their asthma. Additionally, it is important to consider that a majority of the participants in this study were not using QR medications at an elevated level that would reflect poor asthma control, and that greater likelihood of using QR medications does not indicate use at a level that would indicate poor asthma control.

Acute HCU. Parent asthma numeracy skill was not associated with ED visits or sick visits in children, as per adjusted analyses. These outcome measures were dichotomized due to positive skew and elevated kurotsis. Relevant to ED visits, the mean frequency of visits was 1.87 and the significant covariate was child age. As age increased, the frequency of ED visits decreased. When child age was accounted for, ANQ was not associated with frequency of ED visits. However, the analyses indicated a trend towards an increase in ANQ being associated with decreased likelihood of ED visits. Unadjusted analyses revealed the same;

increase in ANQ was associated with decreased likelihood of ED visits. This is consistent with previous literature; low parent asthma numeracy has been associated with increased likelihood of visiting the ED (Rosas-Salazar et al., 2013) and more broadly, patients in the ED tend to have a higher prevalence of low numeracy (Ginde, Clark, Goldstein, & Camargo Jr, 2008). In the latter study, age was also independently associated with numeracy, as was true for the current study.

Relevant to sick visits, the mean frequency of visits was 2.88 and there were significant associations with child age and child gender. The association between sick visits and child age was negative; as one increased, the other decreased. Male children had less frequent sick visits than female children. The latter is consistent with previous literature which reveals that females with asthma are almost twice as likely to use the ED (Awadh, Chu, Grunfeld, Simpson, & FitzGerald, 1996; Lin et al., 2020) and be hospitalized (Stanford, Mclaughlin, & Okamoto, 1999) than males. While previous literature reports ED use, this may also translate to use of sick visits to urgent care centers which have increased over time, as EDs are often considered to be at high capacity (Yee, Lechner, & Boukus, 2013).

Parent Asthma Numeracy and Asthma Control

Subjective Asthma Control. Parent asthma numeracy skill was not associated with asthma control, as determined by ACT and C-ACT. These data were dichotomized as either well controlled or poorly controlled, however mean scores revealed that both participants who took the ACT and those who took the C-ACT were close to the clinical cut-off of 19, with 18.99 for the former and 18.78 for the latter. This is important to consider, as subjective asthma control was not as simple as the dichotomized categories may suggest; the differences between control were subtle in this sample. This is also indicative in the split between participants with poorly controlled (50.4%) and well controlled (49.6%) asthma.

Child gender was significantly associated with subjective asthma control, and male children reported significantly more well controlled asthma than female children. This is consistent with a previous study that reported females are more likely to report poorer breathing control and have a greater perception of dyspnea (Chhabra & Chhabra, 2011), indicating that females may report poor control more often than males. This study also reported that males are more likely to report similar levels of control to females, despite having greater airway obstruction. While this study was conducted in adults, the findings are important to consider when interpreting the results of the self-report measure of asthma control.

Additionally, while parent asthma numeracy was not associated with subjective asthma control, it is important to note the differences between these two self-report constructs. The ANQ contains items that strictly involve the utilization and interpretations of quantitative information, while the ACT and C-ACT involve recognition of asthma related symptoms. The latter measure does not involve the recognition, utilization, or interpretation of quantitative information, as the other outcome variables do. The null findings of this hypothesis highlight how the subjective ACT and C-ACT measures do not require, and are not influenced by, numeracy skills.

Pulmonary Function. Parent asthma numeracy skill was not significantly associated with pulmonary function, as determined by %FEV1. Values for %FEV1 ranged from 45-126%, indicating variance in the participants. However, parent ethnicity was significantly associated with %FEV1. African American and Dominican parents had children with significantly lower pulmonary function compared to Other Latinx parents, whom had children with the highest pulmonary function. These results are consistent with previous literature, which cites African-American ethnicity as a predictor of asthma severity (Ramsey, Celedón, Sredl, Weiss, & Cloutier, 2005) and generally lower %FEV1 values for Black Caribbean/African children, than those children of White and Asian heritage (Whitrow & Harding, 2008).

Sample Characteristics

The above findings are representative of a sample of 10-17year-old Black and Latinx children with asthma, and their parents, who were predominantly female. The results should be interpreted in the context of the demographics of these participants. In this sample, there were few associations between demographic variables and the outcome measures. No demographic variables were significantly associated with ICS adherence or QR use. However, previous literature informs important considerations when interpreting the non-significant findings.

Adherence in the current study sample was generally low, which is consistent with literature that highlights the underuse of ICS medications in ethnic minorities (Arcoleo et al., 2019; McQuaid, 2018; McQuaid et al., 2012). This underuse may be attributed several factors, including social, cultural, political, or geographic variables. Children in the Bronx have high rates of exposure to risk factors, and a unique set of environmental triggers (Warman et al., 2009). They have the highest rates of asthma related hospitalizations, emergency department (ED) visits, and mortality (Garg et al., 2003). It is important to consider this information when understanding the mean scores regarding HCU within this diverse sample of participants. While ICS use, adherence, HCU, and subjective asthma control were not associated with ethnicity, this was in the context of an already diverse population; the results may have differed in a sample with both ethnic minorities and Non-Latinx White participants.

Ethnic background may have also been associated with other demographic variables. Literature suggests that Latinx families are more likely to live below the poverty threshold than African American and White families (Tackett et al., 2020). In the current study, a majority of the participants were living below the poverty threshold and a majority of the parent-child dyads identified as Latinx. Literature suggests that Puerto Rican and Mexican subgroups have the largest disparities in asthma prevalence and control (Lara et al., 2006). Sociocultural factors such as family support (Scheckner, Arcoleo, & Feldman, 2015) and acculturation (Siañez, Highfield, Balcazar, Collins, & Grineski, 2018) are among contributing factors. In this study, differences between the various Latinx subgroups were not analyzed and may have provided important insight. This heterogeneity between Latinx groups warrants further investigation regarding the key differences and their potential in contributing to the results.

Clinical Implications

Most notably, the current study indicates that parent asthma numeracy skill is positively associated with parent illness representations, and therefore parent understanding of asthma aligning with the professional model. This relationship is significant even when parent education, household income, and parent ethnicity are accounted for. Though the directionality of this relationship is not known, clinical interventions to address either of these constructs may improve parent understanding of their child’s asthma. This understanding may inform their subsequent management of their child’s asthma and improve clinical outcomes. Interventions to improve numeracy skill may include brief psychoeducation from providers regarding the quantitative information needed to understand asthma management and control (dosage instructions, information regarding peak flow and spirometry values) that can be provided at clinic visits and follow-ups, to ensure both parents and children have an adequate understanding. Alternatively, assessing parents' asthma illness related beliefs and addressing any misconceptions about asthma, may help parents align their asthma related beliefs closer to the professional model of asthma. It is also important to keep in mind, that while level of education, household income, and parent ethnicity are associated with AIRS scores, they may not be associated with the ANQ. Therefore, assumptions regarding parent asthma numeracy and quantitative capability should not be made based on parent education, income, or ethnicity. It is important to assess parent ANQ in these groups as well and psychoeducation should be provided to all parent-child dyads.

Additionally, the association between asthma numeracy and asthma illness representations may suggest of the clinical utility of the ANQ in quickly identifying asthma illness representations. The ANQ's use as a brief screening tool may assist health care providers in quickly gauging a parent's likely understanding of both numeracy and asthma as an illness. This information can then inform these providers regarding how much time should be spent on basic asthma psychoeducation topics.

This study also indicated there was a trend in unadjusted analyses regarding the association between parent asthma numeracy and ED visits, with an increase in ANQ being associated with decreased likelihood of ED visits. This may imply that parents with greater numeracy skill are likely to have children with fewer ED visits. Again, a brief psychoeducation intervention regarding overview of quantitative asthma information may be helpful in managing asthma control. This can be considered a preventative strategy, particularly if it decreases the likelihood of children utilizing acute health care for their asthma symptoms. Additionally, for those children who have ED visits, providers at that visit can quickly assess parent asthma numeracy as a screening tool that may provide them with information regarding parents' understanding of asthma and their likely adherence to recommendations made in the ED. It is likely that parents with lower numeracy may need more time and assistance from ED providers in understanding recommendations for follow-up care, such as utilizing steroid burst medications and understanding changes in pulmonary function. This information is critical to asthma management.

Lastly, this study indicated that child gender was significantly associated with ED visits, sicks visits, and ACT/C-ACT scores. Girls were more likely than boys to have utilized ED visits and sicks visits, as well as to have lower subjective asthma control. This is important information to keep in mind, as it suggests that girls are more likely to struggle with asthma control. At a clinical level, it may also be important to assess girls' perception of their asthma control and its accuracy. If girls are over-perceiving their symptoms, they may be over utilizing health care or have beliefs closer to the lay model, that asthma is episodic and uncontrollable. If girls are accurately perceiving their asthma control as poor, and managing via HCU, then providers can provide psychoeducation regarding factors that can improve control (ex. adherence, avoidance of triggers). The aforementioned strategies for psychoeducation and quick evaluation regarding asthma control and understanding, can be implemented by a variety of health care providers in order to improve child asthma related outcomes.

Limitations

This study has some limitations. Due to the recruitment of Black and Latinx children, ages 10-17 years old, speaking either English of Spanish, who were treatment-seeking, results are not generalizable to the broad population of individuals with asthma across the globe. However, this sample is representative of the Bronx, NY, where asthma prevalence is particularly high, especially in children.

The cross-sectional design of this study may also be a limitation as it only provided information during two time points (baseline and randomization) of the study; a longitudinal design would have been ideal to understand results over a longer period of time and assess the stability of the construct of parent numeracy as well, and whether parent ANQ scores change across a longer span of time. Additionally, the collection of information at two different time points may have reduced clarity. There may have been a number of factors from one session to the next, that could have influenced the data. The inclusion of two timepoints in this study may also have contributed to the missing data for medications, which is another limitation. If all data were collected at one time point then this may have been avoided. The lack of ICS adherence data is important to consider when interpreting those results. Several participants lost or forgot to bring in their electronic devices to the appropriate session, which led to a large amount of data to be classified as missing. However, despite the inclusion of two time points, all measures were collected prior to the CAPS intervention, so as to minimize the impact of that intervention on the results.

Another limitation of this study was the use of self-report measures, including the ANQ, ACT/C-ACT, and AIRS, which may involve the presence of selection bias on the part of the participants. These participants had chosen to be a part of an intervention study targeted towards improving child asthma outcomes, and it is possible they underreported or overreported on these measures at the beginning of the study when these were administered. Also, this study primarily focused on Parent asthma numeracy and does not address its relationship with child asthma numeracy, which may be an interesting construct. Future studies can take this variable into account in order to assess the similarities and differences each measure has on asthma management and control, and whether one is associated with better outcomes than the other.

Future Directions

The current study raises several questions and possible new directions for future research. While parent numeracy had a positive association with parent asthma illness representations, the causality of this relationship is unknown. Additionally, 3 demographic variables (household income, parent education, parent ethnicity) were significantly associated with parent asthma illness representations. It would be interesting to determine the strength and directionality of all these relationships, as well as their influence over time. There is extensive literature regarding the influence of sociocultural and ethnic factors on asthma illness representations more broadly. It is likely that these factors may influence or be associated with the construct of parent numeracy as well. It would be interesting to address and analyze factors related to family, neighborhood, social support, and acculturation. It would also be interesting, and important, to better understand the heterogeneity between Latinx subgroups with regards to historical asthma outcome trends and factors the influence them.

As previously stated, longitudinal analyses with the predictor ANQ and the current outcome variables may also yield interesting results and should be considered. Given the results indicating that greater parent numeracy skill was associated with worse ICS adherence in unadjusted analyses and a greater likelihood of younger children using QR medications, it is important to determine the extent to which children have the responsibility of managing their asthma medications. Including a measure to assess the responsibility may provide more context for these results and give useful insight into the age at which this population of children tends to manage their asthma on their own. Relative to data collection, in the future it may be helpful to implement strategies to obtain medication management data. Considerations may include: reminder calls to patients to bring devices, participant report of data over the phone after the session, and better technology for remote patient monitoring.

Further research with the ANQ measure may also provide useful information on this construct, and its consistency and reliability. An item-level analysis on the ANQ may help determine the quality of this measure, which items are more difficult and may thus benefit from clarification, and overall how many of the items are needed to determine the construct of numeracy skill (Livingston, 2011). Additionally, evaluating these data and examining the relationships through a path analysis may provide greater information on causality and the relationship between the dependent variables. Lastly, as previously mentioned the current study primarily focuses on parent asthma numeracy without addressing the relationship with child asthma numeracy. Future studies analyzing similarities and differences between these constructs and their relationships with asthma management and control may be interesting.

Conclusions

The study yielded several results. Greater parent asthma numeracy skill was associated with views more closely aligned with the professional model of asthma, in both adjusted and unadjusted analyses. With higher levels of parent asthma numeracy skill, parents aligned closer with views of the professional model of asthma. In unadjusted analyses, parent asthma numeracy was associated with fewer ED visits and lower ICS adherence. Findings differed when covariates were entered in the models. Only those covariates that were significant for each model were included in the adjusted analyses. Other analyses also indicated several significant associations between: (1) parent education and ICS adherence (2) child age and number of ED visits, (3) child age and gender and number of sick visits, (3) child gender and subjective asthma control, (5) parent ethnicity and child pulmonary function, (6) parent education, household income, and parent ethnicity and parent asthma illness representations, (7) interaction of child age and parent numeracy skill on QR medication use, and (8) parent education, household income, and child age on parent asthma numeracy skill.

However, the study analyses also revealed non-significant findings. Parent asthma numeracy skill was not significantly associated with ICS adherence, QR medication use, HCU, subjective asthma control, or pulmonary function in adjusted analyses. Additionally, other analyses indicated that QR medication use was not associated with the ANQ or any demographic variables. The results of the study can be better understood in the context of the diverse participant sample.

Overall, the results of the study provide interesting information on the concept of asthma numeracy and its association with health beliefs. Results suggest that asthma numeracy plays a role in how parents view their child’s asthma, as greater numeracy was associated with parents’ knowledge of asthma, as based on the AIRS. There is potential for the use of the ANQ to assess and screen for parent beliefs about asthma self-management, in order to improve these outcomes. Further research is needed in this area. The results of this study also provide a basis for clinical interventions (psychoeducation, brief screening) to address the constructs of asthma numeracy and illness representations with the goal of improving parent understanding of their child's asthma and management strategies, to improve clinical outcomes. This study offers several interesting results and highlights the need for greater research related to the construct of numeracy, factors that influence child asthma management and control, and significant variables in their relationships.

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Appendix A

Asthma Numeracy Questionnaire

Here are some examples of statements or questions that 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 1,000 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