The Role of Asthma Management Beliefs and Behaviors in Childhood Asthma Immune and Clinical Outcomes

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Objective This study examined associations of asthma management-related beliefs and behaviors with immune markers and clinical outcomes in a sample of 66 children with asthma (ages 9–18 years). **Methods** Children and parents were interviewed about asthma management beliefs and behaviors. Immune measures included stimulated production of cytokines implicated in asthmatic airway inflammation, eosinophil counts, and IgE levels. Clinical outcomes included pulmonary function, symptoms, β-agonist use, and physician contacts. **Results** Children's reports of greater conceptual understanding of asthma, parents' reports of quicker responses to asthma symptoms, and children's and parents' reports of more balanced integration of asthma into daily life were all associated with reduced inflammatory profiles. Inflammatory profiles were found to be a statistically significant pathway linking asthma beliefs and behaviors to clinical outcomes. **Conclusions** These findings suggest that interventions aimed at teaching families better asthma management approaches may have the potential to alter biological profiles in children with asthma.

Key words asthma; children; health behavior.

Introduction

Researchers have long been interested in the role of psychological beliefs in physical illnesses (Kirscht, Haefner, Kegeles, & Rosenstock, 1966). Health-related beliefs may include cognitions and attitudes about what illness is, how one should respond to symptoms, and how efficacious such responses would be. In turn, beliefs are thought to underlie the behaviors that individuals engage in, and subsequently, their health outcomes (Bandura, 1986; Rosenstock, Strecher, & Becker, 1988). Very little empirical data exist, however, testing whether there are biological correlates of beliefs that could explain how beliefs might affect clinical outcomes. The present study tested biological pathways between psychological beliefs and behaviors and clinical outcomes in a sample of children with asthma.

Previous research has found that asthma-related beliefs are linked to both behavioral and clinical outcomes. Several studies of adults with asthma have found that certain beliefs are associated with behavioral outcomes such as treatment adherence. For example, poorer adherence to medication regimens has been associated with beliefs that medications are inefficacious or only necessary when symptomatic, concerns about adverse effects of medications, and the belief that asthma only exists when one is symptomatic (Byer & Myers, 2000; Halm, Mora, & Leventhal, 2006; Horne & Weinman, 2002; Jessop & Rutter, 2003).

In children with asthma, belief about one's ability to perform behaviors beneficial to asthma (self-efficacy) has been associated with clinical outcomes such as asthma morbidity. Both greater child self-efficacy as well as greater parent self-efficacy were associated with better child health status and fewer symptoms among children with asthma (Bursch, Schwankovsky, Gilbert, & Zeiger, 1999). In addition, positive beliefs among parents about how helpful asthma management behaviors would be were associated with fewer days of wheezing and better health status in children with asthma (Wade, Holden, Lynn, Mitchell, & Ewart, 2000). Better asthma management in terms of a better integration of asthma into the family's daily life, a more collaborative relationship with physicians, and more timely responses to symptoms all have been associated with decreased asthma morbidity in children (McQuaid, Walders, Kopel, Fritz, & Klinnert, 2005). Finally, there is

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some evidence to suggest that knowledge is associated with behaviors in childhood asthma. For example, greater knowledge about asthma was associated with better management behaviors in African-American adolescents (Sin, Kang, & Weaver, 2005), although other studies have not found significant effects of knowledge (McQuaid et al., 2005; Wade et al., 2000). Developmental changes in understanding childhood illness have also been examined (McQuaid, Howard, Kopel, Rosenblum, & Bibace, 2002), and in a sample of children aged 7–16 years with persistent asthma, age was positively associated with factual knowledge regarding asthma, and the conceptual sophistication of reasoning about asthma.

All of the above studies have focused on the links between beliefs and clinical and behavioral outcomes in asthma. Very little research has explored the possible biological mechanisms through which asthma management beliefs and behaviors may be linked to clinical outcomes. Elucidating biological mechanisms is important for developing plausible models of how it is that psychological factors such as beliefs can have clinical manifestations in terms of disease outcomes. With respect to possible biological mechanisms, asthma is known to be an inflammatory disease. During an asthma exacerbation, antigens activate T cells which release chemical messengers known as cytokines (IL-4 and IL-13) that activate B cells and signal these cells to produce immunoglobulin E (IgE), which in turn stimulates mast cells to release histamine (Janeway, Travers, Walport, & Shlomchik, 2001, p. 472). Additionally, other cytokines (IL-5) activate eosinophils, which also produce histamine and leukotrienes. The production of histamines and leukotrienes leads to the symptom profile associated with asthma (airway constriction and mucus production). Thus assessing the production of these cytokines, known as Th2 cytokines (IL-4, IL-5, and IL-13), as well as circulating levels of IgE and eosinophils provides an indication of the extent of an inflammatory profile relevant to asthma.

Thus, the current study sought to explore whether asthma management beliefs and behaviors have biological correlates in children with asthma. Specifically, we examined: (a) whether beliefs and self-reported behaviors were associated with immune markers implicated in asthma; and (b) whether these immune markers statistically mediated the relationship between asthma management beliefs/behaviors and clinical asthma outcomes. We hypothesized (a) that asthma management dimensions including greater knowledge, better response strategies, and better integration of asthma into daily life would be associated with reduced inflammatory profiles in children with asthma, and (b) that these inflammatory profiles would serve as one pathway between asthma management and clinical outcomes.

Methods

Participants

Sixty-six children with asthma living in Vancouver, B.C., Canada between the ages of 9 and 18 years comprised this sample. Average age was 12.8 ($SD = 2.8$), 66% were male, 66% were Caucasian (19% Asian descent, 1% African descent, 1% Latin American descent, 4% Native descent, and 9% self-identified as other ethnicity), 83% of parents participating were mothers, average years of maternal education was 15.9 ($SD = 3.0$), and average family income fell into the $50,000–74,999 category. Families were recruited via asthma and allergy clinics, newspaper ads, school newsletters, and community flyers. Eligibility criteria included physician diagnosis of asthma, no other chronic illnesses, proficiency in English, and not on any prescription medications other than asthma medications. Study visits were postponed if children were sick on the day of their scheduled appointment. Ethical approval was granted by the Ethics Board of the University of British Columbia.

Measures

The Health Beliefs Interview

Children and parents were interviewed separately about asthma management beliefs and behaviors, using the Health Beliefs Interview. This open-ended interview developed for this study assessed children's and parents' beliefs about asthma and its management, as well as the behaviors that they engaged in associated with asthma exacerbations. Although the Health Beliefs Interview was a shorter interview, and was administered separately to children and parents, a number of the questions paralleled those of the Family Asthma Management System Scale (FAMSS), a more extensive asthma management interview that has excellent reliability and validity (Klinnert, McQuaid, & Gavin, 1997; McQuaid et al., 2005). We drew on the conceptualization of the FAMSS when we developed our coding scheme for the Health Beliefs Interview. The subscales included in this interview were child conceptual understanding, child and parent response to asthma symptoms, and child and parent balanced integration.

Conceptual Understanding of Illness (Child). Children's understanding of asthma was probed by asking them to explain what asthma was, and any potential causes, triggers, and biological mechanisms involved in asthma. Responses were scored on a 1–6 scale with higher numbers

reflecting a greater conceptual understanding of asthma. The categories of this scale included: ''Phenomenism,'' representing a score of 1, reflecting the least amount of knowledge; ''Contagion,'' a score of 2; ''Contamination,'' a score of 3; ''Internalization,'' a score of 4; ''Physiological,'' a score of 5; and ''Psychophysiological,'' the highest score of 6, reflecting the greatest conceptual understanding of asthma. Guidelines for rating conceptual understanding were drawn from the Developmental Levels of Illness Concepts scale (McQuaid et al., 2002). At the lower end of the scale, children described asthma without clear differentiation between cause and effect—for example, confusing triggers with symptoms of asthma by believing that asthma is caused by chest tightness. At the upper end of the scale, children were able to describe the illness in a psychophysiological sense, attributing multiple causes and their resultant effects on the illness—for example, attributing allergic and psychological triggers and describing changes to the airways and immune system, leading to the symptoms experienced.

Family Response to Asthma (Child and Parent). Children and parents were asked about their beliefs regarding how they would respond to asthma symptoms. Children's responses were coded in terms of how quickly they believed they would respond to symptoms with inhaler use. The majority of children (75%) reported they believed they would take their inhaler ''right away,'' hence this variable was coded into two categories: those who believed they would respond immediately, and those who believed they would wait some time before taking medications.

Parents' responses to asthma exacerbations their child experienced was coded in terms of how long they would wait, after their child's symptoms began, before seeking medical attention. The majority of parents (74%) reported that they would contact their physician that day if symptoms persisted. Hence this variable was coded into two categories: contacting their physician that day (coded as prompt responses) versus waiting a day or longer (responses ranging from 1 day to 1 week, coded as longer responses). Some families (11%) reported that they had never contacted their physician because of an uncontrolled asthma exacerbation, and thus these families had no response coded on this dimension.

Balanced Integration (Child and Parent). Balanced integration referred to the extent to which families were able to integrate illness management into their everyday lives. Children were asked about their beliefs about how much asthma interfered with or changed their daily activities. Those who endorsed the importance of maintaining usual levels of activity as much as possible when feeling symptomatic were coded as having a better balanced integration of their illness into everyday life. Twenty-five percent gave responses indicating that they would keep up with their usual activities or could not think of any they would stop. The remaining 75% of participants reported a limited set of activities that they would continue (that is, only continuing with certain activities, rather than all activities), or reported that they would stop all activities when their asthma worsened. Because only 6% reported that they would stop all activities, we grouped these children together with those that limited activity levels. Hence there were two categories for this variable: children who would keep up with most things versus those who would stop some or everything they were doing when symptomatic.

Parents were asked to discuss the demands they experienced in their daily lives that competed with taking care of their child's asthma. Their beliefs were assessed using the following probes: whether work demands, other child or family responsibilities, or any additional responsibilities conflicted with taking care of their child's asthma. The number of competing demands was coded, and scores ranged from 0 to 3, with a lower score indicating fewer competing demands, and hence a better balanced integration.

For each of the subscales of the Health Beliefs Interview, participants were asked to provide responses based on their beliefs and how they would respond currently. Thirty percent of interviews were independently recoded by a second interviewer and intraclass correlations were computed. Across all subscales, the average coefficient was .72 (range .60–.80).

Biological Pathways

Immune Measures

Cytokine Production. White blood cells' cytokine secretion in response to mitogen stimulation was measured as an in vitro model of allergen exposure, as has been done in previous studies on stress and cytokines in asthma (Kang et al., 1997; Marshall et al., 1998). This technique involved isolating mononuclear cells from blood samples and exposing the cells to an equivalent dose of a mitogen, known as phorbol myristate acetate combined with ionomycin (PMA/INO). Mitogens are substances that trigger T cells to produce cytokines. Cytokines are chemical messengers of the immune system that coordinate inflammatory responses. Because the types of cytokines implicated in asthma are largely released in response to a stimulus, we measured the production of cytokines

after experimental exposure to PMA/INO, as opposed to basal levels of cytokines (which are often undetectable). Greater cytokine production indicates the tendency for immune cells to mount a heightened inflammatory response, which in the context of an inflammatory condition such as asthma, would be considered detrimental.

The protocol for this technique has been detailed elsewhere (Chen et al., 2006), but briefly, involved drawing 16 cc of blood and exposing a fixed number of peripheral blood mononuclear cells (3 million cells/ml) to 25 ng/ml PMA and 1 μg/ml INO for 48 hr. After incubation, supernatants were removed and assayed to determine levels of IL-4, IL-5, and IL-13 using enzyme-linked immunosorbent assays (ELISA) (R&D System, Minneapolis, MN, USA).

Basal Immune Markers. Three cubic centimeters of peripheral blood was drawn into an ethylenediaminetetraacetic acid (EDTA) tube and a complete blood count with differential (Bayer ADVIA 70 hematology system, Holiston, MA, USA) was performed to enumerate eosinophil count. Ten cubic centimeters of peripheral blood was drawn into a serum separator tube (SST), and total IgE values were obtained from serum (Pharmacia UniCAP 100, Uppsala, Sweden).

Clinical Outcomes

Pulmonary Function

Pulmonary function was assessed using spirometry (Vmax/Spectra, SensorMedics, Yorba Linda, CA, USA). Measurements included forced expiratory volume in 1 s (FEV_1), the amount of air forced from the lung starting from full lung capacity. Percentiles were calculated by comparing this value to reference values based on child age, ethnicity, gender, height, and weight. Lower FEV_1 percentiles indicated poorer pulmonary function. Participants in our study had FEV_1 percentiles that indicated largely well-managed asthma (Table I).

The Health Symptoms Questionnaire

Children were asked to report their asthma symptoms during the last 2 weeks. They were asked about the number of days they experienced symptoms (coughing, wheezing, shortness of breath, or chest tightness) throughout the day ($M = 2.8$), while being active ($M = 0.8$), and at nighttime ($M = 2.8$), [1997 National Asthma Education and Prevention Program (Emond, Camergo, & Nowak, 1998)]. A total asthma symptom score was created by averaging responses to these three questions, and the reliability of this measure was 0.79 (Cronbach's α).

Table I. Descriptive Information of Sample

	%	*M*	*SD*	Range
Medications				
β-Agonist		4.2	5.6	0–14
Inhaled corticosteroid		4.5	6.0	0–14
Asthma severity				
Mild intermittent	15.4			
Mild persistent	38.5			
Moderate	32.1			
Severe	14.1			
Biological outcome measures				
IL-4 (pg/ml)		19.5	27.2	0–131
IL-5 (pg/ml)		114.8	83.5	17–452
IL-13 (pg/ml)		534.2	349.0	62–1782
Eosinophil count (10^9 cells/l)		0.4	0.3	0–1.5
IgE		519.8	1175.8	2–9104
Clinical outcome measures				
FEV_1 %		97.4	15.6	53–137
Asthma symptoms score		2.3	2.8	0–14
β-Agonist use		2.0	3.9	0–14
Physician contacts		0.7	1.9	0–15

Medications, number of days participants used inhaled corticosteroids and β-agonists in the 2 weeks prior to their visit. Asthma symptoms score, the average number of days experiencing symptoms during the day, while being active, and at night during the past 2 weeks. β-Agonist use, number of days the child had to use β-agonists in the previous 2 weeks because of asthma exacerbations (the earlier measure of β-agonists included regular use, such as preventatively before exercise or physical activities). Physician contacts, number of times they or their parents had to contact their physician in the last 6 months because of asthma exacerbations. Normative values in healthy volunteers for IgE is 22 kU/l, expressed as a geometric mean (Pharmacia Diagnostics, London, UK). The geometric mean for our sample was 144 kU/l. Healthy eosinophil counts are usually less than .45 cell/L (Boxer, 2004).

Medical Variables

Children were asked the number of times they had to use a β-agonist inhaler because of asthma symptoms during the last 2 weeks (β-agonist use). Children were also asked the number of times they or their parents had to contact their physician in the last 6 months because of asthma exacerbations, not during a regular appointment (physician contacts).

Procedure

Families who participated in this study were first screened for eligibility, and then scheduled for an appointment at our laboratory. Consent and assent forms were signed at the laboratory. A local topical anesthetic cream (EMLA) was applied to the antecubital area of the child's arm an hour before the blood draw. Interviews were administered and audiotaped. Interviewers were trained by the study's primary investigator, and were either undergraduate-level research assistants, graduate students, or the project coordinator. Medications were brought in by the parents,

and prescription information was recorded. Height and weight were taken on a standard medical-grade balance beam scale. The child's lung function was assessed via spirometry. Children were coached in appropriate blowing techniques, and 6–8 trials were done for each child to obtain a laboratory best FEV_1, according to American Thoracic Society guidelines (Miller et al., 2005). Measures were taken at least 4 hr after the last use of a β-agonist. Following spirometry, a sample of the child's blood was drawn. Participants were paid an honorarium of $25 each for their time.

Data Analysis

Data analyses proceeded in three steps: (a) testing relationships between asthma management beliefs/behaviors and immune markers; (b) testing relationships between immune markers and clinical outcomes; and (c) testing whether immune markers statistically mediated the relationship between asthma management beliefs/behaviors and clinical outcomes. Our primary interest was in testing whether specific types of asthma management variables would be associated with immune or clinical variables. Because we did not expect associations to vary depending on which immune marker or clinical variable was used, we created composite immune and clinical indicators. Because each immune marker and each clinical variable had different means and ranges, we first standardized these variables so that each immune marker and each clinical variable would have a mean of 0 and *SD* of 1 so that they would each contribute equally to the composite score. We then averaged all immune variables (IL-4, IL-5, IL-13, eosinophil count, and IgE) to generate the average, composite immune score and similarly, we created the composite clinical score by standardizing and then averaging the clinical variables (FEV_1 percentile to indicate lung function, asthma symptoms, use of a rescue inhaler, and physician contacts). However, because the measure of lung function is in an opposite direction to the other clinical variables—that is, higher scores are better for lung function, whereas higher scores are worse for symptoms—scores on the lung function measure were reverse coded (multiplied by −1) so that the directionality would be the same as the other clinical variables (i.e., better lung function percentiles would now be represented as lower, more negative, scores). Hence, we tested associations between asthma management variables and composite immune and composite clinical variables. All analyses controlled for child age, maternal years of education, and number of days of inhaled corticosteroid use in the 2 weeks prior to the visit. Child age and maternal education were controlled because of the associations reported below. Child self-reported inhaled corticosteroid use was controlled as an indicator of adherence to medications. Medication adherence could serve as an alternative explanation for why beliefs and biological variables may be correlated. Controlling for asthma severity did not modify the pattern of results reported, and thus it was not controlled for.

Partial correlations were used for variables that were continuous, and one-way analyses of covariance (ANCOVAs) were used for variables that were dichotomized. If participants were missing data for a specific variable, they were excluded from analyses using that variable. Effect size estimates are presented for primary analyses in terms of *d*, with values of .2 considered small, .5 considered medium, and .8 considered large (Cohen, 1988).

Results

Descriptive Information

The distribution of scores for the children's understanding of illness question was as follows: 11% of respondents scored a 1 on the 6-point scale, reflecting the least amount of knowledge in the ''Phenomenism'' category; 21% of children scored a 2, corresponding to the ''Contagion'' category; 31% of children scored a 3, corresponding to the ''Contamination'' category; 24% of children scored a 4, corresponding to the ''Internalization'' category; and 13% of children scored a 5, corresponding to the ''Physiological'' level of understanding. None of our participants received the maximum possible score on this scale, of 6 points, corresponding to the ''Psychophysiological'' level of understanding.

Responses to the Health Beliefs Interview (HB1) did not differ by child gender or race, but they did differ by age. Child age was positively correlated with children's conceptual understanding of asthma, $r(65) = .25$, $p < .05$. Children with better balance ratings were on average older than those children with worse balance ratings, $t(64) = 2.37$, $p < .05$. Children whose parents waited longer to contact their physician once asthma symptoms started were also older on average, than those children whose parents contacted their physician sooner, $t(54) = 3.30$, $p < .01$. Mothers' years of education were positively correlated with children's conceptual understanding of asthma, $r(65) = .35$, $p < .01$. Greater years of education also correlated with fewer parent competing demands, $r(60) = -.28$, $p < .05$. Given these associations, we controlled for child age and maternal education in all analyses.

Health Beliefs and Immune Measures

Conceptual Understanding of Asthma

Ratings of children's conceptual understanding of asthma were negatively correlated with the composite immune variable, controlling for age, maternal education, and inhaled corticosteroid use, $r(63) = -.25$, $p < .05$, $d = .51$. This correlation indicated that a greater conceptual understanding of asthma in children was associated with reduced inflammatory profiles (i.e., lower stimulated production of cytokines, lower basal levels of eosinophils and IgE).

Family Response to Asthma

A one-way ANCOVA controlling for child age, maternal education, and child self-reported inhaled corticosteroid use was conducted to examine the relationship between child response to asthma symptoms and the composite immune variable. The results revealed no statistically significant main effect of ratings of child response to asthma on the immune composite, $F(1,55) = 3.12$, $p < .08$, $d = .48$.

There was a main effect of ratings of parents' response to asthma with the immune composite, $F(1,54) = 4.15$, $p < .05$, $d = .55$. Parents who reported calling their doctor by the end of the day after symptom onset had children with significantly reduced immune composite scores ($M = -0.17$, $SD = 0.51$) compared to children of parents who reported waiting longer to contact their physician ($M = 0.19$, $SD = 0.90$), (Fig. 1).

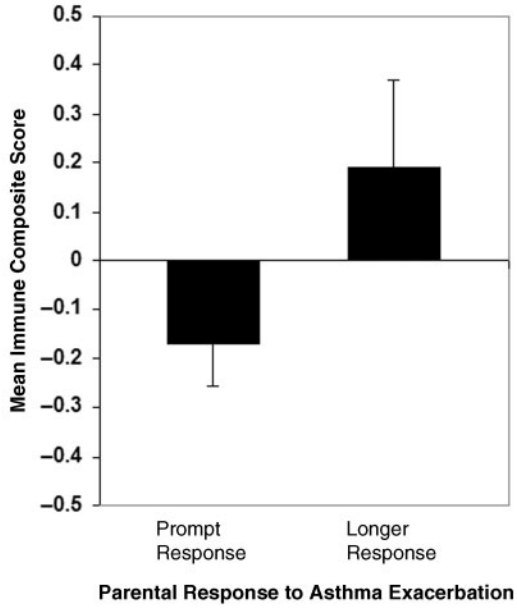

Figure 1. Mean immune composite score by parental response to their child's asthma exacerbations ($p < .05$). Parents were asked how long they would wait, after their child's symptoms began, before seeking medical attention (e.g., phoning their doctor). Responses were coded as prompt (calling that day) versus longer responses (waiting from one day to one week). Mean immune composite score was created by standardizing each immune variable and calculating the average; lower numbers reflect better immune composite scores.

Balanced Integration

A one-way ANCOVA controlling for child age, maternal education, and child self-reported inhaled corticosteroid use was conducted to examine the effect of child balanced integration on the composite immune variable. There was a significant effect of ratings of child balanced integration on the composite immune variable, $F(1,64) = 9.27$, $p < .01$, $d = .76$. Children who reported keeping up with usual activities had lower scores on the immune composite ($M = -0.28$, $SD = 0.43$) compared to children who reported that they stopped some or most things when their asthma worsened ($M = 0.17$, $SD = 0.76$), (Fig. 2).

Partial correlations were conducted to assess the relationship between ratings of parents' balanced integration (as measured by the number of competing demands in their daily lives) and the composite immune variable. Ratings of parents' balanced integration were positively correlated with children's immune composite score, $r(58) = .26$, $p < .05$, $d = .54$. This pattern indicates that an increased number of competing demands in parents'

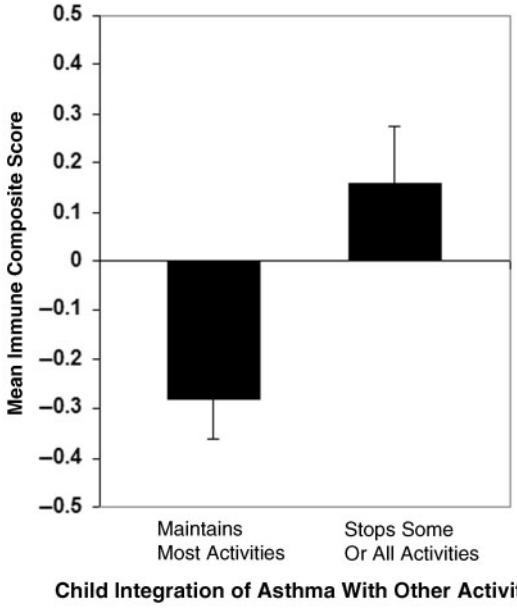

Figure 2. Mean immune composite score by child balanced integration ($p < .01$). Children were asked about how much asthma interfered with or changed their daily activities. Responses were coded as those who would maintain most activities versus those who would stop some or all activities when symptomatic. Mean immune composite score was created by standardizing each immune variable and calculating the average; lower numbers reflect better immune composite scores.

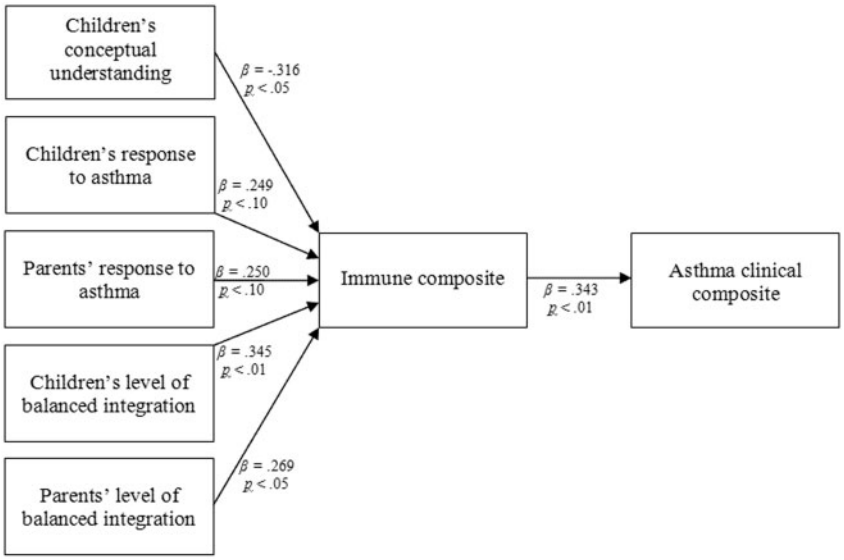

Figure 3. Diagram showing the statistically significant indirect pathways from asthma management variables through the immune composite to the clinical asthma composite. All *z*-statistics for mediation were significant at $p < .05$. Higher numbers for children's conceptual understanding indicates a more sophisticated understanding of asthma. Higher numbers for children's and parents' response to asthma indicates slower response times in dealing with asthma exacerbations. Higher numbers for parents' and children's balanced integration indicate poorer integration of asthma into families' daily lives. The immune composite is scored such that higher numbers reflect greater asthma-relevant inflammation. The clinical composite is scored such that higher numbers reflect greater asthma morbidity.

daily lives was associated with an increased inflammatory profile in children.

Immune Variables and Clinical Asthma Outcomes

Overall, immune variables were significantly associated with asthma clinical variables. Controlling for child age, maternal education, and child self-reported inhaled corticosteroid use, higher scores on the immune composite variable were associated with higher scores on the clinical composite variable, $r(64) = .49$, $p < .001$, $d = 1.12$. This result is consistent with previous research, which indicates that greater inflammatory profiles are associated with greater asthma morbidity (Busse & Lemanske, 2001).

Immune Markers as a Pathway between Asthma Management Beliefs/Behaviors and Clinical Outcomes

Finally, we conducted formal tests of statistical mediation to analyze whether immune markers served as a pathway between asthma management beliefs/behaviors and clinical asthma outcomes. Specifically, we analyzed the significance of the following pathway: asthma management → immune variables → clinical asthma outcomes. We applied the Sobel test with the distributional properties recommended by MacKinnon, Lockwood, Hoffman, West, and Sheets (2002). This statistical test uses a product of coefficients test to determine whether the indirect pathway from an IV (asthma management) through a mediator (immune variables) to the DV (clinical asthma outcomes) is statistically significant. A coefficient of $z > |.97|$ indicates a statistically significant pathway. While other approaches (e.g., Baron & Kenny, 1986) stipulate a set of conditions that must be met for mediation, one limitation of these approaches is that they do not provide a joint test of all the conditions required for mediation, nor do they provide a statistical test of the indirect mediational effect. Hence the product of coefficients test is recommended for tests of statistical mediation.

We tested the role of immune markers for each asthma management variable (Fig. 3). The composite immune variable formed a significant pathway between ratings of children's conceptual understanding of asthma and the composite clinical variable ($z = -2.77$, $p < .05$). Similarly, the composite immune variable formed a significant pathway between ratings of children's response to asthma and the composite clinical variable ($z = 1.66$, $p < .05$), as well as between ratings of parents' response to asthma and the composite clinical variable ($z = 1.57$, $p < .05$). Finally, the composite immune variable formed a significant pathway between ratings of children's level of balanced integration and the composite clinical variable ($z = 1.79$, $p < .05$), as well as between ratings of parent's level of balanced integration and the composite clinical variable ($z = 1.66$, $p < .05$). These findings suggest that immune markers serve as one link between management-related beliefs and behaviors and clinical outcomes of asthma.

Discussion

This study is one of the first to document associations between family asthma management and biological processes implicated in asthma, and offers a unique focus on youth. We found that better ratings of asthma management beliefs and behaviors, in terms of greater conceptual understanding of asthma among children, belief in quicker responsiveness to symptoms among parents, and better integration of asthma into daily life, were all associated with decreased inflammatory profiles in children, as indicated by reduced production of asthma-relevant cytokines, eosinophil counts, and IgE levels. Effect sizes were moderate, suggesting that management-related beliefs and behaviors may be important to understand, for predicting biological profiles in children with asthma. These findings extend previous research on relationships between asthma beliefs or behaviors and clinical outcomes by documenting associations with biological markers. For example, the direction of our findings is consistent with previous research demonstrating that beliefs such as self-efficacy and beliefs in the benefit of asthma management were associated with both behaviors such as better treatment adherence as well as morbidity outcomes such as fewer symptoms (Bursch et al., 1999; Wade et al., 2000).

In addition, decreased inflammatory profiles were associated with better clinical outcomes in youth with asthma, as indicated by a better clinical composite comprised of FEV_1 percentile, symptoms, rescue inhaler use, and physician contacts. The effect size for these associations was large. These results indicate that inflammatory mechanisms associated with Th2 cytokine production and its downstream effects contribute to the clinical manifestation of asthma.

Third, we found that inflammatory profiles constituted a statistically significant pathway from asthma management variables to clinical outcomes. This was true for ratings of multiple types of management dimensions, including children's conceptual understanding of asthma, child and parent response to symptoms, and child and parent balanced integration. Although these data are cross-sectional, the patterns are consistent with an explanation that immunologic mechanisms serve as one factor explaining how the beliefs and behaviors associated with asthma management come to be linked to clinical outcomes.

Overall, these findings document that asthma management beliefs and behaviors are associated with inflammatory profiles that in turn have clinical implications. These findings are preliminary, however, given the small sample size, cross-sectional design, and limited assessment of beliefs and behaviors. In order to further substantiate these findings, future studies need to incorporate longitudinal designs with repeated assessments to determine whether changes in beliefs or management behaviors actually precede changes in immune markers. In addition, future studies need to conduct more in-depth interviews of asthma management, or incorporate multimethod assessments of management behaviors, and test their associations with immune markers.

As briefly noted above, we cannot draw conclusions about the directionality of our findings. It is possible that greater asthma morbidity or heightened inflammatory profiles may shape families' beliefs and behaviors associated with asthma. In addition, the time frame for each of the study constructs did not overlap perfectly. For example, pulmonary function and immune measures were taken at the time of the laboratory visit, whereas physician contacts were assessed over the past 6 months. Future longitudinal studies would allow the time frame for each of these constructs to be more consistent.

Another limitation was the brief assessment of beliefs. Because this was a preliminary study, we conducted a brief interview, and have limited information on psychometrics. Inter-rater reliability for some subscales of the HBI was not high. In theory, this would add noise to a measure, making it less likely to find associations; however, the present study detected a number of associations despite this limitation. Further, parental understanding of illness could also affect asthma management, and was not assessed in the present study. Future research that is able to incorporate more comprehensive, well-validated interviews including both parents and children, such as the FAMSS (McQuaid et al., 2005), into studies of biological processes would provide an important contribution to this literature.

Finally, study measures were limited by relying largely on child and parent self-report. Hence social desirability may have shaped some responses. However, to the extent that social desirability masked true responses, one would expect this to weaken associations with outcome variables; the fact that responses were associated with inflammatory profiles suggests that social desirability may not have been a strong confounding factor in this study. As well, shared-method variance could account for some of the findings, although this would not apply to analyses of immune markers. Future studies that are able to provide additional sources of information and objective measures of adherence (e.g., health care records and electronic medication monitoring devices) would be important to conduct in order to alleviate concerns about shared-method variance and the inaccuracies of self-report measures.

Future research with larger sample sizes should also explore how age affects these relationships. For example, perhaps parent behaviors aimed at managing their child's asthma will be effective in younger children, but less useful in older children as they become more independent and spend more time away from home. Future research should also examine other factors that might predict asthma management beliefs and behaviors, such as socioeconomic background, cultural beliefs, and experiences with the health care system, in order to better understand the origins of asthma management beliefs and behaviors. Finally, future studies could include a more comprehensive set of pulmonary function tests, including small airway measures of lung function.

In sum, the present study found that ratings of asthma management dimensions, including children's conceptual understanding of asthma, parents' responses to asthma symptoms, and families' abilities to integrate asthma into their daily lives all were associated with asthma inflammatory profiles, such that those who reported better asthma management beliefs and behaviors exhibited reduced asthma inflammatory profiles. Furthermore, inflammatory profiles constituted a statistically significant pathway between asthma management and clinical outcomes. This study suggests that interventions that seek to ameliorate asthma morbidity may want to include a focus on asthma management-related beliefs and behaviors, since these factors may influence childhood asthma not only at the clinical level but also at the biological level.

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