Medication Adherence in Pediatric Asthma: Reasoning, Responsibility, and Behavior

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Objective To assess child adherence to preventive asthma medications; to investigate relations between knowledge, reasoning about asthma, and responsibility for management and adherence; and to determine the association between adherence and morbidity.
Methods Participants were 106 children with asthma and their parents. Medication adherence was electronically monitored for 1 month. Participants completed self-report measures. Children were interviewed to assess reasoning about asthma. **Results** Children's adherence was approximately 48% of prescribed doses. Adherence was negatively related to age ($r = -.21$, $p < .05$); minority status, $F(1, 98) = 7.55$, $p < .01$; and morbidity ($r = -.26$, $p < .01$). Age was associated with increased child knowledge ($r = .47$, $p < .001$), reasoning about asthma ($\tau = .23$, $p < .01$), and responsibility for asthma management ($r = .44$, $p < .01$). These variables were not associated with adherence. **Conclusions** Although older children know more about asthma and assume more responsibility for disease management, their adherence is lower than that of younger children. No association was found between adherence and child knowledge, reasoning about asthma, or responsibility for asthma management.

Key words asthma; childhood; adherence; concepts of illness.

Asthma is the most common chronic illness of childhood, affecting approximately 6% of children in the United States (American Lung Association, 2000). Research has revealed chronic airway inflammation as a core disease characteristic (Larsen, 1992). As a result, use of medications that decrease airway inflammation is now a cornerstone of treatment for persistent asthma (National Institutes of Health [NIH], 1997). Routine use of these preventive medications yields many beneficial effects, including reduced airway inflammation (Szefler, 1991) and increased effectiveness of bronchodilators (Simons, 1998). Consistent use of medications, often prescribed with a dosing schedule of two to three times a day, places significant responsibility on the family. Adhering to this type of regimen requires forethought and planning, including filling prescriptions promptly and remembering to take medications regularly. Prescribing medications that must be taken regularly, are inconvenient to use, and offer no immediate benefit sets the stage for poor adherence.

Research has consistently demonstrated poor adherence to preventive asthma medications in both children (Bender, Milgrom, Rand, & Ackerson, 1998; Bender et al., 2000; Celano, Geller, Phillips, & Ziman, 1998) and adults (Apter, Reisine, Affleck, Barrows, & ZuWallack, 1998; Rand & Wise, 1994). Results are more striking when objective measures, as opposed to self-reports of adherence, are used (Bender et al., 2000; Jonasson, Carlsen, Sodal, Jonasson, & Mowinckel, 1999). Low-cost methods, such as canister weighing, suggest that children with asthma take between 40% and 70% of prescribed doses (Bender et al., 2000; Burkhart, Dunbar-Jacob, & Rohay, 2001; Celano et al., 1998). Research using electronic monitoring devices for inhaled medications yields more precise estimates of adherence and suggests that children generally take only 50% to 60% of prescribed doses (Bender et al., 2000; Milgrom et al., 1995).

Despite the centrality of medication adherence to asthma outcome, our knowledge about what predicts

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adherence is limited. Certain discrete variables, such as low household income and minority status (Apter et al., 1998; Bender et al., 2000), appear to be associated with worse adherence. In some studies, child knowledge of asthma has been associated with medication adherence (Bender et al., 1998), although other research has failed to find this association (McQuaid, Kopel, Fritz, Nassau, & Klein, 1999). Some family factors, such as parental criticism (Wamboldt, Wamboldt, Gavin, Roesler, & Brugman, 1995) and global dysfunction (Bender et al., 1998), appear to have a bearing on adherence. Some research also suggests that older children are less adherent than their younger counterparts (Bender et al., 2000). No research to date, however, has investigated developmental processes that may account for this phenomenon.

We propose that children's adherence to preventive asthma medications depends on two key factors: (1) how well they understand asthma and the concept of prevention and (2) how much they are responsible for asthma management in the family context. Children with asthma should have some understanding of disease and management strategies in order to adhere to an asthma management plan. Equally important, however, is that parents have developmentally appropriate expectations for children that derive from the child's understanding of illness and comprehension of the need for preventive management.

Children with asthma and their families vary widely in knowledge and understanding of the disease (Henry, Cooper, & Halliday, 1995; Kieckhefer & Spitzer, 1995). Several gaps in knowledge have been observed, including misperceptions about the function of medications (Kieckhefer & Spitzer, 1995; McQuaid, Howard, Kopel, Rosenblum, & Bibace, 2002) and poor medication techniques (Celano et al., 1998). Few studies, however, have investigated relations between knowledge and objectively measured management behavior.

Knowledge of asthma necessary for appropriate medication use may require more than a basic understanding of the concrete asthma facts. Research has demonstrated that children's understanding of illness becomes more cognitively complex as they mature (Bibace & Walsh, 1980; Brewster, 1982; Iannotti & Bush, 1993; Perrin & Gerrity, 1981). Less cognitively sophisticated children typically comprehend illness in terms of simple associations (e.g., "wheezing is asthma"). With cognitive development, children can link simple causes and effects of illness, such as understanding that exposure to germs results in a cold. Some children at higher stages of development can integrate multiple causes and effects in their understanding of illness (Bibace & Walsh, 1980; Osborne, Kistner, & Helgemo, 1993).

Research with specific pediatric illness populations has only begun to address the influence of children's understanding of illness concepts on adaptation to disease (Drotar, 1995; Glasgow & Anderson, 1995). Two recent studies indicate that although illness knowledge increases with age, school-age children with asthma may not comprehend preventive use of asthma medications (Kieckhefer & Spitzer, 1995; McQuaid et al., 2002). Given that children generally have difficulty understanding preventive health behavior (Perrin & Gerrity, 1981), it is likely more challenging for children with asthma to understand the need to continue taking medications when they have no symptoms. Thus, their ability to grasp the concept of preventive management may be a key predictor of adherence.

The extent to which children's cognitive understanding of illness affects their management behavior depends on how much they are responsible for disease management. Research in various childhood chronic illnesses has indicated that as children grow older, they gradually assume more responsibility for illness management (Anderson, 1995; Drotar & Ievers, 1994; McQuaid et al., 2001). Some data, however, suggest that as parents withdraw responsibility for disease management, children may not necessarily assume responsibility in a consistent or effective manner. Disease management tasks that require higher cognitive processing may be most vulnerable to slippage. One study of patients with diabetes indicated that when parents began to withdraw responsibility for insulin adjustment, adolescents did not always assume responsibility for this task. Cognitive maturity was a key factor in identifying who was able to assume self-management tasks (Ingersoll, Orr, Herrold, & Golden, 1986).

The division of asthma tasks between parent and child should depend, in part, on the child's capacity to understand the principles of asthma management. For the most effective asthma management and adherence, parents should be primarily responsible for asthma care when the children are young and lack the cognitive skill, prospective memory, and level of maturity to remember to take medications regularly. Some research has suggested that inappropriate developmental expectations for asthma management can result in poor adherence (Walders, Drotar, & Kercsmar, 2000), so that children who assume responsibility for asthma management before they can comprehend and implement preventive strategies may be at risk for poor adherence. Optimal adherence may depend on an appropriate "fit" between the child's conceptual understanding of asthma and his or her degree of responsibility for asthma care.

The purposes of this study were to assess basic asthma

knowledge, conceptual understanding of asthma, and responsibility for self-management in a sample of children with persistent asthma and to determine the relations of these variables to adherence to inhaled preventive asthma medications. We expected that children's responsibility for asthma management would increase with age and that adherence would decline with age. We also hypothesized that the interaction or "fit" between responsibility for disease management and level of reasoning about asthma would predict adherence. We further expected that poor adherence to preventive asthma medications would be linked to asthma morbidity.

Method

Participants

Families were recruited for participation through a number of sources, including Emergency Department records, flyers, physician referrals, participation in an asthma education class, and attendance at a summer camp for children with asthma. Participants were 106 children with asthma, ages 8 to 16 (M = 11.6, SD = 2.0). Forty-two percent of the children were female. One parent, typically the mother (92%), also participated. Caucasians (non-Hispanic) made up the largest proportion of the sample (68%), followed by African Americans (23%). The remaining participants identified themselves as Hispanic (5%) or biracial (5%). The average socioeconomic status (SES) across families (M = 41.4, SD = 11.6) fell within Hollingshead (1975) Level IV, corresponding to technical workers and minor professionals. All SES levels were represented within the sample, from unskilled laborers (Level 1) to major professionals (Level V).

All children had physician-diagnosed asthma for at least 6 months prior to participation in the study and were on one or more prescribed daily asthma medications. Specifically, all children were prescribed at least one preventive medication (e.g., Beclomethasone), delivered by means of a metered dose inhaler (MDI), to be taken two or more times daily.

The severity of participants' asthma was assessed by a pediatric asthma specialist according to NIH (1997) criteria. Background information used to assess disease severity was obtained from parental report. This included basic information regarding medication types and dosing regimens. Parents also provided descriptive information regarding the child's functional impairment from asthma (e.g., how many days of school were missed due to asthma in the past year) by responding to a structured questionnaire (Rosier et al., 1994).

Upon review of this information, a pediatric asthma specialist assigned each child an asthma severity rating, from 1 (mild intermittent) to 4 (severe persistent). Similar methods of rating asthma severity have been used successfully in our prior work (Fritz, McQuaid, Spirito, & Klein, 1996; McQuaid et al., 2001). According to this method, 1% of children in this study had mild intermittent asthma, 63% had mild persistent asthma, 31% had moderate persistent asthma, and 5% had severe persistent asthma (there was insufficient information for categorization of two children). As all children in this study were recruited based on their need for daily asthma medications, we expected that few participants would have mild intermittent asthma.

Procedures

Written parent consent and child assent were obtained in accordance with institutional review board guidelines. Families were told that the purpose of study was to investigate how children with asthma of different ages use their medications. During an initial lab visit, children and parents were interviewed separately and completed questionnaire packets. Although all families were told that medication use was being recorded, they were not aware of the specific features of the MDILog device (i.e., the date and time stamp of inhalations and the capacity to detect actuations without inhalation). Children returned home with MDILog monitors attached to each of their daily medications. Medication use was recorded for a period of 4 weeks, starting 3 days after the lab visit. The first 3 days of data were excluded to minimize potential inflation of adherence due to the novelty of the device. To enhance retention and minimize device loss, participants received financial compensation when returning MDILogs at the end of the study period.

Measures

MDILog Data Collection: Medication Adherence. The MDILog electronic asthma medication monitor (Westmed Technologies Inc, Englewood, CO) is a small device, easily attached to an inhaler, which contains a computer chip that records the date and time of each metered dose inhaler actuation. It further indicates whether medication is actually inhaled by use of a temperature-sensitive thermistor. MDILogs can be used with inhalers that use spacers (i.e., devices that enhance medication delivery by propelling medication through a small chamber). The MDILog device performs a self-check and battery test nightly to ensure data integrity.

MDILog Management and Statistical Analyses. Clinical research regarding adherence has indicated that some participants may attempt to alter their own data to appear

more adherent by "dumping" their medication prior to returning the devices that monitor their adherence (Hamid, Kumaradevan, & Cochrane, 1998). The MDILog is uniquely designed to identify these circumstances because it can detect whether a dose actually has been inhaled. An episode of 10 or greater actuations in less than a minute *without inhalation* was defined as a "dump." By this criterion, nine participants "dumped" medication during the course of the study; four of these instances were recorded on the final day of study participation. Medication dumps were cleaned from the data set before adherence was calculated and analyses were performed.

MDILog data records were also examined for systematic errors resulting from device difficulties (e.g., faulty calibration, battery failure). Data from 13 devices were excluded from the analysis due one or more of these problems. Device damage and loss accounted for six additional data files that were unavailable for analysis. This quantity of data loss (approximately 9%) is generally consistent with that in other studies using adherence monitors (e.g., Bender et al., 2000; Nides et al., 1993). This loss of data resulted in the exclusion of six participants from the data set, because no valid adherence data remained after faulty data were removed. The six participants whose data were excluded due to device damage or loss did not differ from the remaining sample in terms of gender ($\chi^2 = .18$, *ns*), asthma severity ($\chi^2 = 1.25$, *ns*), race ($\chi^2 = .86$, *ns*), or age (Mann-Whitney U, $Z = -.14$, *ns*).

Adherence was calculated as *total doses taken per day* divided by *prescribed doses per day.* A "dose" was defined as an actuation that was recorded as an actual inhalation by the MDILog. Days that reflected greater than 100% adherence, due to additional doses recorded, were truncated to 100%. This occurred for approximately 5.7% of study days. Hence, participants were not able to compensate for poor adherence one day by taking additional doses the next. Mean adherence was computed across the entire 28-day study period. If more than one of a child's preventive medications were monitored, mean adherence was computed across medications. Results reported here include data from 136 preventive inhalers across 100 children. For 36 children, mean adherence was computed across two inhalers.

Concepts of Asthma Interview. Children's conceptual understanding of the causes and consequences of asthma was assessed using an adapted version of the Concepts of Illness Interview (Bibace & Walsh, 1980). An extensive description of the interview, scoring system, and general findings with an overlapping sample of children with asthma are published elsewhere (McQuaid et al., 2002). In short, the interview consists of questions regarding illness causality for asthma episodes and beliefs about prevention and medication. The initial questions (e.g., "What causes an asthma episode?") are followed with probes designed to clarify the participant's response and assess the maximal level of conceptual reasoning. Participants' responses were assigned scores from one to six, ordered according to level of causal reasoning regarding illness. Ratings are based on distinctions between external agents and internal processes and causal mechanisms for illness. For example, a response such as "You get asthma from being around pollen," in which a child is unable to elaborate or specify even a vague mechanism for the asthma episode, is assigned a relatively low score (level 2, "contagion"). A response in which the child is able to describe an internal disease process that results in asthma symptoms (e.g., "Asthma is when your lung passages or bronchial tubes don't function properly. Your airways are sensitive to triggers, like pollen. When pollen comes in your airway muscles tighten up and it makes a wheezing noise") is scored at a higher level (level 5, "physiological").

Interviews were audiotaped and transcribed verbatim for later scoring. Although coders were aware the children had asthma due to the nature of the study, they were blind to child age, gender, disease severity, and medication adherence. If several responses were given for a specific topic (e.g., three causes of an asthma episode), these were scored separately. A large subset of protocols ($n = 65$ interviews) was coded by two separate raters for reliability. This resulted in joint coding of 220 responses. There was a moderate level of interrater agreement for ratings of children's asthma responses ($\kappa = .59$). Any discrepancies were resolved by discussion between coders.

The Concepts of Asthma Interview often generated multiple responses per participant regarding causality of asthma symptoms. For example, a participant might name multiple causes of an asthma episode and then generate causal sequences for each. These responses may not necessarily be at the same level of causal reasoning, a notion referred to as the "co-existence concept" (Bibace, Sagarin, & Dyl, 1998). Hence, responses per participant are summarized by the *maximum* response, indicating the most sophisticated level of reasoning expressed. We describe both maximum and modal responses elsewhere (McQuaid et al., 2002). Because these two measures are strongly related (Spearman's $r = .84$, $p < .01$), we present only the maximum response here.

Self- and Parent-Report Measures

Asthma Knowledge Questionnaire (AKQ). The child's basic factual knowledge regarding asthma was assessed by a brief self-report measure adapted from one used extensively in prior studies (Fitzclarence & Henry, 1990). This measure has been used effectively with adolescents to

measure increases in asthma knowledge postintervention (Gibson, Shah, & Mamoon, 1998). The measure is a combination of true/false questions (e.g., "Swimming is the only good exercise for children with asthma") and free response items ("Name the three major symptoms of an asthma episode"). Points are given for each correct response, and a "percentage correct" score is derived.

Asthma Responsibilities Questionnaire (ARQ). The child's degree of responsibility for self-management in the family was measured by the ARQ, a 10-item measure. The ARQ describes 10 specific tasks of asthma management (e.g., remembering to use a preventive inhaler daily, avoiding allergens, using a peak flow meter). To complete the measure, children rate the degree to which they (vs. the parent) are responsible for each task on a 5-point Likert scale. Response options for each task range from 1 (the parent is completely responsible) to 5 (the child is completely responsible). For example, if the respondent believes that parent and child assume equal responsibility for the given task, a rating of 3 would be indicated. A summary score is computed by taking a mean across all completed items. The ARQ has demonstrated good internal consistency (α = .82 for the child version of the instrument) and convergent validity (McQuaid et al., 2001).

Asthma Functional Severity Scale (Rosier et al., 1994). Parents completed the Asthma Functional Severity Scale, which assesses the degree of functional impairment that asthma imposes on children's daily functioning. The scale examines four components of children's asthma morbidity, including frequency of episodes, frequency of symptoms between episodes, intensity of impairment (i.e., the extent to which home or school activities are affected by asthma symptoms) during an episode, and intensity of impairment during the intervals between episodes. The functional morbidity index score is calculated by computing a mean across all completed items. Higher scores indicate greater levels of impairment. Internal consistency estimate for the current sample was calculated at alpha = .78.

Results

Appropriate data transformations were applied to variables unlikely to conform to assumptions of normality and homogeneity of variance. Specifically, *probit* transformations, which normalize distributions of proportional variables (Cohen & Cohen, 1983), were applied to adherence and asthma knowledge scores, both of which were proportional data. Raw scores were retained for sample description. In order to represent the "fit" between reasoning about asthma and responsibility for management, an interaction term (reasoning × responsibility) was created from standardized scores of the Concepts of Asthma Interview and ARQ instrument. A similar term was created to represent fit between knowledge about asthma and responsibility for asthma management (knowledge * responsibility).

The first set of analyses examined overall adherence across the variables of age, gender, SES, race, and asthma severity. Subsequent analyses investigated potential cognitive and developmental correlates of adherence to medication, such as asthma knowledge, reasoning about asthma, and responsibility for asthma management. Last, the relations between adherence to inhaled medications and asthma morbidity were examined. Nonparametric techniques were used where appropriate (e.g., associations between the child's Concepts of Asthma score and asthma knowledge were examined with Kendall's tau [τ], a nonparametric correlation coefficient used when one variable is categorical).

Adherence to Inhaled Medications

Children in this sample represented a wide range of adherence, from those who took none of their prescribed doses during the study period to those who took practically all (99%) of their prescribed doses. The mean level of adherence across children was .48 (median = .48, *SD* = .29), indicating that, on average, children took approximately half of their prescribed preventive medications. As anticipated, older child age was associated with poorer adherence ($r = -.21$, $p < .05$) (Figure 1). Adherence to preventive medications did not differ by gender, $F(1, 98) = .25$, *ns;* by asthma severity, $F(3, 93) = 1.58$, *ns;* or by family SES ($r = .15$, *ns*).

Given the small size of the Hispanic and biracial groups ($n = 5$ each), these were reclassified with the African American group into a general ethnic minority category ($n = 33$). Significant differences in adherence between Caucasian ($M = .53$, $SD = .29$, median = .57) and non-Caucasian participants ($M = .37$, $SD = .26$, median = .38) were found, $F(1, 98) = 7.55$, $p < .01$. These results remained significant when controlling for SES, $F(2, 92) = 4.99$, $p < .01$.

Adherence was negatively related to the functional morbidity index score ($r = -.26$, $p < .01$), indicating that the more adherent children were, the less likely they were to experience frequent symptoms and activity limitation.

Knowledge, Reasoning, and Responsibility for Asthma Management

Children's knowledge regarding the basic facts of asthma varied widely, ranging from 36% to 96% correct on the AKQ. The average knowledge score across children was 74% correct (*SD* = 14 points). A statistically significant gender difference emerged, $F(1, 97) = 5.46$, $p < .05$, indi-

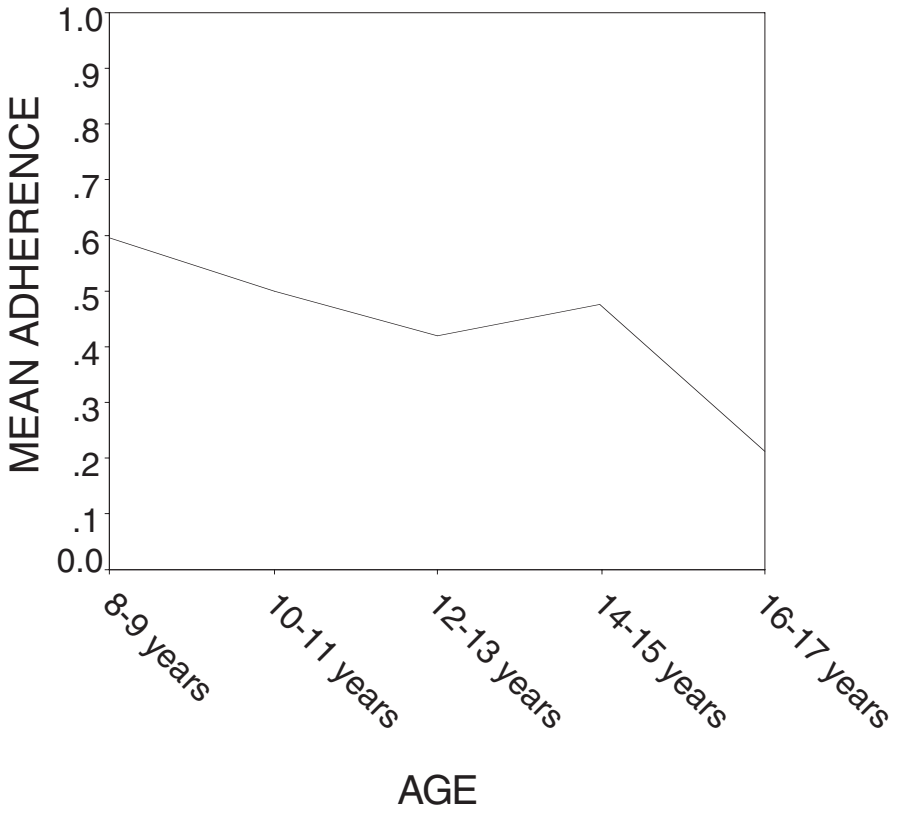

Figure 1. Medication adherence by age.

cating that girls achieved higher knowledge scores (M = 77%, SD = 12 points) than boys (M = 71%, SD = 14 points). Asthma knowledge was significantly related to child age (r = .47, p < .001).

Children demonstrated all but the highest level of cognitive complexity regarding the causes and consequences of asthma as measured by the Concepts of Asthma Interview. The most frequent responses were in the "internalization" category (41%), in which children are able to explain how a sequence of mechanical actions leads to changes in specific internal body parts (e.g., "When a trigger, like pollen, comes in and the muscles in your lungs tighten up"). The next most common response was in the "contamination" category (31%), which represents a basic association between external cause and asthma symptoms (e.g., "You get around pollen and it goes all around and you get sick and have an asthma attack"). Older children demonstrated higher levels of reasoning about asthma (τ = .23, p < .01). Reasoning about asthma was significantly related to illness knowledge as measured by the AKQ (τ = .27, p < .01).

The amount of responsibility assumed for asthma management tasks varied widely. On average, children reported assuming about equal responsibility with parents for various management tasks (M = 3.35, SD = .76). Child report of responsibility for disease management was associated with age (r = .44, p < .01). Asthma management responsibility was also associated with asthma knowledge (r = .22, p < .01) but not with causal reasoning about asthma (τ = .13, *ns*). Relationships between age, conceptual reasoning about asthma, asthma knowledge, and adherence are presented in Table I.

Knowledge, Reasoning, and Responsibility: Relations to Adherence

A series of correlational analyses examined relations between medication adherence and children's knowledge of asthma, reasoning about asthma, and responsibility for asthma management. Analyses revealed that neither basic factual knowledge of asthma (r = –.02, *ns*) nor conceptual reasoning about illness (τ = –.09, *ns*) was related to medication adherence. Child report of responsibility for asthma management was not related to adherence (r = .03, *ns*).

We used hierarchical multiple regressions to investigate whether the interaction between child responsibility for disease management and understanding of illness (basic knowledge and conceptual understanding of asthma) predicted adherence to inhaled asthma medications. Specifically, main effects of asthma knowledge and asthma management responsibility were entered on a first step, with an interaction term (knowledge × responsibil-

Table I. Adherence, Concepts of Asthma, Asthma Responsibilities, and Asthma Knowledge by Age Group

Age (years)	*n*	Adherence *M* (*SD*)	Concepts of Asthma Mode (Range)	Asthma Responsibilities *M* (*SD*)	Asthma Knowledge *M* (*SD*)
8–10	35	.56 (.29)	3.0 (1.0–5.0)	2.95 (.64)	.65 (.12)
11–13	45	.44 (.28)	4.0 (3.0–5.0)	3.39 (.68)	.79 (.13)
14–16	20	.42 (.29)	4.0 (3.0–5.0)	3.93 (.76)	.78 (.10)

ity) entered on a second step. Results were not significant, with the initial step explaining only 2% of the variance, and the second step adding only marginally to the model's prediction, F change = .75, *ns*. Similarly, a hierarchical multiple regression investigating whether the fit between conceptual reasoning regarding asthma and responsibility for disease management predicted adherence was not significant, F change = .20, *ns*. These results suggest that although knowledge and responsibility for disease management are associated with age, they do not appear to relate to adherence behavior.

Discussion

Our findings underscore that adherence to preventive medications remains a significant problem in pediatric asthma. Our results indicate that, on average, children are taking approximately half of their regularly prescribed inhaled medications. Medication adherence was negatively associated with age, such that younger children were more adherent than adolescents, a finding mirrored in the literature regarding adherence in diabetes (Bond, Aiken, & Somerville, 1992; Hanson, Henggeler, & Burghen, 1990) and cancer (Dolgin, Katz, Doctors, & Siegel, 1986; Tebbi et al., 1986). Adherence was also negatively associated with ethnic minority status, even when SES was controlled. This finding is consistent with prior research demonstrating that ethnic minority status is associated with lower medication adherence in adults (Apter et al., 1998) and children (Bender et al., 2000) with asthma. Although no clear explanation for this finding exists, variables such as health care access and communication between health care providers and patients may play a role (Vargas & Rand, 1999). Nonadherence to medications was related to functional morbidity due to asthma, indicating that poor adherence may have consequences for symptom frequency and activity limitation.

Our assessments of children's knowledge of asthma demonstrated that basic factual knowledge of asthma varied widely, from children who demonstrated very limited illness knowledge to those who were able to answer nearly every question correctly on a test of asthma facts. Similarly, children demonstrated a wide range of conceptual reasoning regarding the causes and consequences of asthma. Although some children were able only to name symptoms in describing asthma (e.g., "asthma is wheezing"), others were able to give complex responses integrating multiple causes and effects of asthma episodes. Both factual knowledge and conceptual reasoning about asthma were associated with age, suggesting an accumulation of knowledge and increased ability to reason about illness over development. Responsibility for asthma management was also associated with child age. These findings suggest that as children grow, they know more about asthma and assume more responsibility for self-management.

The interplay between these developmental factors and adherence behavior appears to be complex. Although knowledge and responsibility for management were positively associated with child age, medication adherence was actually *negatively* associated with child age. We had proposed that a mismatch between child understanding of asthma and level of responsibility for asthma management would predict medication adherence; however, the data did not support this hypothesis. This was true whether knowledge was measured in terms of basic asthma facts or in terms of conceptual reasoning regarding the illness. In fact, our data suggest children's understanding of asthma bears little relation to adherence behavior. This lack of findings leaves us with an interesting question: if older children know more about asthma than their younger counterparts, and assume more responsibility for asthma management, why are they actually taking their medications less frequently?

Older children, now in a position of more responsibility for disease management, may be less able or motivated to take care of their asthma for a number of reasons unrelated to their knowledge and understanding of the illness. With less supervision, children may simply be less able to remember to take scheduled medications, regardless of their knowledge of asthma. Alternatively, children who have begun to manage their own illness regimen may attempt to "test out" the efficacy of certain medications by cutting back or eliminating doses without the knowledge of their parents. As social relationships develop, adolescents may choose not to take medications in certain circumstances due to social barriers. Whereas a younger

child may feel less embarrassment in making a quick visit to the nurse for medication, a teenager might not want to leave the lunchroom for fear of "standing out."

As children assume more responsibility for illness management, their own beliefs regarding costs and benefits of regular medication use may have a bearing on adherence behavior. Social cognition models, such as the health belief model, have been used widely in studies exploring adherence to preventive health advice (Rosenstock, 1974). The health belief model combines patients' perceptions regarding concepts such as perceived susceptibility, benefits and costs of treatment, and cues to act to predict behavior. This model has had some success in explaining adherence to medication regimens in adults with diabetes (Bloom-Cerkoney & Hart, 1980) and kidney disease (Cummings, Becker, Kirscht, & Levin, 1981). The health belief model has also demonstrated utility in explaining medication adherence in parents of children with sickle cell disease (Elliott, Morgan, Day, Mollerup, & Wang, 2001) and adolescents with insulin-dependent diabetes mellitus (Bond et al., 1992). This model may have particular relevance in explaining medication adherence in children with asthma, who may see the threat of a serious asthma episode as low, and have few cues to take medications when they are not actively experiencing symptoms.

Another promising approach is to evaluate specific beliefs about medicines in attempting to explain medication adherence. One recent study employed a social-cognitive model to evaluate beliefs about medicines in relation to treatment adherence in a sample of adults with asthma, kidney disease, heart disease, and cancer (Horne & Weinman, 1999). Researchers found that if patients' *concerns* regarding medication use exceeded their estimate of *medication necessity,* poor adherence resulted. For adolescents who begin managing their own asthma regimen, their own beliefs about the need for medication and concerns regarding use may be a more potent predictor of adherence than parental beliefs. In the face of little immediate benefit from medication use, and significant concerns regarding taking medication in front of others, adolescents may simply choose not to take their asthma medications. For young children with asthma, whose parents are primarily responsible for asthma management, it may be the *parents'* estimate of medication necessity and concern that predicts child medication use.

A number of family characteristics not assessed in this study may influence medication adherence. Research has demonstrated that family conflict, which may increase in adolescence, predicts poor self-management in diabetes (Hauser et al., 1990) and in juvenile rheumatoid arthritis (Chaney & Peterson, 1989). Asthma research has indicated that parents who have poor problem-solving skills, and are highly critical of their children, are more likely to have children with severe asthma and increased morbidity (Hermanns, Florin, Dietrich, Rieger, & Hahlweg, 1989; Schobinger, Florin, Zimmer, Lindemann, & Winter, 1992; Wamboldt et al., 1995). It is possible that, for certain families, styles of interaction regarding medication management lead to poor adherence, even in the face of adequate knowledge of disease facts and preventive techniques.

Methodological Limitations

This study investigated the relations between children's understanding of asthma (both factual knowledge and conceptual reasoning), their responsibility for disease management, and their adherence to preventive asthma medications. A number of measurement limitations warrant mention. This investigation relied largely on child assessments of key constructs, such as responsibility for disease management, and reasoning about asthma. Future studies including the viewpoints of other family members, such as parents, could provide alternative perspectives and potentially elucidate findings. Specific information regarding the reading level of various instruments was not available and may have influenced the findings that certain constructs, such as asthma knowledge, were associated with age. Reliability estimates for the Concepts of Asthma interview were only moderate, which may limit interpretation of results using this instrument. Additionally, some specific aspects of the asthma regimen (e.g., use of a peak flow meter, use of quick-relief medications) were not assessed and could provide further insight into the low levels of adherence documented.

Given the range of instruction children and families receive for asthma management, our measurement of "adherence," namely, adherence to preventive asthma medications, is a relatively narrow index. Additionally, we generally relied on families' perceptions of physician recommendations, calculating adherence with reference to families' reports of what they had been told to do. Our estimates of adherence may have been different, and likely lower, had we calculated medication adherence with reference to actual physician recommendations. Last, our study design did not enable us to assess two other important groups: families who chose not to fill their medication prescriptions at all and those who, despite persistent symptoms, have never received a prescription for preventive medications.

Our measurement of adherence was objective and allowed us to eliminate many of the biases of self-reported adherence measures, as well as to identify children's at-

tempts to inflate adherence by dumping. As in other studies that employ electronic monitors to measure adherence behavior, we did encounter device damage, device failure, and data loss. Although there were no obvious systematic differences between participants who were excluded because of device or data loss and those who were retained, the least adherent children may have been more likely to lose their devices. As a result, those participants who were excluded might have been the children with the most marked difficulties in adherence. We also measured adherence for a relatively brief, 4-week time window. Measuring adherence over a longer time period might have resulted in a more representative and stable estimate of adherence, over the course of seasonal changes and asthma exacerbations. This might have also reduced the influence of the novelty of study participation, which could, alone, affect adherence. Additionally, the families in our study may have been more adherent than the general population, as they were electing to participate in a study regarding asthma. It is likely, however, that many of the limitations noted would have resulted in lower adherence estimates than those we found, suggesting that our finding that children are taking approximately half of their prescribed medication may, in fact, be a generous estimate.

Implications for Research and Clinical Practice

Our findings demonstrate that health care practitioners should actively consider developmental issues in the assessment and treatment of children with asthma. Our findings that children present a wide range of understanding and reasoning regarding asthma provide evidence that tailoring educational materials to the developmental level of the child may be critical in facilitating comprehension. At certain stages of development, such as the adolescent transition, children may be at particular risk for declines in adherence and may actually require more active monitoring of adherence behavior.

As effective medications are introduced, and new medication delivery systems with single-day dosing begin to reduce burden on children and families, we may begin to see some changes in families' adherence behavior and subsequent asthma control. Research on health behavior across development, however, suggests that investigating the determinants of adherence behavior and potential mechanisms for behavior change will continue to benefit children with asthma and their families. Qualitative research that explores families' perceptions of the costs and benefits of medication use, prospective designs that evaluate adherence behavior across development, and intervention research that attempts to modify adherence behavior will all be critical areas for future investigation.

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