

Perceptual accuracy of upper airway compromise in children: Clinical relevance and future directions for research

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ABSTRACT

Approximately 80% of children with asthma have coexisting allergic rhinitis. The accurate recognition and assessment of asthma and rhinitis symptoms is an integral component of guideline-based treatment for both conditions. This article describes the development and preliminary evaluation of a novel paradigm for testing the accuracy of children's assessment of their upper airway (rhinitis) symptoms. This work is guided by our previous research showing the clinical efficacy of tools to evaluate children's perceptual accuracy of asthma symptoms and linking accurate asthma symptom perception to decreased asthma morbidity (Fritz G, et al., *Ethnic differences in perception of lung function: A factor in pediatric asthma disparities?* *Am J Respir Crit Care Med* 182:12–18, 2010; Klein RB, et al., *The Asthma Risk Grid: Clinical interpretation of symptom perception*, *Allergy Asthma Proc* 251–256, 2004). The pilot study tests a paradigm that allows for the examination of the correspondence of children's assessment of their upper airway functioning with actual values of upper airway flow through the use of a portable, handheld nasal peak flowmeter. Nine children with persistent asthma were evaluated over a 4-week period. The article describes the rhinitis perceptual accuracy paradigm and reviews the results of a pilot study, showing a large proportion of inaccurate rhinitis symptoms "guesses" by the sample of children with persistent asthma. Patterns of inaccuracy, rhinitis control, and asthma morbidity are also described. Directions for future work are reviewed. The development of clinical tools to evaluate children's accuracy of rhinitis symptoms are needed, given the central role of the self-assessment of symptoms in guideline-based care. Accurate perception of the severity of rhinitis symptoms may enhance rhinitis control, lessen the burden of asthma, and prevent unnecessary emergency use among this high-risk group of children.

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Asthma is the most prevalent childhood chronic illness in the United States.^{3–5} If asthma is not properly controlled, children can experience missed sleep, compromises in social and physical functioning, school absences, and increased emergency department (ED) visits.⁴ Approximately 80% of all children with asthma have coexisting allergic rhinitis (AR), and nearly 40% of those with AR have asthma.⁶ Asthma prevalence is increased when rhinitis symptoms are persistent and severe.^{7–11} Children with asthma and AR symptoms may experience poor rhinitis control and increased asthma morbidity,^{12,13} and managing the two chronic illnesses simultaneously may be challenging for children and families.^{8,9,14}

AR symptoms alone can also compromise children's sleep and daytime functioning.^{10,14–17} Chronic rhinitis also has been independently associated with increased risk for an ED visit in children with asthma.¹⁸ However, many children with asthma who have AR are often not diagnosed with the latter illness.^{19–21} As a result, many children may not be appropriately treated, which can increase their morbidity risk. Barriers related to the underdiagnosis of AR warrant additional study, but may include health-care system barriers (e.g., lack of access to and knowledge about a specialist and lack of a consistent primary care provider).

THE TREATMENT BURDEN OF ASTHMA AND AR

Asthma and AR share key areas of pathogenesis^{22,23} that influence similar treatment procedures.⁹ Children with comorbid asthma and AR may be faced with a combined and often confusing symptom presentation. For example, children with both asthma and AR may have a challenging time distinguishing between upper and lower airway symptoms,¹⁹ which may affect the appropriate use of AR versus asthma medications to control specific symptoms. Advances in management

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approaches are needed to enhance children's ability to detect upper airway symptoms. It is possible that children may have difficulty recognizing upper airway compromise and/or mistakenly overtreat their lower airway or, conversely, may attribute lower airway compromise to AR symptoms and not initiate appropriate asthma treatment.

THE ROLE OF PERCEPTUAL ACCURACY IN PEDIATRIC ASTHMA

We have shown that children's accurate perception of asthma symptoms is associated with lower levels of asthma-related functional impairment and less frequent health-care use (*e.g.*, fewer ED visits).^{2,4,24,25} A clinical method has been developed for characterizing the perceptual accuracy of children's lower airway airflow in which children's subjective assessments of lung function are compared with objective measurements.²⁴ By this method, three patterns of perceptual accuracy emerge: underestimating lower airway flow when objective values show significant pulmonary compromise (dangerous perceptual inaccuracy; underestimation), overestimating lower airway flow when objective values show normal lung function (perceptual magnification or overperception), and accurately perceiving asthma compromise, which correspond appropriately with objective values of lung function. Underperception and overperception of lung function has been associated with ED use and asthma functional morbidity in children.^{24,26,27}

PERCEPTUAL ACCURACY OF UPPER AIRWAY SYMPTOMS IN CHILDREN: DEVELOPMENT OF NOVEL TOOLS FOR FUTURE RESEARCH AND CLINICAL INTERVENTION

Given that clinical guidelines for AR rely on the self-assessment of rhinitis symptoms,⁹ it is clinically useful to develop a paradigm for evaluating the identification and accuracy of children's self-assessments of their AR symptoms. Children who accurately identify whether or not they are experiencing nasal obstruction may be better equipped to assess the severity of their AR symptoms to follow-up with appropriate treatment behaviors (*e.g.*, take regular or as-needed rhinitis medication). Additionally, it may be challenging to accurately identify nasal obstruction in the presence of asthma, because rhinitis symptoms may intensify the perception of asthma symptoms to the point where children overtreat their asthma with rescue medication or seek unnecessary emergency care. Alternatively, underlying rhinitis symptoms may be ignored by patients or families until more obvious asthma symptoms are controlled. A more comprehensive approach to upper and lower airway symptom perception may be useful.^{19,20,28} Given the central focus on symptom reports

in the treatment of both AR⁹ and asthma,⁴ the degree to which perceptual accuracy may differentially detect lower and/or upper airway compromise is critical in guiding treatment steps.

The purpose of this article is to present a pilot study involving the development and initial testing of a clinical paradigm for the assessment of school-age children's perceptual accuracy of their upper airway airflow. The clinical efficacy and methodology for the assessment of children's perceptual accuracy of their lower airway (asthma) symptoms has been presented by our previous work.^{1,2,29,30} The conceptual and methodological, as well as clinical framework for the development of a tool to assess the accuracy of children's upper airway (rhinitis) symptoms is guided from this previous work. In our pilot work, we sought to (1) develop a paradigm to allow for the comparison of children's assessment of their upper airway functioning with actual values of upper airway flow through the use of a portable, handheld nasal peak flowmeter over a 4-week period. Additionally, we explored patterns of accuracy of their upper airway airflow values (*i.e.*, the extent of accuracy versus inaccuracy) and AR control, asthma control, and asthma morbidity (*e.g.*, ED visits and oral steroid use). We present case illustrations of children who participated in this pilot work, to describe the paradigm and children's upper and lower airway functioning. Finally, we present a summary of children's experience of the procedure for descriptive purposes, to assess their impressions of this protocol to improve its methodology for future work.

Given that AR may be underrecognized and undertreated in children, in this pilot work we expected the majority of children's peak nasal inspiratory flow (PNIF), a measure of nasal airflow or obstruction, guesses would be inaccurate; *i.e.*, we predicted that a higher proportion of children's guesses of upper airway flow would be discrepant with actual values measured by the nasal flowmeter. The type of inaccuracy, overestimation (*i.e.*, guesses that reflect more nasal obstruction in comparison with actual values) versus underestimation (*i.e.*, guesses that reflect less nasal obstruction in comparison with actual values), was examined on an exploratory basis. We also expected that higher proportions of inaccuracy would correspond with poorer rhinitis control, poorer asthma control, and higher levels of asthma morbidity.

METHODS

Data for this pilot study were collected from a larger study, Project Nocturnal Asthma and Performance in School (NAPS), that assesses the correspondence of asthma and AR symptoms, sleep quality, and academic functioning in urban children with persistent asthma (R01 HD057220, Koinis Mitchell, PI). The study follows

children (7–9 years of age) across 1 academic year and includes four research sessions: a session held at the participant's home, a clinical evaluation of asthma and AR at our hospital-based asthma and allergy clinic, and two additional home-visit sessions. Each session involves repeated assessments of upper and lower airway symptoms, medication changes, sleep quality, and an assessment of family and cultural risk factors. Children and their caregivers also complete 3-month-long monitoring periods (MPs) during the school year occurring subsequent to the three research sessions. MPs involve real-time, objective assessments of upper airway function (PNIF measured through a nose flowmeter), lower airway function (peak expiratory flow measured through a handheld spirometer), and self-report of nose and asthma symptoms documented in a daily diary. This pilot study was implemented with nine Project NAPS participants, who agreed to take part after completing their participation in the larger study at the end of the school year. All nine participating families completed the 4-week pilot. A separate informed consent process for the pilot study was administered to these families.

Recruitment of participants for Project NAPS occurred in hospital-based ambulatory pediatric clinics, a hospital-based asthma educational program, and four targeted urban school districts. Eligibility criteria for the larger study included child's age between 7 and 9 years; child's legal guardian was willing to participate; caregiver ethnicity was self-identified as Latino (Dominican or Puerto Rican), non-Latino white, or Black/African American; child had physician-diagnosed asthma or breathing problems in the last 12 months and met persistent asthma status either by current prescription of an asthma controller medication; and/or recurrent daytime symptoms, nighttime symptoms, activity limitation, rescue medication use, or two or more oral steroid bursts in the previous 12 months (as per National Heart, Lung, and Blood Institute Expert Panel Report⁴ definition of persistent asthma). Exclusionary criteria included moderate-to-severe cognitive impairment, use of stimulant medication for attention deficit hyperactivity disorder, intermittent asthma, another pulmonary or chronic health condition, or a diagnosed sleep disorder (*e.g.*, restless leg syndrome) that would confound the primary hypotheses of the larger study.

Research assistants approached the first nine families who completed participation in the 1st year of data collection for the larger project to assess their interest in participating in the pilot study. Approval for the pilot was obtained from the Institutional Review Board of Rhode Island Hospital, Providence, RI.

Data collection for the AR perception pilot study occurred in the participants' homes during two research visits separated from each other by a 4-week

MP. During the initial visit, informed consent was obtained and orientation to the protocol was provided. Although children and their caregivers were already very familiar with using the peak nasal flowmeter and daily diary, having used it for an academic year in the larger study, these instruments were reintroduced with special emphasis on the additional perceptual accuracy protocol (described later in text).

Children were shown how to record their subjective assessments, and research assistants provided instruction and encouragement until children established an acceptable level of proficiency, which in all cases happened quickly. At the conclusion of the pilot MP, children and parents answered open-ended questions about the protocol to assess their understanding of the subjective measurements and to provide feedback about study procedures. Family report measures related to participant characteristics and asthma and AR status, and the clinical asthma and AR evaluation were completed during families' participation in the parent study.

Measures

Participant Characteristics. Primary caregivers provided basic demographic information including the participating child's age and gender, family income, and parent and child ethnicity.³¹

Baseline Diagnosis of Asthma and Classification of Persistent Asthma Status. Confirmation of persistent asthma was made at the clinic session by a study clinician using standard guidelines.⁴ Criteria for continued participation in the study included a current prescription for an asthma controller medication and/or a persistent level of asthma symptoms as defined by National Heart, Lung, and Blood Institute Expert Panel Report.⁴ Baseline lung function (forced expiratory volume in 1 second FEV₁, forced expiratory volume in 1 second/forced vital capacity) was measured using spirometry (nSpireHealth, Longmont, CO) before and after short-acting β -agonist administration, following American Thoracic Society standards (American Thoracic Society/European Respiratory Society, 2005).

Baseline Diagnosis of AR and Classification of AR Severity. Presence of rhinitis symptoms was not a requirement for study entry; however, it was evaluated during the clinic visit by (1) evidence on physical examination,³² (2) type and frequency of parent report of symptoms in the past month (AR Symptom Summary),³³ and (3) allergy skin-prick testing (Greer Laboratories, Lenoir, NC) to perennial and seasonal allergens common to the northeastern United States. If participants were found to have rhinitis, severity was

classified according to Allergic Rhinitis and Its Impact on Asthma guidelines⁹ as intermittent or persistent (persistent status defined as symptoms for >4 days a week for every week of the month) and mild, moderate, or severe (moderate/severe defined as having one or more disturbance of sleep, impairment of daily activities, impairment of school, or troublesome symptoms).

AR Perceptual Accuracy Protocol

Objective Measure of Nasal Obstruction. PNIF was obtained using an In-Check nasal flowmeter (Clemente Clark International);^{34,35} a portable handheld nasal inspiratory flowmeter with an attached face mask. PNIF identifies nasal congestion, with a measure of how quickly the air can move through the nose when inhaling forcefully.³⁶ Nasal peak flowmeters are reliable, valid, and user-friendly, particularly when compared with laboratory-based electronic tools (*e.g.*, rhinomanometry), and they provide an objective assessment of upper airway obstruction in children³⁷ and adults.³⁴ Data have shown the correlation of PNIF with patients' symptoms of nasal blockage³⁸ and other objective measures of nasal airway function, such as rhinomanometry.^{32,39} The nasal flowmeter includes a range of 0–350 L/min, with lower numbers indicating more nasal obstruction. At present, no normative PNIF values are available; hence, raw values were analyzed and are presented in this article.

Children were trained to complete PNIF maneuvers in the standing position, by emptying the lungs of air and then placing the mask over the nose and mouth. With the mouth closed, children then breathed in through their nose as quickly and forcefully as possible. They recorded the PNIF measurement in the daily diary. Children were instructed to repeat this maneuver three times in a row each morning and each evening before taking their asthma and/or allergy medications. Research assistants guided the children through the steps needed to attain good quality measurements, including how to reset the device between efforts, read the measurement from the device, and record obtained values in the diary. Parents were present during these orientation and training procedures and were encouraged to facilitate their children's completion of this protocol during the MP. Children's technique and level of effort were directly observed at multiple times during the MP and retraining was conducted as needed. Additionally, research assistants reviewed PNIF values recorded in the daily diary during interim home visits to identify patterns that could suggest protocol drift (*e.g.*, large discrepancies across the three efforts suggesting failure to reset the device between uses). When discrepancies of this type were

found children and parents were queried and retrained as needed.

AR Perceptual Accuracy. A protocol was developed to assess perception of upper airway compromise using a similar, well-established paradigm developed by our group to assess perception of lower airway compromise in children.^{1,2} Nine pilot participants were oriented to the upper airway symptom perception protocol using a script that described all procedures in age-appropriate language, including recording each "nose flow guess" and corresponding nose flow measurements in the daily diary.

Specifically, children were instructed to draw a line that represented their nose flow assessment at that moment on a picture of the PNIF meter (Fig. 1). Anchor pictures and text descriptions appeared at high and low extremes of the PNIF picture to illustrate the continuum of nose flow (*e.g.*, "When your nose is blocked your number will be lower" "When your nose is clear your number will be higher"). Children recorded their three successive nose flow efforts on a separate page. Instructions appeared in the diary for each step (*e.g.*, "Write your FIRST morning nose flow numbers here!"); visual cues such as arrows and text boxes, large font, and pictures were used as much as possible in the daily diary to make it appealing and easy to use for child participants. Research staff reviewed procedures until children and parents expressed comfort with the protocol.

Asthma Control. At baseline and after the MP, parents and children completed the Asthma Control Test (ACT),⁴⁰ a well-validated questionnaire of asthma-related impairment commonly used in the classification of asthma severity. For children <12 years of age, four items were completed by the child and three additional items were completed by the parent. Using standardized scoring procedures,⁴⁰ we dichotomized scoring into "poor" versus "good" control, using a total cutoff score of 19.

Rhinitis Control. At the start and end of each MP, parents completed the Rhinitis Control Assessment Test,⁴¹ to assess symptom control in patients with AR. Because of young age group selected for this study, the six-item test was administered to the parents rather than the children. For each question, there were five response choices, each of which was paired with a numeric value. A standard scoring system was implemented to divide final test scores into two categories, "well-controlled" or "not well-controlled," using a cutoff score of 21.

Asthma Morbidity. At each session during the parent study, parents were asked whether their child had

EXAMPLE

For example, I guess that I can sniff a “120” this morning so I draw a line at “120” on the picture of the PNIF. Whenever you see this picture in the diary, you will mark your guess for those sniffs.

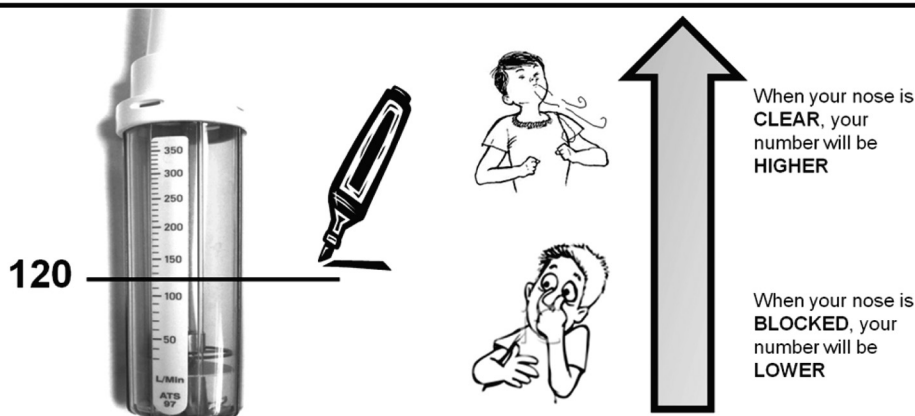


Figure 1. Protocol instructions for peak inspiratory nasal flow (PNIF) “guess.” This figure illustrates an example that was used to orient parents and children to the correct way of marking a nasal flow “guess” in the daily diary.

visited the ED for asthma and whether their child had used oral steroids for an asthma exacerbation in the previous 4 weeks. A dichotomous variable was then created for each of these morbidity indicators indicating whether or not the child had experienced any asthma-related ED visits and oral steroid use, respectively, across the entire study period.²⁵

Open-Ended Feedback Regarding AR Perceptual Accuracy Protocol. At the conclusion of the symptom perception protocol a brief open-ended feedback interview was conducted with child pilot participants and their parents to assess their experiences with the protocol and to obtain feedback about how to improve procedures. Questions covered the content of the protocol (e.g., “Was anything confusing about doing a guess?”) and the format of the pilot diary (e.g., “Did the picture help you understand how to make a guess?”).

RESULTS

Characteristics of the nine pilot participants appear in Table 1. Children were 8.2 years old on average (SD = 0.86) and virtually evenly distributed across gender and poverty status. Five participants had mild persistent asthma, two had moderate persistent asthma, and 1 had severe persistent asthma. ACT scores at the time of pilot study participation indicated that two participants had poorly controlled asthma; the remaining seven were well controlled. Eight of the nine participants met criteria for rhinitis. One participant did not complete the clinical evaluation session, but based on physician and repeated self-report measures administered throughout the protocol, the child likely had rhinitis. On examination by a study clinician, three children were classified as having mild intermittent

Table 1 Characteristics of the nine pilot participants

Measure	
Age, yr (M [SD])	8.2 (0.86)
Gender	
Male	<i>n</i> = 5 (56%)
Female	<i>n</i> = 4 (44%)
Poverty status	
Above poverty threshold	<i>n</i> = 5 (56%)
At or below poverty threshold	<i>n</i> = 4 (44%)
Asthma severity*	
Mild persistent	<i>n</i> = 5 (56%)
Moderate persistent	<i>n</i> = 2 (22%)
Severe persistent	<i>n</i> = 1 (11%)
Asthma control	
Poorly controlled	<i>n</i> = 2 (22%)
Well controlled	<i>n</i> = 7 (78%)
Rhinitis severity*	
Mild intermittent	<i>n</i> = 3 (33%)
Moderate/severe intermittent	<i>n</i> = 2 (22%)
Moderate/severe persistent	<i>n</i> = 3 (33%)
Met criteria for AR	<i>n</i> = 8 (89%)
Treatment for AR	
Not receiving treatment	<i>n</i> = 7 (78%)
Receiving treatment	<i>n</i> = 2 (22%)

**One participant did not complete the clinical evaluation session; therefore, asthma and rhinitis severity are unclassified for this participant. AR = allergic rhinitis.*

rhinitis, two had moderate/severe intermittent, and three had moderate/severe persistent rhinitis. Seven of eight participants were receiving no treatment for AR at the time of study participation.

PNIF Summary

Preliminary processing of PNIF data served to retain values representing each participant's best efforts (the highest of the three efforts within each trial)^{36,42} across the MP and to identify and exclude improbably high values (those ≥ 3 SDs either from the case or sample mean PNIF value). By these criteria, less than 1% (*i.e.*, 1 of 163 efforts across participants) were identified as outliers. Given the potential for improper use of the device (*e.g.*, failing to reset the device between efforts), the low frequency of outliers suggests our efforts to train and encourage participants to use the device correctly were successful.

PNIF Mean and SD Values

Given there are no normative values for PNIF measurements, each participant's pilot trials were converted to "percent of personal best" units for descriptive purposes. Across all pilot trials and participants, the mean PNIF measurement obtained during the first MP (MP1) was 78.4% personal best (SD = 9%), with case mean PNIF values ranging from 58.6 to 91.4%. Mean PNIF for MP2 was 78.6% (SD = 5.5%), with case mean PNIF values ranging from 66.5 to 84.5% personal best. Mean PNIF for MP3 was 76.8% personal best (SD = 4.1), with case mean PNIF values ranging from 70.7 to 83.9%.

Perceptual Accuracy of the Upper Airway

Perceptual accuracy was computed through correlations, between nose flow guess and actual PNIF values, both expressed in raw PNIF units (L/min), for each trial. The mean correlation from morning trials across cases was $r = 0.48$ (SD = 0.22), with a range of $r = 0.02$ – 0.80 . This wide range is similar to what our group has found in previous work characterizing perception of lower airway symptoms in children with asthma by the same method.³⁰

We also computed difference scores (PNIF guess – actual). On average, 83% of efforts across morning and evening trials were inaccurate (SD = 14%; range = 58–100%). A negative difference score indicates a guess of more perceived nose obstruction than the actual measurement indicated. Of 154 morning trials across participants, the mean difference score was -8.4 L/min (SD = 25.6), with a range of -160 – 103 . Fifty-seven percent of difference scores across the sample were negative (PNIF guess < actual) indicating that the majority of inaccuracy tended toward overestimation of nose obstruction. Seventeen percent of difference

scores were equal to 0 indicating accuracy, and 26% were positive (guess > actual) indicating underestimation of obstruction. These results suggest that the majority (83%) of trials were perceived inaccurately.

Given the wide range in difference scores (*e.g.*, -1 to -160), we next sought to describe the proportion of cases with at least a ± 20 L/min difference score. The value was chosen based on research with adults (Wilson, 2003⁴³) suggesting that a change of at least 19 L/min is clinically relevant. By this criterion, on average, 34% of efforts across morning and evening trials were discrepant by at least 20 L/min (SD = 19%; range, 11–71%). Fifty-one of 154 morning trials (33%) produced guess values that were at least 20 L/min discrepant from objective measurements. An almost identical pattern of results emerged for trials performed in the evening.

Inaccuracy in Upper Airway Symptom Perception, Control of Rhinitis, and Asthma Morbidity

We then explored associations between patterns of inaccuracy of upper airway symptoms and clinical outcomes. Children whose rhinitis was not well controlled during participation in the pilot ($n = 2$) had a higher proportion of inaccurate trials in which their nose flow guesses were at least 20 L/min discrepant from actual nose flow values ($M = 41\%$; range, 36–45%), relative to children with well-controlled rhinitis symptoms ($n = 7$; $M = 33\%$; range, 11–70%). A case-level examination of the proportion of guesses that were ≥ 20 L/min discrepant from actual nose flow measurements indicated that four participants had proportions above the sample mean of 34% (range, 36.4–70.8%). Three of these children had poorly controlled asthma at the time of their clinic visit, and three had experienced a clinically significant asthma event during or within the 12 months before study participation.

Two case examples illustrate the co-occurrence of inaccurate upper airway symptoms perception and asthma morbidity. The first is a 7½-year-old boy with mild persistent asthma and a history of at least one clinically significant event (ED visit or course of oral corticosteroid use) during or in the 12-month prior study participation. This child's asthma and rhinitis were classified as poorly controlled (by ACT and Rhinitis Control Assessment Test assessments) at the time of pilot study participation. Thirty-six percent of his PNIF guesses were 20 or more L/min discrepant from his actual nose flow values, which is comparable with the sample mean discrepancy value (34%). Next is a 9-year-old girl with moderate persistent asthma and a history of clinically significant events during and/or directly before study participation. She had a very high percentage of PNIF guesses that were ≥ 20 L/min (71%), relative to the sample mean.

DISCUSSION

Allergic Rhinitis and Its Impact on Asthma guidelines emphasize the importance of symptom report in the assessment, management, and treatment of rhinitis.⁹ Increased rhinitis symptoms can contribute to detriments in children's sleep and quality of life¹⁶ and to higher levels of asthma morbidity.⁸ Children's ability to accurately report on their AR symptoms has important implications for the management of AR (e.g., whether or not they need regular or as-needed nasal medications) and can assist in the early treatment of asthma (e.g., rescue medication) to prevent an acute attack. However, there are no available instruments or paradigms to assess the extent to which children can accurately perceive nasal compromise. Development of such paradigms may further understanding of how perception may impact clinical outcomes in comorbid asthma and AR.

Results from our initial pilot work suggest that children as young as 7 years old may be able to understand an AR perceptual accuracy protocol and "guess" their nasal flow. According to the open-ended interviews administered at the conclusion of study participation, pilot participants had little to no difficulties understanding the symptom perception protocol. The majority of comments relating to the pilot protocol were positive. For example, a majority of the participants found it easy to guess their nose flow and felt it helped them to better understand whether and when they had trouble with nose symptoms. A number of helpful suggestions for enhancing the formatting of the AR perceptual accuracy items in the daily diary (e.g., having the presentation of the visual reminders available on a daily basis) were integrated for further work in this area.

Preliminary results showed the majority of the AR perceptual accuracy "guesses" reflected inaccuracy in the ability to detect upper airway compromise. Previous research examining PNIF with adults⁴³ suggests a change of at least 19 L/min is clinically relevant and after applying this guideline, our preliminary results showed that, on average, 34% of efforts across trials were discrepant. Furthermore, examination of patterns of inaccuracy of upper airway obstruction (i.e., underperception versus overperception) with AR and asthma clinical outcomes lend preliminary evidence to the association between upper airway perception and problems with rhinitis control and asthma morbidity. Given the small sample and exploratory nature of this study, however, further work is clearly needed to assess the effectiveness of this approach.

There are a number of limitations of this preliminary work that will be addressed in the further development of this paradigm. The sample size of this pilot study is small and limits the ability to detect significant

effects. This upper airway perceptual accuracy paradigm needs to be tested with larger samples of children who have comorbid asthma and AR, to evaluate its effectiveness in identifying children with poor AR perceptual accuracy abilities and higher levels of asthma morbidity. Larger samples are also needed to evaluate whether perceptual accuracy of AR varies among specific ethnic groups, as has been found in our previous work with lower airway perception.¹

Second, given the one-airway theory suggesting that asthma and AR can be manifestations of an atopic syndrome,⁴⁴ children may still have difficulty differentiating between upper and lower airway flow, despite our best efforts to develop a protocol that teaches and trains children to focus on their upper airway flow. It is possible that lower ventilatory effort may influence upper airway flow, an effect that may be challenging to account for within this upper airway perception paradigm. It is worth noting, however, that children and caregivers with both asthma and AR need to respond to both asthma and AR symptoms on a daily basis in real life. Therefore, it is important to assess the extent to which they are able to accurately make this distinction using naturalistic paradigms regardless of these potential mechanistic confounds. In future research, we will also collect information on the assessment of children's lower (*via* home spirometry) and upper airway airflow simultaneously to examine lung function in accordance with their PNIF guesses.

Although the peak nasal flowmeter has been found to be a reliable and valid tool for assessing nasal airway patency in children and adults,³⁴ there are no objective methods for assessing level of effort as there are with lung function tests (e.g., flow-volume loops in spirometry). This is true of any noncomputerized handheld plastic device. It is simply a limitation in technology, because no device has been developed for take-home use in rhinitis research. Our best current method for estimating effort is the use of systematized observations by trained research assistants to assess children's effort and PNIF values. Third, there are also no PNIF norms available; therefore, we rely on percent of personal best values to consider children's "best" peak nasal flow values. Less than a handful of studies with small samples outside the United States have published PNIF norms.⁴⁵ One study included a large sample of children in Greece and results showed differences in PNIF by age and gender.⁴⁶ Studies have not yielded data for urban ethnic groups of children pertinent to the United States, and it is unclear what constitutes healthy and compromised AR functioning in these groups. There is also limited information on what constitutes a clinically meaningful change in PNIF values among children (there is limited information available on adults)³⁴; therefore, more research is needed with repeated measurement of PNIF over time

in correspondence with other rhinitis and asthma assessment indicators.

Finally, it is important to note that our upper airway perceptual accuracy paradigm focuses on upper airway airflow, and not children's report of specific rhinitis symptoms (*e.g.*, extent of nasal congestion). Although PNIF values appear to correspond to reports of rhinitis symptoms in children in our preliminary work,²¹ the perception of upper airway airflow by children may be different compared with the perception of other rhinitis symptoms (*e.g.*, congestion and postnasal drip). Future research also needs to examine which aspects of rhinitis (*e.g.*, subjective congestion, objective nasal airflow limitation, or the other rhinitis symptoms such as postnasal drip, *etc.*) are associated with poorer asthma status (*e.g.*, decline in lung function or increase in asthma symptoms). Furthermore, there is evidence suggesting that PNIF values correspond poorly with subjective measures of rhinitis symptoms and measures of sensation and congestion in adults.^{47,48} It is important to acknowledge the differences in procedures used to measure PNIF across these studies and the need for further assessment to compare objective and subjective measurements in larger samples of children.

Finally, it is also possible that in our paradigm, after children provided a "guess" of their nasal airflow value, they may have attempted to meet or exceed this value in their actual inspiratory effort. Therefore, their actual PNIF value may have been an underestimation of their "true" nasal airway airflow obstruction. When testing this paradigm in future research, we need to consider whether "hiding" children's guesses may need to be integrated into this approach.

Future research testing this paradigm should focus on children who have trouble accurately detecting upper airway obstruction (*e.g.*, children who are poorer symptom perceivers). Results from this research can inform interventions focused on enhancing perceptual accuracy of the upper airway, with an emphasis on early detection of warning signs that may influence upper and lower airway compromise. The associations between perception and clinical outcomes may vary, indicating a variety of intervention approaches. For example, future work could elucidate whether upper airway overestimation is related to lower airway compromise. Children who do not recognize nasal symptoms may be at risk for missing an early warning sign for future asthma and AR morbidity. If poor perceivers have poorer asthma control and AR control and use health care resources more frequently (*e.g.*, ED visits), then it may be clinically worthwhile to enhance education on recognition of early warning signs, which often are nasal.

We have established success in testing children's perceptual accuracy of asthma in using a similar par-

adigm.² Given the overlap between asthma and AR and the potential for AR to function as a significant risk factor for asthma, we sought to develop and document an initial evaluation of a clinical tool for assessing upper airway symptom perception in children. Preliminary data with a small sample show that children appear to understand the protocol, although future research is needed to evaluate its effectiveness and examine the correlation with lower airway symptom perception.

PNIF values can provide objective data for nasal obstruction to guide symptom assessments³⁶ and, eventually, inform clinical cutoffs for effective and compromised upper airway functioning in children. With regard to our pilot work, we were mainly interested in comparing the PNIF values to children's guesses of their upper airway flow to provide information on the degree of perceptual accuracy of children's nasal airway compromise. It is possible that similar to children's perceptual accuracy of their lower airway compromise and the association with indicators of asthma morbidity,¹ perceptual accuracy of upper airway compromise can also inform treatment steps for both AR and asthma. Clearly, future work is necessary with larger samples to confirm the effectiveness of this paradigm. Our pilot work is a first step toward the development of a clinical tool, analogous to our well-established lower airway symptom perception paradigm,² to assess upper airway symptom perception. The overall goal of this work is to contribute to the evidence base needed to advance understanding, medical self-management, and behavioral treatment approaches of the coexistence of asthma and AR in children.

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