

The Perception of Asthma Severity in Children

Lindsay Still¹ · William K. Dolen¹

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Abstract The ability to perceive the onset and severity of symptoms of worsening asthma is important, not only for initial diagnosis but also for early identification of an asthma exacerbation and prompt management. There are subjective and objective methods for identifying symptoms. Symptom perception is affected by multiple mechanisms, and not all patients can accurately perceive symptoms of airflow limitation. Hyperperceivers will report substantial discomfort in the face of minimal bronchoconstriction, and poor perceivers will report no symptoms even in the presence of severe obstruction. The use of objective measures of airflow limitation is essential for such patients. Regimens for training perception in children and adults have been studied and are available.

Keywords Asthma · Perception · Peak expiratory flow rate · Spirometry · Resistive load training

Introduction

In the USA alone, 6.8 million children have a diagnosis of asthma [1]. In 2011, asthma exacerbations accounted for over 1.8 million emergency department visits [2]. The ability to perceive the onset and severity of symptoms of worsening

asthma is very important, not only for initial diagnosis but also for early identification of an asthma exacerbation and prompt management. Underestimation of one's symptoms can result in increased asthma morbidity, while overestimation can lead to unnecessary use of quick-relief medications [3]. Symptom perception is multifactorial. Neurophysiologic mechanisms, cognitive development, physical development, sociocultural context, and psychiatric comorbidities all play a role in how a patient perceives asthma symptoms.

Bronchoconstriction and Symptom Perception

The methods for subjective assessment of airflow limitation rely on how a patient perceives and reports symptoms of bronchoconstriction, such as wheezing, shortness of breath, chest tightness, or increased effort to breathe. These methods include the keeping of symptom diaries and monitoring frequency of use of rescue medications. Objective assessments of airflow limitation in patients with asthma depend on pulmonary function testing, using measurement of lung volumes and simple spirometry and monitoring the peak expiratory flow rate (PEFR). Chest auscultation is unsatisfactory because substantial obstruction can be present when the examination is normal [4, 5]. Since these are not practical for everyday use (or are not used), a patient's ability to perceive and report symptoms of bronchoconstriction is vital for accurate diagnosis [6], for successful asthma management, and to avoid near-fatal or fatal asthma exacerbations.

However, not all patients can accurately perceive dyspnea or other symptoms of airflow limitation, even when obstruction is severe [7]. Some (hyperperceivers) will report substantial discomfort in the face of minimal bronchoconstriction, leading the clinician to question whether these symptoms are due to bronchospasm, anxiety, or other factors [8•]. Others

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✉ Lindsay Still
lstill@augusta.edu

¹ Division of Allergy-Immunology and Pediatric Rheumatology, Department of Pediatrics, Medical College of Georgia at Augusta University, 1120 15th Street, Augusta, GA 30912, USA

with severe obstruction (poor perceivers) will report no symptoms at all. In children with asthma, poor perception of symptoms is common and can be severe [9]. Spirometry is an invaluable tool to differentiate a poor perceiver from a hyperperceiver.

Mechanisms

The mechanisms underlying poor perception are poorly understood. Patients with severe asthma differ from others with mild asthma and normal individuals, in reporting symptoms from bronchial challenge [10] and from the application of external resistive loads [11•]. The concept of temporal adaptation (briefly, chronic obstruction causing diminished perception of obstruction) accounts for some but not all causes of poor perception [10, 12]. In a report from an NIH workshop on symptom perception in asthma, Banzett and colleagues noted that symptom perception is the result of multiple processes, (1) “activation of afferent endings by pathophysiologic stimuli,” (2) “transmission and processing of information in neural pathways,” (3) “interpretation in the cerebral cortex,” and (4) “acknowledgment by the patient,” discussing various proposed mechanisms in detail.

Symptom Assessment

A variety of scales and questionnaires are available for assessing the frequency and severity of asthma symptoms. Most scales and questionnaires have been developed for adults, but few have been adapted for children. The ability to perceive symptoms, such as cough or dyspnea, and express them requires a certain level of cognitive development. School-aged children are able to express breathlessness but may express this as “bad breathing.” The language used to describe dyspnea can help differentiate a diagnosis. Chest tightness is usually associated with asthma while “air hunger” is attributed to a cardiac etiology [13].

Harver et al. [14] assessed how children with asthma described breathlessness. One hundred children, ages 8–15 years old, with a physician diagnosis of moderate to severe persistent asthma were enrolled in the Taking Responsibility for Asthma Control (TRAC) study. To qualify, participants must carry a diagnosis of asthma for 2 years, use a controller medication daily, and report occasional asthma symptoms. The participants filled out a breathlessness questionnaire from the American Thoracic Society concerning statements that described their “uncomfortable awareness of breathing.” Pulmonary function testing and an asthma severity questionnaire were also performed. The study was repeated 2 months following the initial visit. The following four descriptors were the most frequently selected: “My chest feels tight,” “I cannot

get enough air in,” “I feel out of breath,” and “My breathing is heavy.” The study also showed children who perceived their asthma as more severe would select a greater number of descriptors. Descriptions did not vary by age, race, asthma duration, gender, BMI, or severity variables (self-reported asthma severity). Of note, an NIH-sponsored asthma outcomes workgroup in 2012 concluded that no currently available instruments qualified as core instruments for NIH-sponsored research for asthma symptoms or asthma-related quality of life [15•].

Symptom perception can also be affected by how asthma control alters one’s life. Ungar and coworkers conducted a survey of 52 parents of asthmatics and 44 adolescents with asthma to determine which asthma control parameters were most important [16]. A best-worst scaling (BWS) tool assessed the most preferred and least preferred attributes in asthma control. Night-time symptoms, wheezing or chest tightness, medication changes, frequency of emergency department visits, and physical activity limitations were the attributes studied. Parents reported a preference for an absence of night-time symptoms and decreased emergency department visits. Adolescents placed a high priority on the absence of physical activity limitations and frequent emergency department visits. Both groups reported an indifference to changes of medications. Understanding the key preferences of patients and parents is key to ensuring the effectiveness of asthma management and patient-centered care.

Risk Factors for Poor Perception

Nuijsink et al. [17] sought to define various risk factors for poor perception of bronchoconstriction. The study included 210 children, ages 6–16 years old, with a diagnosis of moderate to severe asthma. Each participant underwent a methacholine challenge. During the challenge, participants were asked to rate their degree of breathlessness by using the Borg scale. Poor perception of bronchoconstriction was noted in participants with a lower baseline FEV1, less quick-relief medication use, and severe airway hyperresponsiveness.

Motomura et al. [18••] performed a similar study with acetylcholine-induced bronchoconstriction and dyspnea perception using the Borg scale. Bronchial responsiveness was divided into mild and severe based on the amount of acetylcholine required to decrease the FEV1 by 20 %. Severe bronchial hyperresponsiveness (BHR) required a smaller dose of acetylcholine compared to the mild BHR group. Asthmatic children with severe BHR and high FeNO levels had reduced perception of dyspnea. Children with a lower FeNO level and mild BHR were able to perceive mild bronchoconstriction. Severe BHR, elevated FeNO level, and a low baseline FEV1 are risk factors for poor perception and increased asthma morbidity.

Cognitive Factors

Anxiety and depressive disorders are associated with an increase in subjective asthma symptoms. Feldman et al. [8•] studied child and caregiver anxiety and depression as predictors of the child's perception of lung function. A convenience sample was obtained on 97 children, ages 7–11 years old, with a diagnosis of asthma, and their caregivers. Children and their caregivers underwent extensive anxiety and depression screening, in addition to PEFr training, pulmonary function testing, asthma control questionnaire, and asthma severity scoring. Over a 6-week period, children would predict their PEFr prior to performing PEF. Caregivers and children were blinded to the actual PEFr values. Doser devices were also placed on inhaled corticosteroids in addition to quick-relief medications to determine the number of actuations taken over a 30-day period. Asthma perception was stratified into the following zones: accurate zone (close match between predicted and actual PEFr value), danger zone (predicted PEFr value was greater than actual PEFr value), and magnification zone (predicted PEFr value was lower than actual PEFr value). Higher levels of children's anxiety resulted in hyperperception of respiratory compromise (magnification) and increase in quick-relief medication use. Depressive symptoms in children did not affect predicted PEFr value but did show an increase use of quick-relief medications. Of note, children of caregivers with a depressive disorder or an anxiety disorder also showed lower pulmonary function and worse asthma control when compared to those of caregivers without the disorder. The presence of anxiety may distract children's and their caregiver's ability to perceive their asthma symptoms accurately. Anxiety may also result in misinterpreting symptoms of anxiety for symptoms of asthma.

Koinis-Mitchell et al. [19] investigated the association between attention and the ability to perceive asthma symptoms. A variety of objective and parent report attention-based instruments were used to assess attention. In addition, participants had extensive intelligence, behavior, anxiety, and depression screening performed. Comparing predicted and actual PEFr values using a spirometer assessed symptom perception. From this study, specific attention skills assessed on performance tasks are consistent in determining children's ability to detect changes in respiratory functioning when compared to level of intelligence or psychiatric comorbidities. Children who pay careful attention to internal cues associated with pulmonary compromise show accurate perception. Excessive attention may result in symptom magnification. Thus, children who are more focused are likely to perceive their symptoms accurately, or they may be highly attuned to their symptoms and overinterpret them. Children with poor performance on tasks requiring increased attention correlated with an underperception of PEFr values. Individuals with ADHD can be at a higher risk of asthma morbidity due to poor perceptual sensitivity.

Cultural Factors

Perception of asthma control has not been well-studied in different cultures and ethnic groups. Fritz et al. [20] assessed how certain cultures perceive changes in lung function. This study included 512 children, ages 7–16 years old, from Puerto Rico and Rhode Island (290 Puerto Rico Latinos, 115 Rhode Island Latinos, and 107 Rhode Island non-Latino white children). The children predicted their PEFr prior to use of their spirometer. The correlation between their PEFr predicted and actual values was categorized into an accurate zone, a danger zone, and a magnification zone. Additional measures were obtained including poverty threshold, asthma severity, asthma morbidity, asthma health care use, child somatization inventory (CSI), emotional expression, and intelligence. Older age, male sex, less poverty, ability to report somatic complaints, and greater intelligence were all associated with better perceptual accuracy. Non-Latino white (NLW) children were more accurate compared to Latino children. Latino children tended to over-perceive their symptoms. Inhaled corticosteroid (ICS) use did not have any relation to accuracy of symptom perception. It was postulated that higher magnification scores in Latino children were related to prior experience with asthma mortality or near-fatal asthma exacerbations in family members.

Body Habitus

Obesity can contribute to the variable nature of symptom perception in asthma. Obese individuals report higher rates of asthma symptoms and asthma morbidity [3]. Two hundred children, ages 7–17 years old, were recruited for a study completed by Kopel et al. [3]. Symptom perception was measured using a spirometer and PEFr feedback values. Additional information was obtained on all participants, including sociodemographic information, BMI, asthma severity, and pulmonary function testing. Younger participants, ethnic minorities, and obese white individuals had lower accuracy scores and poor symptom perception. Asthmatics may misinterpret symptoms associated with physical deconditioning or “being out of shape” for an asthma exacerbation. There was no association with symptom perception and obese minorities compared to non-obese minorities.

Sah et al. demonstrated obese children were more likely to have comorbid conditions and non-specific symptoms that were not associated with greater airflow limitations [21•]. A lower functional residual capacity and asthma symptoms triggered by daily living activities, such as walking, implied poor asthma control may be overestimated in this population. In addition to deconditioning, alterations in chest wall mechanical properties due to obesity could contribute to the perception of dyspnea in patients with asthma.

Managing Perception Issues

PEFR meters have been used for asthma self-management in individuals with poor symptom perception. These, and spirometers intended for home monitoring, are readily available. Although PEFR meters are inexpensive and readily obtainable, technique variables such as patient effort limit their use in individuals of all ages, especially with young children. Spirometry is a more accurate and reproducible measurement of asthma severity and control, and it is the monitoring method of choice in both subspecialty and primary care settings. PEFR monitoring should be a supplemental tool to spirometry, as some individuals with abnormal spirometry will have a normal or near-normal PEFR.

However, perception training by use of PEFR feedback in adults has shown improved symptom perception and adherence to ICS therapy. Feldman et al. [22••] performed a trial of PEFR feedback training to determine if this would aid in symptom perception. The study included 192 children, ages 7–15 years old, and their parents. Children were placed in either a PEFR feedback group or no feedback group. Both children and their parents received extensive training on how to use a hand-held spirometer for home monitoring of PEFR. Over the next 6 weeks, children would predict their PEFR and enter the value into a spirometer. Individuals in the PEFR feedback group saw their PEFR value after each use while children in the no feedback group were blinded to their PEFR values. Asthma perception was stratified into the following zones: accurate zone, danger zone, and magnification zone. Doser devices were placed on ICS and quick-relief meter dose inhalers to track the number of actuations taken per day. The children's gender, ethnicity, and poverty level did not affect symptom perception. Children enrolled in the PEFR feedback intervention had lower rates of underperception and higher rates of accurate PEFR values. Older children in the feedback group also had a higher percentage of predictions in the accurate zone. Children in the no PEFR feedback group were in the danger zone 42 % of the time compared to 15 % in the PEFR feedback group. The PEFR feedback group showed higher rates of ICS adherence, but ICS medications were used less than half of the time. Quick-relief inhaler use was elevated in the PEFR feedback group. This could be attributed to awareness of a low PEFR value, prompting use of a quick-relief inhaler.

Resistive Load Detection

Resistive load detection is another method that has been used to improve patient perception of respiratory sensations. The procedure requires an individual to breathe continuously on a circuit attached to a pneumotachograph and a two-way non-rebreathing valve. Resistive loads are added to the circuit by

switching to a valve with added resistance, and additional airflow resistance is obtained by attaching PVC pipe tubing with nylon screens to the circuit. During each session, an individual transitions between an open valve and a valve with added resistance. The goal is to determine if an individual can detect the change in airflow resistance. Resistive load detection provides feedback for correct judgments of added resistive loads. In adults with asthma, this approach has improved sensitivity to airflow obstruction. Harver et al. [11•, 23••] studied resistive load detection in a large group of children with persistent asthma to determine if this training would improve their asthma symptom perception. One hundred and fifty-five children, ages 8–15 years old, started with an initial training session for resistive load detection. The participants were then randomly assigned to feedback or no feedback groups for training sessions. After each stimulus was presented, the child was asked to indicate if there was a change in resistance to breathing. Children in the feedback group were able to discriminate between increased or decreased resistance more accurately. Physical development, cognitive development, adherence regimens, and symptom experience were variables in the study that could predict whether a participant would be more or less accurate. Of concern, it is not clear to what extent external resistive loads are similar to internal resistive loads, such as seen in asthma or methacholine-induced bronchoconstriction. Resistive load detection stimulates mechanoreceptors but does not account for additional physiologic and psychologic factors involved in bronchoconstriction. Other investigators have presented conflicting data as to how well resistive load detection correlates with the perception of airway obstruction [24–26].

Cough Detection Devices

Rhee et al. [27] studied a device that detects cough by use of a mobile system platform for continuous audio analysis. The number of cough events is continuously analyzed, and real-time data are translated into a chart for patient review. A total of 84 teens (42 with asthma and 42 controls) were recruited to participate in a 7-day trial. FeNO levels and pulmonary function testing were obtained at the beginning and end of the study. Additional variables were measured only in the asthma group and included asthma control questionnaire (ACQ), pediatric asthma quality of life questionnaire (PAQLQ), health care utilization, visual analog scale (VAS), and an asthma control diary. Cough counts were negatively associated with FEV1, asthma control, and overall quality of life. Cough counts did not show any association with FeNO levels. The cough detection (ADAM) device did have poor diagnostic sensitivity. The chance of identifying an individual with asthma was 51 % using a 20 coughs/day cutoff. However, the specificity to classify those without asthma was 73 %. The

device did show false events depending on the amount of environmental noise, about 2 coughs/h. Poor sensitivity was attributed to good disease control in the asthma group. Overall, the primary use of this device is to alert an individual to the presence of a persistent cough. The cough may or may not be secondary to poor asthma control.

Clinical Implications

Many physiologic and psychologic factors interact in determining how an individual will notice changes in airflow obstruction. Because inaccurate perception is prevalent in adults and children, one cannot rely on only the clinical history and physical examination for diagnosis of asthma, determining the level of control, ongoing management, or assessment of exacerbations. Furthermore, history and examination will not identify poor perceivers or hyperperceivers. Thus, as noted by the Expert Panel 3 report, objective assessment of lung function is an essential component of asthma assessment and management [28]. These guidelines recommend “periodic daily peak flow monitoring” for known poor perceivers; a similar recommendation is appropriate for hyperperceivers. Inexpensive spirometers intended for home monitoring are also available; however, home spirometers are not well-validated and are not recommended in current guidelines. In the office, spirometry is the objective assessment of choice.

Conclusions

The perception of asthma severity in children and adults is multifactorial. Physical and cognitive development, psychiatric comorbidities, gender, race, and prior asthma experience mold children’s view of asthma. Investigation into asthma perception is complicated in children due to a reduced verbal ability to describe the sensation of breathlessness, chest tightness, and dyspnea. PEFR monitoring or use of other devices may aid in symptom detection of airflow limitation and in training perception. Resistive load training is another intervention that warrants further study.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:

- Of importance
- Of major importance

1. Bloom B, Jones LI, Freeman G. Summary health statistics for U.S. children: National Health Interview Survey, 2012. Vital and health statistics Series 10, Data from the National Health Survey. 2013(258):1-81.
2. National Hospital Ambulatory Medical Care Survey: 2011 Emergency Department Summary Tables. 2011.
3. Kopel SJ, Walders-Abramson N, McQuaid EL, Seifer R, Koinis-Mitchell D, Klein RB, et al. Asthma symptom perception and obesity in children. *Biol Psychol*. 2010;84(1):135–41. doi:10.1016/j.biopsycho.2009.11.007.
4. McFadden Jr ER, Kiser R, DeGroot WJ. Acute bronchial asthma: relations between clinical and physiologic manifestations. *NEJM*. 1973;288:221–5.
5. Shim CS, Williams Jr MH. Evaluation of the severity of asthma: patients vs. physicians. *Am J Med*. 1980;68:11–3.
6. van Gent R, van Essen-Zandvliet LEM, Rovers MM, Kimpen JLL, de Meer G, van der Ent CK. Poor perception of dyspnoea in children with undiagnosed asthma. *Eur Respir J*. 2007;30:887–91.
7. Rubinfeld AR, Pain MCF. Perception of asthma. *Lancet*. 1976;1(7965):882–4.
- 8.•• Feldman JM, Steinberg D, Kutner H, Eisenberg N, Hottinger K, Sidora-Arcoleo K, et al. Perception of pulmonary function and asthma control: the differential role of child versus caregiver anxiety and depression. *J Pediatr Psychol*. 2013;38(10):1091–100. doi:10.1093/jpepsy/jst052. **In children age 7-11, anxiety is associated with hyper-perception of asthma symptoms and increased rescue medication use. Depressive symptoms were associated with increased rescue medication use, but not perception of lung function. Children whose caregivers had anxiety or depression were more likely to have low pulmonary function than those whose caregivers did not have anxiety or depression.**
9. Baker RR, Mishoe SC, Zaitoun FH, Arant CB, Lucas J, Rupp NT. Poor perception of airway obstruction in children with asthma. *J Asthma*. 2000;37(7):613–24.
10. Burdon JGW, Juniper EF, Killian KJ, Hargreave FE, Campbell EJM. The perception of breathlessness in asthma. *Am Rev Respir Dis*. 1982;126:825–8.
- 11.• Harver A, Dyer A, Ersek JL, Kotses H, Humphries CT. Reliability and predictors of resistive load detection in children with persistent asthma: a multivariate approach. *J Asthma*. 2015;52(2):146–54. doi:10.3109/02770903.2014.955188. **The authors evaluated reliability of resistive load detection in 75 asthma patients age 8-15 years. Of these, 31 performed reliably in 4 sessions. Factors affecting reliability were development (cognitive and physical), experience with asthma symptoms, and medication adherence.**
12. Ottanelli R, Rosi E, Romagnoli I, Ronchi MC, Lanini B, Grazzini M, et al. Perception of bronchoconstriction and bronchial hyper-responsiveness in asthma. *Clin Sci*. 2000;98(6):681–7.
13. Schweitzer C, Marchal F. Dyspnoea in children. Does development alter the perception of breathlessness? *Respir Physiol Neurobiol*. 2009;167(1):144–53. doi:10.1016/j.resp.2008.12.001.
14. Harver A, Schwartzstein RM, Kotses H, Humphries CT, Schmalzing KB, Mullin ML. Descriptors of breathlessness in children with persistent asthma. *Chest*. 2011;139(4):832–8. doi:10.1378/chest.10-2388.
- 15.• Krishnan JA, Lemanske Jr RF, Canino GJ, Elward KS, Kattan M, Matsui EC, et al. Asthma outcomes: symptoms. *J Allergy Clin*

- Immunol. 2012;129:S124–35. **Children with poor perception of asthma have lower baseline FEV1 and less use of rescue medications.**
16. Ungar WJ, Hadioonzadeh A, Najafzadeh M, Tsao NW, Dell S, Lynd LD. Parents and adolescents preferences for asthma control: a best-worst scaling choice experiment using an orthogonal main effects design. *BMC Pulm Med*. 2015;15:1–10.
 17. Nuijsink M, Hop WC, Jongste JC, Sterk PJ, Duiverman AE. Perception of bronchoconstriction: a complementary disease marker in children with asthma. *J Asthma*. 2013;50(6):560–4. doi:10.3109/02770903.2013.792347.
 - 18.●● Motomura C, Odajima H, Tezuka J, Harada J, Okada K, Nishima S. Perception of dyspnea during acetylcholine-induced bronchoconstriction in asthmatic children. *Ann Allergy Asthma Immunol*. 2009;102(2):121–4. doi:10.1016/s1081-1206(10)60241-4. **It appears that Latino children, as a group, were less accurate in perceiving lung function than non-Latino children.**
 19. Koinis-Mitchell D, McQuaid EL, Seifer R, Kopel SJ, Nassau JH, Klein RB, et al. Symptom perception in children with asthma: cognitive and psychological factors. *Health Psychol*. 2009;28(2):226–37. doi:10.1037/a0013169.
 20. Fritz GK, McQuaid EL, Kopel SJ, Seifer R, Klein RB, Mitchell DK, et al. Ethnic differences in perception of lung function: a factor in pediatric asthma disparities? *Am J Respir Crit Care Med*. 2010;182(1):12–8. doi:10.1164/rccm.200906-0836OC.
 - 21.●● Sah PK, Teague WG, Demuth KA, Whitlock DR, Brown SD, Fitzpatrick AM. Poor asthma control in obese children may be overestimated because of enhanced perception of dyspnea. *J Allergy Clin Immunol*. 2013;139–45. **Obese children with asthma may over-estimate symptoms of airflow limitation.**
 - 22.●● Feldman JM, Kutner H, Matte L, Lupkin M, Steinberg D, Sidora-Arcoleo K, et al. Prediction of peak flow values followed by feedback improves perception of lung function and adherence to inhaled corticosteroids in children with asthma. *Thorax*. 2012;67(12):1040–5. doi:10.1136/thoraxjnl-2012-201789. **The authors provided spirometric feedback to children who predicted their PEFr. The sessions provided greater accuracy in PEFr prediction, and less under-perception of low PEFr.**
 - 23.●● Harver A, Kotses H, Ersek J, Humphries CT, Ashe Jr WS, Black 2nd HR. Effects of feedback on the perception of inspiratory resistance in children with persistent asthma: a signal detection approach. *Psychosom Med*. 2013;75(8):729–36. doi:10.1097/PSY.0b013e3182a8bcde. **The authors evaluated feedback training by perception of resistive loads in 155 children with asthma. The training sessions increased discrimination between increases or no increases in resistive load.**
 24. Fritz GK, Adams SK, McQuaid EL, Klein R, Kopel S, Nassau J, et al. Symptom perception in pediatric asthma: resistive loading and in vivo assessment compared. *Chest*. 2007;132:884–9.
 25. Bijl-Hofland ID, Cloosterman SGM, Folgering HTM, Akkermans RP, Van Schayck CP. Relation of the perception of airway obstruction to the severity of asthma. *Thorax*. 1999;54:15–9.
 26. Julius SM, Davenport KL, Davenport PW. Perception of intrinsic and extrinsic respiratory loads in children with life-threatening asthma. *Pediatr Pulmonol*. 2002;34:425–33.
 27. Rhee H, Belyea MJ, Sterling M, Bocko MF. Evaluating the validity of an automated device for asthma monitoring for adolescents: correlational design. *J Med Internet Res*. 2015;17(10):e234. doi:10.2196/jmir.4975.
 28. National Asthma Education and Prevention Program TEPotDaMoA. Expert Panel Report 3 (EPR-3): Guidelines for the Diagnosis and Management of Asthma. Bethesda MD 2007.