Conceptual and Methodologic Issues in Quantifying Perceptual Accuracy in Childhood Asthma

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Delineated methodologic issues in the study of symptom perception in childhood asthma. A review of past and recent psychophysiological and clinical studies of both adults and children presents the methodologic and analytic approaches that have been applied to quantify perceptual accuracy. Peak expiratory flow rate, forced expiratory volume in the first second, and force expiratory flow can serve as objective measures of asthma. A visual analog scale, a numerical guess, and a categorical description as subjective measures all have clear strengths and weaknesses. Correlational analysis of subjective-objective data, arithmetic differences between subjective guess and objective value, and an error grid categori-

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zation can each be applied to calculate an accuracy index on an individual subject. Illustrative examples reveal that the same data lead to different indices depending on the method chosen. Empirical research is needed to standardize various methodologic approaches. Given the increasing prevalence, severity, and morbidity of pediatric asthma, the study of symptom perception may be a critical component in our understanding of asthma management, and will likely lead to useful clinical interventions.

KEY WORDS: symptom perception; asthma; perceptual accuracy.

Asthma is not only the most common chronic illness of childhood, but despite considerable improvement in the many aspects of asthma treatment, the prevalence, severity, and mortality related to this illness are on the rise. The prevalence of asthma in American children 18 years or younger increased nearly 40% from 1981 to 1988—an increase that translates into approximately 2.7 million children (Taylor & Newacheck, 1992; Weitzman, Gortmaker, Sobol, & Perrin, 1992). Furthermore, from 1980 to 1987, the asthma mortality rate increased 42% in children under age 20, with the highest increase in poor, urban, minority children (Evans, 1992; Weiss, Gergen, & Crain, 1992; Weiss & Wagener, 1990). In addition to the risk of death, there is a high risk of morbidity from pediatric asthma. Asthma accounts for 30% of pediatric hospitalizations (Gortmaker & Sappenfield, 1984), for approximately one third of school absences (Weitzman, Klerman, Lamb, Menary, & Alpert, 1982), and for numerous other psychosocial complications including reduced participation in sports and extracurricular activities (Nocon, 1991).

Psychiatrists and psychologists have studied psychosomatic aspects of bronchial asthma for decades. Specific emotional conflicts (French & Alexander, 1941); separation issues (Purcell et al., 1969); temperament (Kim, Ferrara, & Chess, 1980), family systems (Minuchin et al., 1975), personality (Glasberg, Bromberg, Stein, & Luparello, 1969), and psychopathology (Tietz, Kahlstrom, & Cardiff, 1975) have all been explored over the years as causal or contributory factors in asthma. It has been established that children with asthma and psychological problems have asthma that is more difficult to control. They require more concurrent antiasthma medication, especially corticosteroids (Fritz & Overholser, 1989), require a greater number of emergency room visits (Dirks et al., 1977), hospitalizations (Baron et al., 1986; Fritz & Overholser, 1989), and longer hospitalizations (Strunk, Mrazek, Fuhmann, & Labrecque, 1985), exhibit poorer compliance with oral theophylline (Christiaanse, Lavigne, & Lerner, 1989), and more frequently die of asthma (Kravis, 1987; Sears & Rea, 1987; Strunk, 1987). The early clinical work in this area that tried to establish an asthmatic personality type (Sperling, 1968) has been largely discounted, and there is now solid evidence documenting the heterogeneity of personality styles.
Perceptual Accuracy in Childhood Asthma

and psychosocial difficulties found in patients with asthma (Kinsman, Dirks, & Jones, 1982; Mrazek, 1988). Yet despite general understanding that psychosocial problems are associated with more morbidity and mortality, few studies have been able to demonstrate which specific psychological processes are most critical in influencing asthma outcome, or in documenting that a psychological intervention could ameliorate or prevent morbidity and mortality (Gustafsson, Kjellman, & Cederbald, 1986; Liebman, Minuchin, & Baker, 1974).

Perhaps more than any other illness, asthma necessitates a working partnership between physician, patient, and family for optimal treatment to take place. The episodic nature of asthma and the potential for rapid symptom progression has led to increased emphasis on self-management approaches, including national efforts by the National Heart, Lung and Blood Institute and the National Institute for Allergy and Infectious Diseases (Mellins, 1989; Parker, Mellins, & Sogu, 1989). Proper self-management leads to timely treatment and reduces the risk of iatrogenic problems and medication side effects. Some reports describe noncompliance or delay in seeking emergency care as major “avoidable” factors linked to the increase in asthma deaths (Kravis, 1987; Kravis & Kolski, 1985; Sears, 1988; Sears & Rea, 1987; Strunk et al., 1985). This finding makes self-management efforts especially salient.

The purpose of this review is to examine, from a conceptual perspective, one key component of the self-management process: accurate perception of asthma symptoms. We start by reviewing psychological and physiological factors hypothesized to affect perceptual accuracy in asthma and review the scant empirical data on this topic. Having reviewed what is known, we (a) propose a definition of perceptual accuracy in asthma; (b) examine existing objective and subjective assessment approaches that have been utilized in both clinical practice and the research literature; and (c) discuss pros and cons of different indices of perceptual accuracy that may be used by clinicians and researchers when working with asthma patients. We conclude with a discussion of the clinical and research implications of symptom perception for asthma management.

PSYCHOLOGICAL AND PHYSIOLOGIC FACTORS AFFECTING PERCEPTUAL ACCURACY

Inaccurate perception of asthma symptoms, which may occur for a variety of reasons, may be one common mechanism whereby a variety of psychosocial problems lead to out-of-control, or even fatal, asthma. The accurate perception of changes in respiratory function and consequent appropriate initiation of self-management is a complex skill. First, there must be a perceptual capability to detect airway changes. This capability requires intact proprioceptive neurons in the lungs and respiratory muscles, and unimpaired neuronal pathways to the
brain. Second, the person must be motivated and able to pay attention to these inputs. Third, the individual must accurately distinguish which perceptions correspond to changes in respiratory function due to bronchoconstriction versus which perceptions are due to changes in anxiety levels, emotional distress, pain, or other illness. Finally, the person must have the cognitive skills, knowledge, and the motivation to initiate an appropriate sequence of self-care assessments and treatments.

The ability to focus attention on respiratory changes may vary between person as well as within persons, although empirical studies of relevant factors are scarce. For example, it seems plausible that children with ADHD may have more difficulty than other children. The severity of their current psychological symptoms may interfere with attention. Likewise, concurrent stressors and resultant anxiety or dysphoria may either distract attention from respiratory sensations or lead to enhanced focus and hypersensitivity to them. In chronic pain patients, for example, the threshold for detecting and complaining of pain is lowered when there is concurrent depression (Roy, Thomas, & Matas, 1984).

The ability to distinguish physical sensations from emotional states is likely dependent on a number of factors, including familial teaching or modeling, cultural input, and genetic predisposition. Developmentally, younger children often complain of somatic symptoms when they feel distressed for emotional reasons (Campo & Fritsch, 1994), in part because they have not yet learned to sort out the different states. This ability requires a family culture (Fabrega, 1990) that helps teach children to distinguish between physical and psychological distress, as well as to express it. Patients with somatization disorders appear to have a different neuropsychologic makeup that includes a lower threshold for experiencing bodily sensations coupled with a difficulty expressing emotional states which has been termed “alexithymia” (Barsky, Goodson, Lane, & Cleary, 1988).

Certain psychological factors, such as depression or anxiety, may affect an individual’s motivation to intervene when symptoms are perceived. Abnormalities in the autonomic nervous system may be synergistic in depression and asthma (Miller, 1987). Anxiety has been documented to interfere with accurate labeling of symptoms as well as motivation to initiate appropriate action. Kinsman and associates (Dirks & Kinsman, 1981; Dirks, Schraa, Bron, & Kinsman, 1980) have shown that adult asthmatics who are high or low on a “panic-fear” dimension have more hospitalizations than those who score in the moderate range. In this work, low anxiety was hypothesized to lead to delay in seeking treatment; high anxiety levels were associated with poor discernment between respiratory and anxiety-related symptoms, leading to overutilization of treatment. This work was partially replicated in children (Baron et al., 1986). Others have reported an association between poor perception of respiratory sensation and a defensive style of repression (Steiner, Higgs, & Fritz, 1987).

There is a pertinent and substantial body of basic research in which well-
established methods of psychophysics (the study of the relationship between a physical stimulus and the sensation of it) have been adapted to assess sensory thresholds in respiration. Although this research to date has only involved adults and has not been related to clinical problems or settings, the findings have some relevance for the study of perceptual accuracy. In a typical study, added resistive loads of varying magnitude are applied with a breathing apparatus for one or several breaths, separated by "unloaded" breaths. The sensory threshold is defined as the smallest added resistance that can consistently be detected.

Individual adult subjects have been found to differ in their threshold for detecting the added load; children have not been studied. Passive respiration is associated with less accurate resistance detection than active respiration, indicating that active contraction of the respiratory muscles is essential in the detection of resistance (Killian, Mahutte, & Campbell, 1980). Research has also shown consistent findings whether the change in resistance occurs in the bronchial tree or at the mouth (Zechman & Wiley, 1986), suggesting that the perceptual process involves receptors in extrathoracic and intrathoracic airways plus muscles of the chest. In other experiments, airway anesthesia has not been found to alter load detection thresholds (Chaudhary & Burki, 1980).

In studies that have examined the effect of age on respiratory sensation, older adults seem less able to perceive added respiratory loads than younger adults (Akiyama, Nishimura, Kobayashi, Yamamoto, & Miyamoto, 1993; Tack, Altoe, & Cherniack, 1981). Variability in resistive load detection threshold is rather small from one assessment to the next in a given adult. Variability is much larger among adults. In one study, normal adults showed only 7% within-subject variation but 230% variation in threshold level between subjects (Killian, Mahutte, & Campbell, 1981).

Despite the promising results in some of the basic research and the logical appeal of the relevance of perceptual accuracy to clinical management of asthma, few studies have been conducted with actual patients. Rubinfeld and Pain (1976), using a methacholine challenge, found that 15% of adult asthmatics were unable to sense even marked airway obstruction. Burki, Mitchell, Chaudhary, and Zechman (1978) found adult patients to vary markedly in their ability to detect added resistive loads. Ergood, Epstein, Ackerman, and Fireman (1985) found no differences between adult asthmatics' and nonasthmatics' perception of respiratory function at rest or after moderate exercise. In the only study to date that deals with pediatric asthma patients, Sly, Landau, and Weymouth (1985) found no relationship between actual forced expiratory volume in the first second (FEV₁) and subjective ratings of FEV₁ in a group of children with asthma before or after an educational program. However, this study was compromised by its reliance on a single measure of subjective/objective correspondence obtained only twice, before and after the intervention.

More recently, there have been three studies suggesting that impaired symp-
Symptom perception may be a salient factor in predicting asthma outcome. Kikuchi, Okabe, and Tamura (1994) have demonstrated that the lack of perception of dyspnea is associated with near-fatal attacks of asthma in adults. Similarly, disregard of asthma symptoms is a factor that differentiated between children who eventually died from their asthma and those with equally severe asthma who did not die (Strunk et al., 1985; Zach & Karner, 1989).

Although this line of work is promising, it has been limited thus far by small samples and imprecise measurements of perceptual accuracy of respiratory symptoms. Before more work can be done to elucidate the numerous processes involved in the development and maintenance of symptom perception, a standardized and sensitive means of assessing respiratory sensation must be developed.

**Definition of Perceptual Accuracy**

We propose that a useful definition of perceptual accuracy is the degree to which subjective assessment of asthma symptomatology/severity corresponds with an objectively measured rating of severity. This definition implies an individual pattern that is determined from multiple observations of the correspondence between subjective and objective measurement. It also requires an objective change in respiratory status. Thus, an extremely accurate person is one who can subjectively distinguish small changes in physiologic function. Symptom perception accuracy is conceived to have both state-dependent and stable characteristics. Clinical experience (but as yet no empirical evidence) suggests that there is some stability in perceptual accuracy at least over a several week period; stability over longer periods (e.g., year-to-year) is unknown. Changes in this ability over development (e.g., from latency age to adolescence) have not been studied. Accuracy may also vary with situational changes such as the severity of an asthma episode, the setting (outdoors vs. doctor's office), or the level of psychological stress. The number and frequency of ratings needed to determine an individual's level of accuracy have yet to be determined by clinical study, but both symptomatic and symptom-free periods should be included.

**Objective Measurement of Respiratory Status**

Pulmonary physiologists have developed numerous indices and ratios that use volume, pressure, and flow measurements to describe function at various points in the respiratory cycle. In pediatric practice the number of frequently utilized indices is much smaller, but a single, validated "gold standard" does not exist. By far the most commonly used objective measure is the peak expiratory flow rate (PEFR). This National Institute of Health (Mellins, 1989) "Guidelines for the Diagnosis and Management of Asthma" has recommended regular mon-
itoring of PEFR. The major reason for the ubiquity of PEFR is ease and economy of measurement; PEFR is easily assessed with an inexpensive, hand-held peak flow meter. No other pulmonary function test approaches the technological simplicity of PEFR. Predicted normal values are available based on height, gender, and ethnicity, but individually determined baseline normal values are preferable for clinical use. Most children quickly learn their typical normal range. Disadvantages of using PEFR as the objective measure of asthma include the fact that it is highly effort-dependent and that there may be considerable variability between different brands of hand-held meters (Eichenhorn, Beauchamp, Harper, & Ward, 1982). Further, recent data suggest that because PEFR measures predominantly large airway function, a subgroup of children whose asthma involves primarily peripheral airways may not be monitored appropriately with PEFR (Klein, Fritz, Yeung, McQuaid, & Mansell, in press).

A reasonable alternative to PEFR is the FEV₁. This test is somewhat less effort-dependent than PEFR and may provide a more “complete” picture of lung function. Currently, FEV₁ is obtained only through full spirometry requiring more sophisticated and expensive equipment, careful monitoring, and physician interpretation. These factors limit the usefulness of FEV₁ in the clinical assessment of perceptual accuracy for they preclude easy self-monitoring.

The forced expiratory flow in the midportion of a breath (FEF25–75) primarily measures small airway function and is much less effort-dependent than PEFR. Like FEV₁, it can only be measured with spirometry equipment. FEF25–75 is an especially important index of asthma severity in the subgroup of children whose acute asthma episodes are characterized by peripheral airway compromise.

Subjective Assessment of Respiratory Symptoms

One of the most straightforward approaches to subjective quantification of symptoms is to ask patients to predict, based on their present asthma symptoms, what their objective pulmonary function test result would be at that moment. This is a reasonable approach to subjective assessment because PEFR monitoring is increasingly common among patients with asthma and the PEFR values are readily understood by both patients and physicians. Many asthma patients now monitor PEFR at home and are familiar with their personal range in readings. Thus, they have sufficient practice and feedback to help shape subjective assessments. For research purposes, the subjective and objective assessments are expressed in the same units, making analyses easily understood.

There are several potential disadvantages to subjective prediction of PEFR values. First, PEFR may not be a sensitive enough measure of pulmonary function for some children. Klein et al. (in press) found a significant number of
children (17%) had normal PEFR values even when they were clinically symptomatic. FEF_{25-75} was a more sensitive objective index of pulmonary functioning for this subgroup of asthmatic children. A second disadvantage of the PEFR prediction approach stems from the observation that many developmentally younger children think of illness in categorical terms—"healthy," "sick," "not too good," and so forth. To express their status in continuous numbers may be a cognitive challenge for young children. Finally, whether PEFR or FEF_{25-75} is used as the objective index, there can be a recency effect to the prediction process. That is, some patients—especially younger, cognitively concrete children—may tend to guess the same value as they did on the last occasion. This effect can lead to an artifactually accurate (or inaccurate) guess that does not reflect an actual assessment of physiologic state.

A second approach to subjective assessment is the use of a visual analog scale (VAS). With a VAS, a patient picks a rating from a 100-mm line that may or may not have verbal or pictorial anchors. For example, one end of the line might be the rating "terrible asthma" and the other end, "no symptoms"; the patient marks the line somewhere in-between. In another type of VAS, pictorial anchors are used. One such instrument, the Brown Asthma Visual Analog Scale (Fritz, Spirito, Yeung, Klein & Freedman, 1994) was developed for children with asthma. In this scale, both verbal anchors and cartoon depictions are used to help orient a child to the use of the scale.

The advantage of a VAS is that it requires summation of symptoms and a judgment, which means that it is more global. The "gut feeling" reflected in such a global assessment may very well be the real basis for subsequent action or inaction in asthma self-management. Because it is continuous, one can look for small changes in symptomatology detected by the patient. One disadvantage of a VAS is that it requires the ability to use a combination of verbal or pictorial anchors and a proportional spatial relationship between anchors, making the approach clearly inappropriate for developmentally immature children with pre-operational cognitive abilities. Further, patients develop response sets; for example, they may consistently rank extremes. Others do not use the extremes of the scales but, instead, develop a response set that truncates the use of potential values. In these cases, the advantages of the VAS are minimal unless the patient is reeducated to the use of the scale.

A third approach to subjective assessment is categorical description. In this type of approach, a simple scale may be used. For example, five verbal descriptors might represent choices to describe asthma symptomatology (e.g., none, a little, some, pretty bad, or awfully bad—the worst). Such categorical descriptors have an advantage because they are commonly used in everyday life. Descriptors may be more understandable than a VAS and the wording can be changed and defined by the investigator to ensure proper understanding of the terminology by a particular population. Although categorical scales commonly employ verbal
descriptors, they can also use pictorial descriptors for young children, such as the FACES scale used by children to quantify pain (McGrath, 1987). The disadvantage to the categorical approach is the limited variability; it discourages attempts at distinguishing subtle differences in symptomatology. In addition, categories may not have the same meaning across patients. There may also be intraindividual variation in rating tendencies that are more problematic when using a scale with a small number of points.

A fourth approach to assessing symptomatology is to ask the patient what treatment is indicated by symptomatology. In other words, the symptoms are categorized on the basis of the extent of treatment needed: inhaler versus nebulized medications versus urgent visit to the physician. The advantage to such a rating system is that it is clinically relevant and easily understood by patients who are knowledgeable in self-management techniques. A major disadvantage to such an approach is that it confounds treatment knowledge and judgment, and perception of illness. A child who perceives pulmonary changes adequately but lacks self-management knowledge would be incorrectly classified regarding perceptual ability using this approach. In addition, utilizing treatment categories means this method has the same problems as other categorical approaches. Finally, treatment plans can vary between one physician and another, making it hard to compare across practices or in research populations.

DEVELOPMENTAL CONSIDERATIONS IN OBJECTIVE AND SUBJECTIVE ASSESSMENT

In clinical practice, the treating physician relies on a symptom report from the child with asthma and/or the parent regarding pulmonary functioning and then provides guidelines regarding when and how to manage acute symptoms according to the overall treatment plan. For the youngest children, this approach relies almost entirely on the parent's ability to notice symptomatic changes in the child's presentation. However, this process likely lays the groundwork for the development of children's own symptom perception, for children are thought to acquire concepts of health and health skills through repeated opportunities for practice of these behaviors in the home (Tinsley, 1992).

As children approach school age and begin to have responsibility for monitoring their symptoms, their own ability to attend to changes in respiratory status and initiate appropriate treatment becomes increasingly important. Recent research demonstrates that with increasing illness knowledge and developmental progress, school-aged children begin to rely more on internal physiologic cues as signs of health difficulty (Hergenrather & Rabinowitz, 1991). Experienced physicians find that children as young as 6 years old can reliably use a hand-held peak flow meter if provided with appropriate instruction and parental monitoring.
of the procedure (Clark, Evans, & Mellins, 1992). As children progress towards adolescence, they begin to take more responsibility not only for identifying symptoms but for self-management. Thus the developmental progression from the preschooler's total reliance on parental care of their asthma, to the school-aged child's active participation in symptom identification, to the adolescent's central position in asthma self-management means that the role and importance of symptom perception may vary with developmental stage.

The child's age and overall cognitive level should serve as a guide for choosing the appropriate subjective measurement of current symptomatology. Some children are more familiar with either verbal or pictorial categories; others may be able to effectively use graphs or number lines for a more fine-grained assessment of symptom state. We have observed that younger children (7 years and below) are more comfortable using categories. Graphical representation using a visual analog scale with pictorial anchors is likely the optimal choice for this younger group (Fritz et al., 1994). Children 8 years and older can often guess their own peak flows and give a more precise description of how their current state compares to previous exacerbations. However, there appear to be significant differences in this ability, which may be related to experience, psychological and/or family factors. Future research is needed to determine more precisely how these factors change over time and interact with critical developmental transitions.

INDICES OF PERCEPTUAL ACCURACY

Selection of appropriate objective and subjective variables and their measurement at a number of points are essential steps in determining the perceptual accuracy of a particular patient. The method by which these data are analyzed or summarized is also an important factor in the determination. Several approaches are conceptually possible, but they do not necessarily lead to the same classification of perceptual accuracy when applied to an individual patient's data. The almost total lack of published research studies unfortunately means that previous work on the utility of a particular approach cannot be cited. Our own work to date provides the basis for the three approaches which are described briefly; data from five illustrative cases are then analyzed with each approach. The five cases were selected because they represent the full range of perceptual ability and their data sets have different characteristics.

Correlational

If a sufficient number of trials are available, a child's subjective and objective ratings at each point may be statistically correlated; the correlation coeffi-
cient can be used as an indication of the magnitude of perceptual accuracy for the given child. The advantages of this correlational approach include the creation of an index of association that depends little on specific scale properties. Subject variables (e.g., VAS or "guess" of predicted PFT value) can be standardized and combined, creating a more stable subjective index to correlate with objective measurement. This fact may explain why correlation coefficients have been the most commonly used statistical index in quantifying the accuracy of subjective perception in asthma research (Fritz, Klein, & Overholser, 1990).

Despite the appeal of such an approach, it is subject to the same limitations of most correlational methods; a sufficient number of observations are needed for a valid index, and the correlation is likely to be low if there is insufficient variability on indices measured. In the latter case, poor perceptual accuracy could be confused with statistical artifact. Further, low correlations are likely to contain no information regarding the type of perceptual error; overestimation of symptoms is indistinguishable from underestimation even though the medical consequences are very different. Table I summarizes these issues and the overall variability of correlational analyses of 30 subjective (either VAS ratings or guesses of PEFR) and objective (PEFR, FEV₁, or FEF₂₅₋₇₅) assessments for five different children with asthma (selected for illustrative purposes). For example, Subject 2 had VAS ratings that were very restricted, and the correlations with pulmonary function were poor. Subject 5, in contrast, had a similar mean VAS rating but more variability (larger SD); the correlation with pulmonary function was better. Statistical significance testing was done to illustrate the magnitude of the subjective-objective association reflected in the coefficients obtained.

**Arithmetic Differences**

When the same specific measurement scales are used for objective and subjective ratings, the actual value obtained on the objective measure may be subtracted from the patient's guess that immediately preceded it according to the formula

\[
\left| \frac{\text{Guessed Value} - \text{Actual Value}}{\text{Predicted Value}} \right| \times 100 = \text{difference.}
\]

The Predicted Values in the formula above may be obtained from normative tables (e.g., Polgar & Romadhaf, 1971). Since normal PFT values depend on the size of the child, this adjustment to the raw difference score is done to approximately standardize the magnitude of the difference. These difference scores are then summed over all observations. The mean difference score summarizes the subject's average guessing error; using the absolute value of the differences avoids the artifact of errors in opposite directions canceling each other out.
Table I. Five Illustrative Subjects Demonstrating Variability of Correlations Between Subjective and Objective Data

<table>
<thead>
<tr>
<th>Subject (sex/age)</th>
<th>VAS</th>
<th>VAS and PEFR (r)</th>
<th>VAS and FEV₁ (r)</th>
<th>VAS and FEF₂₅-₇₅ (r)</th>
<th>Guess</th>
<th>Guess and PEFR (r)</th>
<th>Guess and FEV₁ (r)</th>
<th>Guess and FEF₂₅-₇₅ (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 M/13</td>
<td>2.7</td>
<td>3.3</td>
<td>.13</td>
<td>-.07</td>
<td>-.06</td>
<td>70.0</td>
<td>1.7</td>
<td>-.06</td>
</tr>
<tr>
<td>2. M/10</td>
<td>4.6</td>
<td>2.6</td>
<td>-.03</td>
<td>-.07</td>
<td>-.02</td>
<td>93.1</td>
<td>9.8</td>
<td>-.13</td>
</tr>
<tr>
<td>3. F/15</td>
<td>50.7</td>
<td>12.9</td>
<td>.21</td>
<td>-.12</td>
<td>-.11</td>
<td>88.3</td>
<td>7.6</td>
<td>-.21</td>
</tr>
<tr>
<td>4 F/10</td>
<td>12.7</td>
<td>7.1</td>
<td>.50</td>
<td>-.25</td>
<td>.25</td>
<td>67.7</td>
<td>4.2</td>
<td>.46</td>
</tr>
<tr>
<td>5. M/12</td>
<td>5.6</td>
<td>16.8</td>
<td>1.11</td>
<td>.29</td>
<td>.29</td>
<td>75.7</td>
<td>7.7</td>
<td>.37</td>
</tr>
</tbody>
</table>

*VAS = visual analog scale rating (mm); PEFR = peak expiratory flow rate; FEV₁ = forced expiratory volume in the first second; FEF₂₅-₇₅ = forced expiratory flow in the midportion of the breath; Guess = subjective guess of PEFR (in % of expected PEFR).

r = correlation coefficient.

* p < .05
Unlike correlational analysis, an advantage of calculating the arithmetic differences is that the *direction* of inaccuracy can be meaningfully indicated. To depict the magnitude of imprecision in either direction, the sum of overestimations (subjective PFT guess > objective PFT measure) and the sum of underestimations (subjective PFT guess < objective PFT measure) are calculated. These indices can be interpreted individually or summarized in a ratio:

\[
\frac{\sum \text{overestimation}}{\sum \text{underestimation}} = \text{Over/Under Ratio}
\]

Because this method relies on mean differences, it is impossible to distinguish between a pattern of multiple small errors or a few large errors. The same mean value could result from either pattern, and a nonrepresentative outlier can have an unduly large impact on the final index. This approach is also cumbersome to apply when the subjective and objective variables are not in the same units. Finally, the arithmetic summary does not deal with the clinical relevance of the data, as differences of similar magnitude are weighted equally no matter what the child's clinical status at the time of the measurement.

Table II details the arithmetic summaries of the five illustrative patients' PEFR data compared to the corresponding guess. Results from correlational analyses may not agree with results from arithmetic differences approach. In our selected cases this discrepancy is most obvious regarding Subject 1 who is categorized as highly accurate with the arithmetic summary and inaccurate using the correlation coefficients.

<table>
<thead>
<tr>
<th>Subject (sex/age)</th>
<th>Mean difference(^a) (% )</th>
<th>Mean difference(^b) (absolute value) (%)</th>
<th>Over/under ratio</th>
<th>Over/under ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Σ overestimation(^c)</td>
<td>Σ underestimation(^d)</td>
<td>(\sum \text{overestimation})</td>
<td>(\sum \text{underestimation})</td>
</tr>
<tr>
<td>1. M/13</td>
<td>1.8</td>
<td>2.9</td>
<td>70</td>
<td>16</td>
</tr>
<tr>
<td>2. M/10</td>
<td>6.2</td>
<td>11.9</td>
<td>272</td>
<td>86</td>
</tr>
<tr>
<td>3. F/15</td>
<td>-11.6</td>
<td>12.2</td>
<td>9</td>
<td>356</td>
</tr>
<tr>
<td>4. F/10</td>
<td>-0.5</td>
<td>2.1</td>
<td>39</td>
<td>54</td>
</tr>
<tr>
<td>5. M/12</td>
<td>1.5</td>
<td>6.2</td>
<td>115</td>
<td>72</td>
</tr>
</tbody>
</table>

\(^a\) Difference = \(\left(\frac{\text{PEFR Guess} - \text{PEFR actual}}{\text{PEFR predicted}}\right) \times 100\% .\)

\(^b\) Summation of overestimation (subjective PEFR > objective PEFR); numbers adjusted for 30 observations.

\(^c\) Summation of underestimation (subjective PEFR < objective PEFR); numbers adjusted for 30 observations.
Error Grid Analysis

Cox et al. (1985), working with adult patients with diabetes, developed a graphic system in which a subjective estimate of blood sugar is plotted against the corresponding actual blood sugar level and then categorized on clinical grounds. This creative approach may be modified for asthma; the resulting grid takes the arithmetic summary described above a step further because the grid is grounded on clinical specifications. The categories on the grid consider the actual pulmonary status (indicated by the objective measure) and the implications of decisions for self-management that would be based on the subjective estimate. Although the grid system could be applied to any pulmonary function variable, the present status of PEFR makes it the clear choice to use in the development of the error grid analytic approach. The subjective/objective data for all the observations of a single subject are plotted on a grid.

As shown in Figure 1, the grid is divided into several areas. The diagonal is the line of identity, reflecting perfect subject-objective agreement. The vertical line at 80% of the child's best value (Self Best) is an arbitrary point at which PEFR can be considered to reflect clinically significant compromise (N.I.H., 1991). Zone A (Accurate) includes points for which the subjective estimate is within ±10% of the actual PEFR. Zones B.O. (Benign Overestimation) and B.U. (Benign Underestimation) include inaccuracies that have benign consequences in self-management. Zone B.O. includes clinically uncompromised points in which the subject overestimated PEFR; no intervention is needed or undertaken. Zone B.U. includes points where a compromised PEFR is exaggerated in the estimate; needed intervention would be vigorously pursued. Zone D (Dangerous) includes overestimates of clinically compromised PEFR; it is considered dangerous because the need for self-management interventions would be overlooked. Zone E (Erroneous) reflects the potential for overtreatment since it includes points at which a normal-range PEFR is perceived as compromised.

The error grid analysis provides a comprehensive display of the degree of accuracy in a child's subjective estimate, the extent and direction of inaccuracy, and the clinical risk (or lack thereof) potentially resulting from the specific inaccuracy. The approach allows the use of Area A alone to reflect overall accuracy. Alternatively, the grid can be used to generate a complete profile of accurate guesses, overestimations, and underestimations.

The main disadvantage of the error grid analysis stems from the arbitrary nature of the threshold for PFT abnormality. There is no empirical evidence for choosing 10%, 20%, or any other decrease from an individual's normal baseline level of pulmonary functioning as indicative of an asthma episode. Further, it is essential in using the error grid approach to have an individualized baseline (the child's personal best PFT value obtained when completely asymptomatic and exerting maximal effort) to use in standardizing the objective observations. Pub-
Fig. 1. Grid analysis in the accuracy of PEFR perception. Area A: Accurate area; Subject estimated PEFRs accurately. Area D: Dangerous area; Subject overestimated PEFRs while having low PEFRs. Area E: Erroneous area; Subject underestimated PEFRs while having normal PEFRs. Area B.O.: Benign overestimation area; Subject overestimated PEFRs while having normal PEFRs. Area B.U.: Benign underestimation area; Subject underestimated PEFRs while having low PEFRs.

Established tables only approximate normal values for a given child due to individual anatomic and functional variation.

Table III summarizes the data for the five illustrative subjects analyzed with the error grid approach, as indicated by the percentages of their guesses falling in Zone A. Similar to the findings with the arithmetic approach, Subjects 1 and 4 are the most accurate. Relatively few points fall in the clinically dangerous zone, with Subjects 1 and 3 having no such observations. The "over/under ratio" is

<table>
<thead>
<tr>
<th>Subject (sex/age)</th>
<th>Zone A (Accurate) (%)</th>
<th>Zone D (Dangerous) (%)</th>
<th>Zone E (Erroneous) (%)</th>
<th>Over/under ratio</th>
<th>Over/under ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. M/13</td>
<td>90</td>
<td>9.5</td>
<td>0</td>
<td>9.5</td>
<td>9.5</td>
</tr>
<tr>
<td>2. M/10</td>
<td>51</td>
<td>11.0</td>
<td>11</td>
<td>3.5</td>
<td>2.3</td>
</tr>
<tr>
<td>3. F/15</td>
<td>53</td>
<td>0</td>
<td>48</td>
<td>0.0</td>
<td>1.1</td>
</tr>
<tr>
<td>4. F/10</td>
<td>79</td>
<td>10.0</td>
<td>3</td>
<td>1.0</td>
<td>6.1</td>
</tr>
<tr>
<td>5. M/12</td>
<td>58</td>
<td>24.0</td>
<td>5</td>
<td>1.3</td>
<td>1.5</td>
</tr>
</tbody>
</table>

*Zones A, D, E, B.O., and B.U. are described in Figure 1 legend.
similar to the one obtained in the arithmetic approach, as both reflect a subject's tendency to err in a consistent direction. Two of five (Subjects 1 and 2) demonstrate degrees of overestimation of pulmonary function more frequently than underestimation; the other three do not demonstrate a pattern.

**CLINICAL IMPLICATIONS**

The majority of children with asthma require some objective measurement of pulmonary function to optimize self-management. Despite some of its drawbacks, PEFR is still the most widely accepted and easily accessible measure. Hand-held computerized spirometers are now more readily available (e.g., from Pulmonary Data Service, Louisville, CO), making possible the clinical use of less effort-dependent indices such as FEV₁, or FEF₂₅₋₇₅, in the future. Clinicians can contract with patients and their families to keep a diary of medication usage, subjective symptom ratings, and the corresponding pulmonary function data. This undertaking serves to provide useful baseline data while it educates and structures the family in asthma management.

Although PEFR measurements once or twice daily are commonly recommended by pediatricians, compliance may be a problem—especially when added to an already complicated regimen of several medications, allergen avoidance, nasal washes, exercise monitoring, and so forth. For children with documented poor perceptual accuracy, daily PEFR assessment will continue to be essential. However, for children who have demonstrated high perceptual accuracy, PEFR monitoring may be needed only to confirm detected changes. Not only may compliance with PEFR monitoring be improved, but other aspects of the regimen may not suffer due to compliance or conflict over how much time needs to be devoted to asthma.

Demonstrated perceptual accuracy may help the parents and physician trust the patient to be responsible, thus allowing many children additional independence and control over their asthma. Development of improved accuracy in symptom perception can be used as an objective indicator of when the child is ready to take the next step in asthma self-management. Empirical evidence of their child's perceptual ability may reassure parents and thus prevent the developmental problems associated with overprotection.

Early and accurate perception of asthma symptoms, if linked to timely and appropriate treatment, should reduce asthma morbidity. With an accepted standardized measurement of respiratory symptom perception, the importance of accuracy as a predictor of outcome in asthma morbidity and mortality can be tested. It cannot be assumed that more accuracy will always be associated with less morbidity or mortality. As was shown to be the case with the panic-fear construct of Kinsman et al. (1982) or compliance with medical treatments in
Perceptual Accuracy in Childhood Asthma

general (Asburn, 1981), it may be that there is an optimal window of accuracy. Too little accuracy may indeed lead to more emergency room visits and hospitalizations, due to disregard of warning symptoms and delay initiating treatment. On the other hand, too much sensitivity may extract a price in quality of life: It may indicate too much focus on the illness and its treatment at the expense of other areas of development. Consideration of the clinical implications of perceptual accuracy leads to several important questions for which there currently are no answers: Can perceptual accuracy be enhanced with educational efforts or motivational programs? Do family characteristics of dealing with physical symptoms affect perceptual accuracy for children with asthma? Will biofeedback training improve a child’s perceptual ability?

RESEARCH IMPLICATIONS

Accuracy of symptom perception is an important component of chronic pediatric illness, and it is a realm in which the knowledge base of child psychologist and psychiatrists is especially relevant. Although the processes involved in symptom perception have to date been almost completely ignored in empirical research on children with asthma or other chronic illnesses, the potential is great for an improved understanding of perceptual accuracy to enhance medical management. Areas in need of basic research include (a) determinants of perceptual accuracy and risk factors for inaccuracy; (b) cognitive ability in relation to perception; (c) the impact of affective state (anxiety or depression) on the perceptual process; (d) the possible role of psychological defenses such as repression and denial in blunting perception of physical symptoms; and (e) longitudinal changes across development in perceptual ability. As this review indicates, the methodology for studying symptom perception in children and adolescents is currently being developed. A number of choices about objective physiologic measures, subjective assessment, and analytic approaches are summarized in Table IV. Consideration of the practicalities involved in data collection, familiarity with children’s responses, and clinical judgment are essential in making the choice. Research comparing the various approaches to quantify perceptual accuracy is needed to empirically determine which is most effective.

As regards subjective assessment, continued research in accuracy of symptom perception should lead to methods to enhance subjective data provided by children. With the myriad alternatives in subjective assessment, objective assessment, and analytical method, each giving slightly different results, the picture can at first seem perplexing. The complex picture can be unclouded if we understand the different assumptions and limitations for each of the analyses: Correlation analysis assumes a linear relationship between subjective and objective assessment; arithmetic differences may be biased by outliers; and error grid
Table IV. Summary of Methodologic Considerations in Studying Symptom Perception in Asthma

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objective pulmonary status</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEFR</td>
<td>Easy, inexpensive, familiar</td>
<td>Effort dependent</td>
</tr>
<tr>
<td>FEV₁</td>
<td>Less effort dependent than PEFR</td>
<td>Laboratory measurement only</td>
</tr>
<tr>
<td>FEF₂₅₋₇₅</td>
<td>Least effort dependent</td>
<td>Laboratory measurement only</td>
</tr>
<tr>
<td><strong>Subjective estimate</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PFT prediction</td>
<td>Readily understood from home PEFR monitoring</td>
<td>Continuous variable difficult for those who think categorically</td>
</tr>
<tr>
<td>VAS</td>
<td>Global judgment obtained</td>
<td>Recency effect</td>
</tr>
<tr>
<td><strong>Categorical scale</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>May be more realistic</td>
<td>Limited variability</td>
</tr>
<tr>
<td></td>
<td>Wording can be tailored to developmental level</td>
<td>Categories may not mean the same to all individuals</td>
</tr>
<tr>
<td><strong>Treatment indicated</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clinically relevant—reflects self-management</td>
<td>Confounds symptom perception with illness knowledge and judgment</td>
<td></td>
</tr>
<tr>
<td><strong>Analytic approaches</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correlation</td>
<td>Not dependent on absolute scale properties</td>
<td>Artifact possible when variability is limited</td>
</tr>
<tr>
<td>Arithmetic</td>
<td>Can show direction of error</td>
<td>No directionality of error</td>
</tr>
<tr>
<td>Error grid</td>
<td>Shows direction of error</td>
<td>Outliers affect the mean</td>
</tr>
</tbody>
</table>

The analysis assigns subjective guesses arbitrarily into zones. With further studies to refine the definition of the accurate zone and to validate various zones, the error grid can potentially be a useful research and clinical tool for identifying high risk asthma patients. Future research in perceptual accuracy should provide a critical first step in reducing asthma morbidity through the identification of high-risk patients and the enhancement of appropriate medical interventions.
REFERENCES


