Chapter 9
Home Monitoring of Asthma: Symptoms and Peak Flow

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Monitoring is an established component of asthma control. Its purpose is to provide the patient an ongoing evaluation of the severity of the disease. The importance of such an evaluation cannot be overestimated as it guides corrective measures needed to keep asthma under control. All asthma patients monitor severity at some level, but only some do it systematically. The term 'home monitoring' implies the latter. It has been a part of asthma self-management programs since their inception. And while no one questions the necessity of monitoring for asthma control, its contribution to asthma self-management is not fully understood.

Two forms of home monitoring have emerged: symptom monitoring and peak flow monitoring. Symptoms monitored include both subjective elements of an asthma exacerbation (i.e., dyspnea, chest tightness, cough, wheeze, and congestion), and objective indices of asthma severity such as activity limitation and nighttime awakenings. Respiratory indices monitored can include any of the several lung functions but only peak expiratory flow rate (PEFR) has been used widely. It is not uncommon for symptom and peak flow monitoring to be practiced together for asthma self-management. Despite the accepted value of monitoring, a great deal of interest has been devoted to examining the relative effectiveness of the two in asthma control.

In this chapter, we describe common home monitoring practices and validation procedures, outline developments with potential to improve accuracy of symptom and PEFR indices, and review research on effectiveness of home monitoring in asthma self-management.

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Home Monitoring Practice

Symptom Monitoring

Monitoring of symptoms includes practices that differ in terms of the demands they place on patients. In the simplest case, symptom monitoring is not considered an intervention but conducted to gain information about variability of symptoms that might be useful in the interpretation of findings (Charlton et al. 1994; Ignacio-Garcia and Gonzalez-Santos 1995). Although patient reactions to monitoring are not of primary interest in this procedure, the act of observing and recording symptoms may affect the way in which some patients deal with their asthma. A somewhat more demanding procedure involves providing the patient with general guidelines for reacting to symptoms. These may involve instruction in tracking the severity of asthma with symptoms, in using symptoms to identify triggers of asthma, and in corrective action required when symptoms occur (e.g., Creer et al. 1988; Kotses et al. 1995). Symptom monitoring may be made even more demanding when combined with an action plan, a formal set of recommendations for control of asthma at different levels of severity. One such plan, for example, specified symptom benchmarks that cued administration of an increasing amount of a bronchodilator and initiation of steroid administration (Turner et al. 1998). The National Institute of Health (NIH) recommends use of a formal action plan (NIH 2007).

Symptoms such as cough, wheeze, and others may be recorded individually (e.g., Santanello et al. 1997) or in the aggregate by expressing the effect of all symptoms in a single asthma severity score (e.g., Fritz et al. 1990). The two forms of monitoring yield different information. Recording symptoms individually has the

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advantage of preserving the response characteristics of patients and the disadvantage of complicating the interpretation of symptoms. Symptoms monitored in the aggregate resolve the interpretation problem but mask unique symptom patterns that may be potentially important. There is no compelling reason for preferring one form of symptom assessment consistently over the other.

PEFR Monitoring

The PEFR is the fastest rate of exhalation that can be maintained for 10 ms (Wright and McKerrow 1959). Patients can measure it at home with an inexpensive meter. The measurement requires the patient to exhale forcefully through the meter and to record the value indicated. Introduction of a meter, even one as simple as that used by most patients, necessitates patients be trained in its use. As consistency of patient recording procedures is desirable, a commonly used set of training guidelines is recommended.

Several issues must be dealt with before the patient can use the meter effectively. First, it is essential that the meter be kept clean, in good working condition, and recalibrated periodically. The latter is important because some meters lose calibration after a few hundred tests (Shapiro et al. 1991). Second, the PEFR is effort-dependent. To get a good reading, exhalation into the meter must be as forceful as possible. Inevitably, the effort-dependency of PEFR recording leads to error, as it is difficult to achieve maximum expiratory effort consistently (Gannon et al. 1999). Additional error is introduced because effort-dependent pulmonary functions can be influenced by subtle factors (Harm et al. 1984). To compensate for these errors, the best of three PEFR readings taken a minute apart is considered as the best estimate of PEFR (NIH 2007). Third, the PEFR is subject to diurnal variation; it is usually lower in the morning than it is in the evening. If daily range is of interest, two scores a day, one in the morning and one in the evening, must be taken. If daily variation is not of interest, or if two recordings per day are judged to place too heavy a burden on the patient, one recording will suffice. When PEFR is recorded but once a day, it is important that the reading be made at the same time each day. Fourth, the procedure for recording the PEFR is standardized. NIH recommends specific steps (i.e., stand up, take a deep breath, etc.) be followed in testing PEFR (NIH 2007).

A single PEFR score is meaningless to the individual and useless for managing asthma. To be informative, the score must be compared to a standard. Any one of a number of standards may be used, but the benchmark recommended by NIH (2007) is the "personal best" score. It is the highest score the patient can achieve during regular testing throughout a 2-week period. Asthma severity is measured by PEFR expressed as the percentage of personal best score. NIH (2007) recommends the distribution of percentage scores be subdivided into severity ranges representing little or no asthma (80–100% personal best–green zone), worsening asthma (50–79% personal best–yellow zone), and dangerous asthma (below 50% personal best–red zone). Each zone is associated with specific recommendations for asthma management.

Like its symptoms counterpart, PEFR monitoring has been used in asthma self-management programs that feature different levels of patient demand including: solely for data collection (e.g., Ignacio-Garcia and Gonzalez-Santos 1995), in moderately structured self-management (e.g., Creer et al. 1988), and in self-management that includes a formal action plan. (e.g., Turner et al. 1998). Recent recommendations from the National Asthma Education and Prevention Program Expert Panel Report-3 (NIH 2007) include peak flow monitoring in patients who: have moderate or severe persistent asthma; have a history of severe exacerbations; poorly perceive airflow obstruction and worsening asthma; or prefer this monitoring method. The latter two recommendations were based more on panel consensus judgment than on sufficient clinical literature that would provide stronger, evidence-based conclusions.

Considerations of usage and attitudes bear on peak flow monitoring preferences. First, the percentage of patients who use a meter regularly is low, reportedly 10% in one study (Kendrick et al. 1993) and 16% in another (Garrett et al. 1994). Second, patients who described a scenario of a slowly evolving asthma attack mentioned a peak flow meter only 25% of the time (Garrett et al. 1994). Third, only 20% of the parents of pediatric patients described a peak flow meter as useful for detecting of respiratory problems when the child was not exhibiting signs of respiratory distress (Lloyd and Ali 1992). Clearly, peak flow monitoring has not been highly endorsed by patients, but the question of monitoring preference has not been answered directly.

Several investigations have confirmed low levels of patient compliance with regular peak flow monitoring (e.g., Cote et al. 1998; Kamps and Brand 2001). If patients do not see benefits to monitoring adherence is likely to be poor (Clark et al. 1992), routine monitoring of peak flow may be difficult; it requires the availability of both a meter and a suitable place in which to execute an expiratory maneuver, and it may interfere with other activities. Aspects of peak flow monitoring may be inconvenient or distracting for both pediatric and adult patients and place demands on patients that make the practice of peak flow monitoring challenging (McMullen et al. 2002). Finally, it is inconclusive whether peak flow monitoring interventions are cost-effective (Willems et al. 2006).

Validating Measures Used in Home Monitoring

Symptoms

Objective measures of lung function have long been considered the most suitable criteria for validating most categories of asthma symptoms. Therefore, correlations between symptom scores and respiratory indices represent the key estimates of validity. The correlations indicate how closely symptoms mirror aspects of respiration but they do not address the question of symptom-monitoring effectiveness. Nevertheless, evidence that symptoms represent a reliable, subjective index of airflow obstruction is important if they are to provide useful information about asthma. Unfortunately, validation studies of asthma symptoms have painted something less than a clear picture.

A summary of findings from a score of studies may be stated briefly: the relationship between asthma symptoms and lung function varies considerably between patients and, on average, is characterized by a correlation in the low-to-moderate range. Some patients exhibit a strong relationship between symptoms and lung function, but others do not. Patients who exhibit perceptual error demonstrate a significant difference between objective levels of airflow obstruction and subjective measures of perceived asthma severity. In a study of 37 children with asthma, for example, Fritz et al. (1990) reported correlations between symptom severity and PEFR that ranged from 0.16 to −0.86. Similar findings were reported by Brouwer et al. (2006); in a study of 36 children with asthma, correlations between asthma severity scores and corresponding FEV_1 values in individual patients ranged from 0.51 to −0.28. Individuals in the low portion of the distribution of correlations may be said to exhibit perceptual error. Perceptual error also has been reported in studies of: (a) changes in bronchomoter tone induced by drugs (Burden et al. 1982; McFadden et al. 1973; Orehek et al. 1982; Rubinfeld and Pain 1976), (b) naturally occurring pulmonary variation (Bye et al. 1992; Ferguson 1988; Nguyen et al. 1996), (c) asthma symptoms recorded either in the aggregate (Fonseca et al. 2006; Fritz et al. 1990; Higgs et al. 1986; Kendrick et al. 1993; Peiffer et al. 1989), and (d) or individually (Apter et al. 1997; Apter et al. 1994; Cabral et al. 2002; Atherton et al. 1996; Pauli et al. 1985; Reeder et al. 1990; Santanello et al. 1997; Shingo et al. 2001). A recent review (Kotses et al. 2006) described these studies and others in detail.

The reasons for perceptual error in the interpretation of asthma symptoms are not altogether clear, but several factors may be involved. One factor may be adaptation or tolerance to obstruction. Perceptual error is greater in patients who either have become accustomed to a high level of obstruction (Rietveld and Everaerd 2000) or exhibit low values of either FEV_1 (Burden et al. 1982; Bijl-Hofland et al. 1999) or $FEF_{25–75\%}$ (Apter et al. 1997) compared to other patients. It is greater in patients with life-threatening asthma than in others (Julius et al. 2002), and it is more likely to occur during asthma exacerbation (Yoos et al. 2003) than at other times. Each of these findings suggests that asthma severity in one form of another interferes with symptom perception, but evidence to the contrary also has been reported (Cabral et al. 2002; Fritz et al. 1990; Rietveld et al. 2001).

Psychological factors that interact with environmental variables may contribute to perceptual error. They are invoked when changes in breathlessness are reported in the absence of concomitant changes in lung function, and other antecedent conditions cannot be identified. Asthma patients reported more symptoms in the absence of pulmonary change either when listening to wheezing sounds (Rietveld et al. 1997) or during conditioning of asthma symptoms (De Peuter et al. 2005). Similarly, imagery was associated with increased perceptual error in patients (Rietveld et al.

1999), as was watching affective film clips (von Leupoldt et al. 2006). These changes have been attributed to the effects of emotional or cognitive factors.

Psychological factors considered as traits also have been linked to perceptual error. In general, psychological trait relationships are hard to evaluate, as often closely related measures of the same construct do not agree. Consistency can also be a problem, especially when relationships are weak. Anxiety in children as measured by the Revised Children's Manifest Anxiety Scale, for example, has been reported to be both related (Chen et al. 2006) and unrelated (Fritz et al. 1996a, b) to symptom perception. Another personality trait, repressive defensive style, was associated with heightened symptom perception in adult asthma patients (Steiner et al. 1987), but not in children with asthma (Fritz et al. 1996a, b).

An additional set of factors comes from the field of sensory psychophysics and turns on appreciation of the separate and independent forces of *perceptual sensitivity* and *response bias* on judgments of the presence or absence of airflow obstruction (Harver and Mahler 1990, 1998). The first of these, sensitivity, represents the patient's capability for making discrimination about the presence or absence of acute airflow obstruction; how well a patient is able to make correct judgments and avoid incorrect ones. The second, response bias, provides an index of the patient's criterion for acting on information arising from the discrimination and refers to the non-sensory factors that affect judgments of symptom severity; how risky a patient might be in acting on the perceived discrimination (Baird 1998).

Demographic factors such as age, gender, and race represent yet another category of perceptual error inquiry. For these variables, the results have been mostly negative (e.g., Cabral et al. 2002; Fritz et al. 1990; Fritz et al. 1996a, b). Intelligence was related to perceptual accuracy in children (Fritz et al. 1996a, b), but the relationship was not strong. Overall, demographic variables do not appear to have a major impact on symptom perception of asthma.

Peak Expiratory Flow Rate

The PEFR is used in asthma monitoring because it is an indirect index of airway tone, an all-important quantity associated with asthma symptomatology. In home monitoring, there is no particular reason for preferring PEFR to other airflow measures except that it was the first measure used for that purpose (Wright 1978), and, as a result, continues to be the standard. Both mechanical testing and testing in patients have been conducted to determine whether PEFR describes airway status adequately.

Mechanical testing of accuracy and reliability of a number of PEFR meters was conducted by subjecting them to airflow patterns generated by a computer-controlled syringe (Gardner et al. 1992). Each meter was tested with a number of different airflow patterns all of which adhered to the testing recommendations of the American Thoracic Society (Gardner et al. 1987). Overall, the response of the meters was judged to be acceptable. The meters tended to overestimate mid-range PEFRs, but not by very much. All of them appeared to be capable of tracking airflow variation as required in asthma self-management.

The accuracy of PEFR measured mechanically is far different from that measured by patients during home monitoring. The latter has been studied most notably by comparing PEFR recordings both to measures of airflow derived from a forced expiratory volume maneuver and to measures of airflow resistance. Such studies have shown that PEFR is related to other pulmonary responses, but not strongly, a conclusion consistent between studies with widely dissimilar methodologies. In half of over 6,000 adult patients, percent-of-predicted PEFR differed from percent-of-predicted FEV_1 by more than 10% (Aggarwal et al. 2006). In 18% of 91 children with asthma, PEFR was in the normal severity zone but FEV_1 was not, and concordance between PEFR and $FEF_{25-75\%}$ was low (Klein et al. 1995). In twenty-four asthma patients who exhibited an FEV_1 drop large enough to place the patient in a lower zone of severity, the associated PEFR drop did not affect severity zone status (Gautrin et al. 1994). In 102 patients, intra-subject variability was greater in PEFR than it was in FEV_1 (Vaughan et al. 1989). And in healthy individuals, the correlation between PEFR and total respiratory resistance was, on an average, only −0.41 (Westlund et al. 1987).

Error in PEFR recordings may be introduced by any one of the several factors. Of these, the most important may be the effort-dependency of PEFR. As noted earlier, an accurate PEFR requires the patient to apply maximal effort during the expiratory volume maneuver. If the patient does not, the reading will underestimate the patient's airflow capability. Related to effort dependency of the PEFR is the quality of its expiratory maneuver. A less than maximal effort may result in reduction of maneuver quality, a quantity that may be evaluated by examination of the flow-volume curve. Maneuver quality is affected by age and by anti-inflammatory medication usage (Thompson et al. 2006). Therefore, it is possible that these variables affect PEFR accuracy. Air trapping, a result of airway closure caused by inflammation, also can affect the PEFR accuracy. In a study of 669 patients with asthma and 85 healthy individuals, air trapping was accompanied by normal PEFR but reduced FEV_1 and $FEF_{25–75\%}$, and a concomitant decrease of the ability of PEFR to predict the other measures (Eid et al. 2000).

Improving Effectiveness of Home Monitoring

Symptom Perception

The lack of agreement between objective and subjective measures of asthma severity is a vexing problem for many patients. As noted earlier, most patients use symptoms as guides in asthma control, but the practice is helpful only to some. Others, those in whom the link between symptoms and asthma severity functions imperfectly or not at all, may often be left feeling overwhelmed by the enormity of efforts needed to control asthma, and constantly surprised by the seriousness of the condition when it demands their attention. Such patients require techniques that have the potential to reduce the difference between objective and subjective measures of asthma severity and improve understanding of the physiological basis of asthma symptoms (Banzett et al. 2000; Stahl 2000). Unfortunately, the available candidates for such a role are few, but several approaches have been examined.

1. *Peak expiratory flow rate training*. In efforts to improve the accuracy of subjective respiratory sensations, patients estimated PEFR daily and compared their estimates with actual PEFR and respiratory sensations. It was assumed that improvement in the accuracy of PEFR estimates would generalize to recognition of asthma symptoms. This is a plausible idea, and studies were successful in showing PEFR estimation with feedback resulted in more accurate estimates of PEFR (Silverman et al. 1990; Silverman et al. 1987). The early studies were confirmed by recent work that included better controls. Children with asthma who estimated PEFR for at least 15 days under conditions of accurate feedback exhibited less error in their estimates than children who received no feedback (Kotses et al. 2008). The potential usefulness of all PEFR training studies was limited, however, by the restricted range of PEFR values to which the children were exposed.
2. *Detection of added resistive loads*. To overcome the restricted range problem, researchers have turned to added resistive load detection. Combining added loads with feedback can provide training conveniently in the recognition of respiratory resistance throughout a wide range of values. Briefly, the technique consists of inserting screens that obstruct airflow, to varying degrees, into the patient's breathing circuit, and recording the patient's sensitivity to them. Feedback of accuracy of the patient's perception of added loads has the effect of improving the patient's sensitivity to them (Harver 1994; Harver et al. 2008; Stout et al. 1997). Because asthma symptoms involve a large measure of respiratory resistance decreases, improvement in recognition of respiratory loads could generalize to improvement both in recognition of asthma symptoms and in asthma; but empirical tests of this hypothesis have only begun.
3. *Error grid analysis*. This procedure combines a graphic representation of clinically meaningful asthma severity zones (e.g., the NIH green, yellow and red zones) with a scatter diagram of actual versus estimated PEFR scores both expressed as a percent of personal best (Feldman et al. 2007; Fritz and Wamboldt 1998; Fritz et al. 1996a, b; Klein et al. 2004). Points representing the divergence between estimated and actual PEFR fall into safe or dangerous areas as defined by asthma severity zones. Examination of the scatter diagram of estimated versus actual PEFR values may reveal characteristic patterns of over- or underestimation of PEFR and thereby provide guidance for improved accuracy. Scatter diagrams may be based either on estimates made by a sample of patients or on numerous estimates made by a single patient. The error grid analysis has yet to be applied systematically in clinical settings.

Pulmonary Monitoring

Widespread PEFR home monitoring did not begin until after the introduction of the mini-Wright meter (Wright 1979), a low-cost device that patients could keep at home. That meter and a number of similar meters developed shortly thereafter were limited to measurement of a single quantity, the PEFR. Subsequent development in technology produced meters that measured multiple pulmonary functions and included storage capability. Such meters provided additional possibilities for monitoring asthma severity and maintained records conveniently. It is likely that the next stage of meter development will include devices with the ability to derive functions based on one or more measures that can improve both evaluation of asthma severity and prediction of asthma exacerbation. Potential improvements in the usefulness of pulmonary monitoring described below suggest such a possibility.

1. *Conditional probability*. Conditional probability, as the term is applied to asthma, represents the probability of an asthma attack given the occurrence of a critical PEFR value. The critical PEFR value, determined empirically, is the PEFR score at which prediction of an asthma attack is maximized. The difference between the likelihood of an attack when PEFR is above or below the critical value represents the increase in predictability afforded by the computation of conditional probabilities. Using this procedure, Taplin and Creer (1978) documented a threefold increase in predictability of asthma in two patients. Additional improvements in the procedure led to a nearly fivefold increase in asthma predictability (Harm et al. 1985). There is no doubt that improved prediction of attacks based on PEFR would be useful for patients. But it is equally apparent that computation of conditional probabilities is beyond the capabilities of many patients. Incorporating computation of conditional probabilities into a meter that also has the ability to record and store PEFR values as well as record asthma attacks may benefit asthma management.
2. *Identifying periods of ineffective pulmonary monitoring*. Air trapping is characteristic of individuals with severe asthma (Sorkness et al. 2008), a group representing 5–10% of asthma cases. Patients with severe asthma exhibit a great deal of asthma morbidity and utilize health care facilities to a disproportionate degree. As noted earlier, they also fail to benefit from PEFR monitoring, as increases in air trapping result in dissociation between PEFR and other pulmonary functions (Eid et al. 2000). Other patients may be subject to air trapping, but for only some of the time. Air trapping episodes may identify periods during which the pulmonary monitoring yields unusual results or is ineffective. The simultaneous monitoring and comparison of several pulmonary functions may help identify these periods.
3. *Other possibilities*. There is no end to the potential improvement for control of asthma that more comprehensive monitoring may bring (Reddel 2006). Some patients, for example, may be more likely to benefit from monitoring an index other than PEFR. Others may require a complex derivative function to adequately describe their asthma condition. Whatever the need, it is likely to be met in future versions of pulmonary meters for home use.

Effectiveness of Home Monitoring in Asthma Self-Management

We start this section with two conclusions: (a) the contribution of home monitoring to asthma control is not clear; and (b) the relative effectiveness of symptom and PEFR monitoring has not been determined. These conclusions are bewildering, in view of the amount of research conducted on asthma self-management including enthusiasm for the role of peak flow monitoring in asthma management that has persisted for decades (e.g., Cross and Nelson 1991; Jain et al. 1998), and the degree of effort devoted to ferreting out the most efficient form of monitoring. But a look at the details of self-management research quickly reveals the source of the confusion. Asthma self-management is not just one intervention; it is a group of loosely related interventions. Within this somewhat unstructured universe, self-management programs differ from one another in their content, in their method of instruction, and in the setting in which they are applied. Interactions between the various elements of self-management may produce outcomes that cannot always be duplicated by any of the components. It is one thing, for example, to be taught the use of a PEFR meter by a nurse and another to learn the skill by reading a pamphlet, just as it is different to learn the proper use of asthma medication at a group meeting or in a conference with one's physician. And appreciating the distinction between control and quick-relief medications may be difficult unless one has some understanding of the nature of asthma. Returning to questions of home monitoring, it is possible that both the effectiveness of home monitoring and the relative superiority of either symptom or PEFR monitoring vary between self-management programs that differ in their composition. It is also possible that the relative advantage of one method over the other is contingent on patient variables such as illness severity, sociodemographics, and race (Yoos et al. 2002).

In this section, we review research on home monitoring in asthma self-management. We discuss controlled studies in which home monitoring was an independent variable as well as studies that focused on formal peak flow action plans. The studies fall into two categories as determined by their experimental designs: peak flow monitoring versus medical management, and peak flow monitoring versus symptom monitoring. Designs vary somewhat within the categories.

Peak Flow Monitoring Versus Medical Management

Evaluating peak flow monitoring is not straightforward. Because, it is a technique that is usually a part of an asthma self-management program, it makes sense to evaluate it within that context. But this is not the only possibility. Peak flow monitoring may be evaluated simply as an independent treatment. This was done in three studies (Ayers and Campbell 1996; Drummond et al. 1994; Jones et al. 1995) that featured individualized peak flow plans for adult asthma patients in which two thresholds were identified: one signaling either a start or an increase in steroid use, and a second indicating a need to seek medical assistance. Except for two additional independent variables in one study (Drummond et al. 1994), one of which consisted of enhanced education, other interventions relating to asthma self-management were not included. Controls used in the studies also were similar. They involved medication adjustments made by physicians. Investigators in the threes studies examined a variety of dependent variables including pulmonary scores, medication use, symptoms, health-care usage, and psychological factors. At the end of the study periods, which varied between roughly 6 (Ayers and Campbell 1996) and 12 (Drummond et al. 1994) months, differences between the patient-adjusted and the physician-adjusted medication groups were not observed.

PEFR action plans also have been evaluated as a part of a more comprehensive asthma self-management program. In this case, they have been compared to a control condition approximating medical management. Programs for adults (Gallefoss and Bakke 2000; Ignacio-Garcia and Gonzalez-Santos 1995; Lahdensuo et al. 1996) and for children with asthma (Charlton et al. 1994) have been tested. Most frequently, the action plans have been paired with educational programs that covered, at the very least, aspects of medication and basic asthma physiology, but in some studies, education was extensive. Patients in studies were followed for periods ranging from 6 to 12 months. In each study, improvements accrued to the PEFR group. The types of improvements that were observed included reductions in symptoms, work or school absenteeism, clinic visits, medication use, and improvement in quality of life. Additionally, a complex action plan that included a combination of both PEFR and symptom monitoring yielded benefits in comparison to a medical management group, but the number of patients studied was small (Woolcock et al. 1988).

Peak Flow Versus Symptom Monitoring

Comparisons of PEFR and symptom monitoring plans also have yielded inconsistent findings. Just as in comparisons between PEFR plans and medical management, the inconsistencies may be related to the inclusion of other interventions. In general, when other interventions were kept at a minimum, differences between PEFR and symptom monitoring plans did not emerge (Adams et al. 2001; Buist et al. 2006; Charlton et al. 1990; Malo et al. 1990; Wensley and Silverman 2004). Patients in these studies were both adults (Adams et al. 2001; Buist et al. 2006; Charlton et al. 1990; Malo et al. 1990) and children (Charlton et al. 1990; Wensley and Silverman 2004) who were tested on a variety of dependent variables throughout periods ranging from 3 to 12 months, or longer. In some studies, information about asthma was provided to patients either in the form of leaflets and pamphlets (Adams et al. 2000) or in informal discussions (Charlton et al. 1990), but it did not seem significant, as it was far less than that included in a comprehensive asthma education program.

In some investigations, however, peak flow monitoring proved to be more useful than symptom monitoring, at least for some patients (Bheekie et al. 2001; Yoos et al. 2002). Additionally, when patients were given extensive asthma education in addition to the action plans, PEFR monitoring usually was superior to symptom monitoring (Cowie et al. 1997; Lopez-Vina and del Castillo-Arevalo 2000; Turner et al. 1998). Those who monitored asthma severity with PEFR had either fewer emergency visits (Cowie et al. 1997) or unscheduled physician visits (Turner et al. 1998) than those who monitored symptoms. Patients using PEFR action plans also exhibited better treatment adherence and had slightly higher percent of predicted FVC scores than those using symptom plans (Lopez-Vina and del Castillo-Arevalo 2000). These observations lead to an obvious conclusion, but one that may be misleading. The findings represent only a few of the variables tested. The vast majority of variables were not sensitive to the type of action plan employed.

A consistent observation, not only in comparisons between symptom and PEFR plans but also in evaluations of PEFR plans against medical management is the association between PEFR plan benefits and education. The effects of PEFR plans appear to be potentiated by education (McGrath et al. 2001). But this conclusion may be overstated. It is contradicted by one study in which educated patients with a PEFR plan did not differ from those either with a symptom plan or with no plan (Cote et al. 1997). The authors attributed the failure, in part, to sustained care, a benefit enjoyed by all patients in the study. But it is possible that sustained care confers benefits that in some way are similar to those afforded by comprehensive asthma education.

In a recent review, Brouwer and Brand (2008) concluded that monitoring lung function adds little, if anything, to symptom monitoring in tracking asthma severity. Their conclusion is reasonable, despite some evidence to the contrary in the form of studies attesting to PEFR benefits. However, PEFR monitoring should not be written off. As we noted in our discussion of technical progress, its potential is great. But more importantly, a number of basic questions about the effects of PEFR monitoring have not been answered completely. These include concerns both about the training and the conduct of PEFR monitoring, and the wide variability consistently evident among patients between objective and subjective assessment of asthma severity. Once such questions are resolved, strong recommendations about the best ways to monitor asthma severity will emerge.

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