Symptom monitoring in childhood asthma: a randomized clinical trial comparing peak expiratory flow rate with symptom monitoring

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Background: Accurate symptom evaluation is a critical component of asthma management. Limited data are available about the accuracy of symptom evaluation by children with asthma and their parents, or the impact of various symptom-monitoring strategies on asthma morbidity outcomes.

Objective: The purpose of this randomized clinical trial was to evaluate the effect of three different intensities of symptom monitoring on asthma morbidity outcomes.

Methods: One hundred sixty-eight children (ages 6 to 19) of diverse racial, geographic, and socioeconomic backgrounds were randomized to 1 of 3 treatment groups (subjective symptom evaluation, symptom-time peak expiratory flow rate (PEFR) monitoring, daily PEFR monitoring) in this longitudinal, clinical trial. Outcome measures included a summary asthma severity score, forced expiratory volume in 1 second, symptom days, and health care utilization.

Results: Children who used PEFR meters (PFMs) when symptomatic had a lower asthma severity score, fewer symptom days, and less health care utilization than children in the other two treatment groups. Minority and poor children had the greatest amount of improvement using PFMs when symptomatic. Results were much less striking in white families. Thirty percent of families in the PFM treatment groups discontinued use entirely by 1 year postexit, whereas the majority of families who continued use (94%) used them only when symptomatic to inform symptom interpretation and management decisions.

Conclusions: Not every child with asthma needs a PFM. Children and families facing extra challenges as a result of illness severity, sociodemographic, or health care system characteristics clearly benefited most from PFM use.

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INTRODUCTION

Accurate symptom evaluation is a critical component of asthma management. Asthma symptoms may be highly variable, requiring an ongoing evaluation of symptoms and modification of the management plan.[1] Symptom evaluation not only guides self-management strategies, but symptom report by the patient is also a primary source of information guiding the stepwise approach to asthma management by the health care provider.[2] However, limited data are available about the accuracy of symptom evaluation by children with asthma and their parents, or the impact of various symptom-monitoring strategies on morbidity outcomes.

Standard strategies to improve the monitoring and management of respiratory symptoms by patients include educating patients to improve their *subjective* symptom perceptual accuracy through training in symptom recognition, as well as *objective* home pulmonary monitoring either on a daily or symptom-time basis using a peak expiratory flow rate (PEFR) meter (PFM). A number of studies have examined the usefulness of PFMs at home for ongoing pulmonary monitoring and for improving the prediction and detection of a potential asthma exacerbation.[2–11] Results of the studies have been mixed, with some finding positive outcomes in disease management,[5–8] whereas others report no differences in morbidity outcomes between individuals using only subjective symptoms and those using PFMs to evaluate symptom severity.[9–11] Few studies have included children, and those that did, tended to evaluate them in somewhat controlled settings, such as asthma camp, rather than in their natural home setting.[12] Questions have been raised about the quality of the existing evidence related to PEFR monitoring, about which patients benefit most from PEFR monitoring, and about how often PEFRs should be measured.[2,3,13]

The overall aim of this longitudinal randomized clinical trial was to identify the effect of three different intensities of symptom monitoring in childhood asthma on clinical outcomes, as well as to evaluate the possible burden of the various monitoring strategies. Treatment groups were: group 1, subjective symptom monitoring; group 2, PEFR monitoring when symptomatic; group 3, PEFR monitoring twice daily and when symptomatic.

Our goal was to evaluate the potential contribution of PFM use to decreased asthma morbidity, over and above education related to symptom recognition and asthma self-management.

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METHODS

Study Population

The study protocol was approved by the University of Rochester Medical Center institutional review board. Participants were recruited from diverse primary care settings to assure racial, socioeconomic, and geographic diversity. In each of 11 primary care settings, all school-aged children and adolescents who carried a diagnosis of asthma were identified through examination of computerized data sets and chart review. Because the aim of the study was the evaluation of symptom-monitoring strategies, we attempted to eliminate children who had mild asthma and were only rarely symptomatic. As an initial screening criterion, we used the number of asthma-related health care visits in the previous year as a surrogate marker for severity. Potential subjects, based on age (6 to 19 years) and severity (more than three asthma-related visits in the previous 12 months) criteria, were asked to participate in the study if they met two additional criteria: 1) the family was English-speaking; and 2) the child had not used a PFM in the previous 6-month period, and the family could not identify personal zones for the child.

Of the 337 potential subjects who were eligible based on age and severity criteria, 168 (50%) were enrolled, 74 (22%) declined, 71 (21%) were ineligible (primarily because they were current PFM users), and 24 (7%) could not be reached. Table 1 presents participant characteristics by race, socioeconomic status (SES), age, sex, and geographic location. Race is a crucial variable in the analyses reported in this paper. Only black and white participants are examined in the racial subgroup analyses because the group of other races is small (n = 16) and diverse, including Hispanic, Asian, and Indian children, and their numbers are insufficient to include in models jointly with other important variables.

Table 1. Sample Description

Characteristic	Number	%
Race		
White	111	66%
Black	41	24%
Other	16	10%
SES		
Upper SES	85	51%
Lower SES	83	49%
Gender		
Female	69	41%
Male	99	59%
Age		
School-age	125	74%
Adolescent	43	26%
Geographic location		
Urban	57	34%
Non-urban	111	66%

Study Design

Figure 1 presents the study design and a profile of patient recruitment and ongoing enrollment in the study. After screening for inclusion criteria, agreement to a home visit was obtained (generally through a phone call). Informed consent for the child to participate was obtained from the parent, and assent was obtained from the child at the first home visit. A research nurse gathered sociodemographic data, baseline information regarding asthma morbidity in the previous 3 months, and current medication use from the parent and spirometry from the child during the intake interview in the home. The parent and child were then oriented to the data collection tool (a weekly diary) to be used during the subsequent 3 months of baseline asthma morbidity monitoring. The research nurse made phone contacts with the families every 2 weeks to collect the diary data. After the 3-month period of baseline diary keeping, children were randomized into the three treatment groups by a stratified random procedure based on race, age, and urban/non-urban setting.

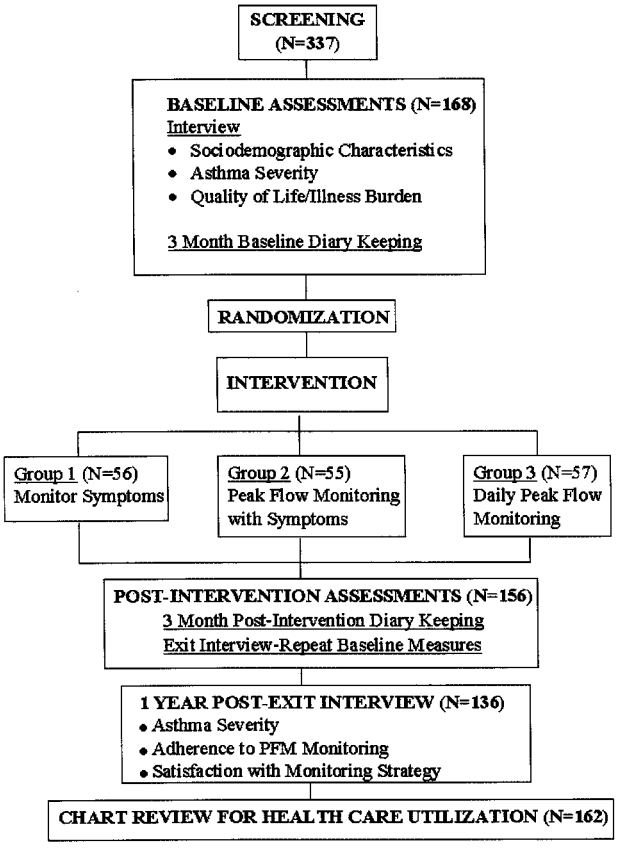

Figure 1. Design for longitudinal randomized clinical trial.

Intervention

At the completion of the third month of the baseline pretreatment data-gathering period, another home visit was made by one of the study nurses. At that time, *all* families received asthma education related to the pathophysiology of asthma, triggers, medications, and treatment goals as well as written materials reinforcing this information. They also received training in asthma symptom recognition, early and late symptoms that indicate inadequate asthma control, and symptom management. Families were referred to their primary care providers if the medication regimen appeared to be suboptimal (based on their current level of symptoms) or if treatment questions arose. Each group then received further training in their symptom-monitoring strategy as specified by group assignment (Fig 2).

Each group subsequently entered a 2-week period of daily practice with their particular form of symptom monitoring. At the end of the 2-week period, a followup home visit was made by the same study nurse who: 1) evaluated the family's competence with their particular method of symptom monitoring; 2) established zones based on either "personal best" PEFR readings or increasingly severe asthma symptoms as indicated by group assignment; 3) developed a personal action plan that specified changes in management strategy based on symptom or PEFR and symptom zones; and 4) reviewed the use of data collection tools and procedures to be used during the 3-month postintervention period. If the child experienced an exacerbation during the time designed to establish personal best PEFR reading, data collection was extended to capture 2 weeks of baseline functioning. The personal action plan for all treatment groups listed the child's routine asthma medications for the green zone, detailed additional rescue medication use in the yellow zone (based on symptoms [in group 1] or symptoms and PEFR readings [in groups 2 and 3]), and asked the family to contact the health care provider in the red zone immediately. All children received standard care, consisting of routine asthma care with their health care providers throughout the study period.

To maintain blinding for the postintervention data collection, the nurses worked as a team and each collected postintervention diary data related to symptoms, medications, and health care utilization on the subjects she did not train and thus did not know group assignment. Information collected at that time did not include PEFR data and families had been instructed not to reveal treatment group information during the phone calls.

At the end of the third month of postintervention diary keeping, an exit interview was scheduled, and morbidity measures completed at the intake interview were repeated. PEFR diary data (groups 2 and 3) and symptom diary data (group 1) were collected at the exit home visit in a sealed envelope. Updated personal best PEFR values were calculated based on diary data at exit and families were instructed about the need and method for periodically re-calculating personal best. One year postexit, a phone interview was conducted assessing current asthma morbidity, ongoing adherence to the assigned monitoring strategy, and knowledge related to zones and the personal action plan. Medical records were reviewed for health care utilization 1 year preintervention and 1 year postintervention.

Measures

Background information. Data regarding the child's age, illness duration, sex, race, family composition, insurance coverage, and SES (Hollingshead two-factor index of social position)[14] were obtained at intake to the study.

Asthma morbidity outcomes. There is no intrinsic biologic measure of asthma severity, and no single, ideal asthma outcome measure. One must therefore resort to various surrogate markers. We developed a composite asthma severity score that included five components using an interview that evaluated symptom frequency, symptom duration, activity limitation, nighttime symptoms, and days missed from school because of asthma during the previous 3-month period (Table 2). Scores on each component were scaled from 1 to 3, with higher values indi-

INTERVENTION	GROUP 1 SUBJECTIVE SYMPTOM MONITORING	GROUP 2 OBJECTIVE SYMPTOM TIME ONLY MONITORING	GROUP III OBJECTIVE DAILY AND SYMPTOM TIME MONITORING
Asthma Education and Personal Action Plan for Symptom Management	X	X	X
Training in Subjective Asthma Symptom Recognition	X	X	X
Peak Flow Meter Training Instructions to do *symptom time* objective monitoring		X	X
Peak Flow Meter Training Twice *daily* objective monitoring			X

Figure 2. Treatment overview.

cating greater severity, and a mean severity score was obtained. We evaluated the internal consistency of the 5-item summary score by computing Cronbach's α, which was 0.77. We further evaluated its construct validity by examining the correlation of the summary score with a variety of clinical and physiologic measures. We hypothesized relationships between the composite severity score and spirometry, health care utilization, and child and parent Quality of Life. Each of these measures was significantly correlated with the composite asthma severity score at levels ranging from $r = 0.27$ to 0.60 and significance levels ranging from 0.06 to 0.0001.

A weekly diary was used to track the total number of days per week (over a 3-month period both baseline and postintervention) that the child was symptomatic with cough, wheezing, shortness of breath, and nighttime awakening; used additional quick relief medications or steroid bursts; had school absenteeism because of asthma; or used health care services for managing asthma. The nurses called the families every 2 weeks to collect diary data.

A Renaissance spirometer was used to measure a number of aspects of pulmonary function, including forced expiratory volume in 1 second (FEV_1). All pulmonary measurements (flow-volume expiratory loops) were evaluated by a pulmonologist for adequacy of the maneuver. The Renaissance spirometer computes a race adjustment for black patients.

Health care utilization. Communication among the hospitals, emergency departments (EDs), and practice settings in Rochester, New York, is sufficiently good that we believe that almost all medical care rendered was captured in the child's medical record. We also obtained information about the sources of care from the family. Medical records were reviewed in all primary care practices, as were hospital records of children who had an asthma admission during the study period.

Table 2. Composite Severity Score

Now I'd like to ask you about your child's asthma over the past 3 months.	
Frequency of asthma symptoms	
Intermittent, brief (<1 hr). Wheeze/cough/shortness of breath no more than two times weekly	1
Symptoms >2 times weekly which may last several days	2
Frequent exacerbations; symptoms may be continuous	3
Wheeze/cough/dyspnea/tightness pattern	
Symptoms only with exposure to triggers or with exercise	1
Symptoms between acute episodes	2
Continuous or daily symptoms	3
Activity Level (when taking routine asthma medications)	
Can exercise with peers with no or brief (<½ hour) symptoms	1
Symptoms after more than 5 minutes of exercise	2
Symptoms with any exercise	3
Sleep Disruption	
Infrequent (<2 times a month) nocturnal cough/wheeze	1
Up at night with symptoms 2–5 times a month	2
Frequent sleep disruption with symptoms (>5 times a month)	3
School Attendance	
Missed no days of school in the past 3 months because of asthma	1
Missed 1–4 days of school in the past 3 months because of asthma	2
Missed >5 days of school in the past 3 months because of asthma	3

Measurements of treatment experience and adherence. Families were asked at exit how satisfied they were with their assigned symptom-monitoring strategy and how likely they were to continue to use that method of monitoring. Adherence to the assigned monitoring strategy was also measured 1 year postexit using an open-ended interview that asked about the perceived usefulness and burden of the assigned monitoring strategy, ongoing PFM use, the function of the PFM for the families, and knowledge about personal zones and related self-management strategies. We also elicited the families' reasons for adherence and nonadherence. Questions were framed in a nonjudgmental way, acknowledging that families have diverse preferences and styles for symptom monitoring that are all acceptable.

Statistical Models and Methods of Analysis

Our interest was in evaluating effects of the intervention by looking at treatment group differences for the outcomes described above, controlling for important influences on asthma severity. All outcome variables were measured at baseline before the intervention and 3 months after intervention (exit). Some of the outcomes were measured a third time, 1 year after exit. A 3×2 repeated-measures design (treatment by time) thus forms the core of the statistical models for evaluation for the first set of variables, and a 3×3 repeated measures for the second set of outcomes. The key test of whether the intervention has had an effect is the test of the time-by-treatment interaction and partitionings of it. Although we test the overall interaction, the focus of the interpretation is on the test of specific, preplanned treatment-by-time contrasts partitioned from the 3×2 or 3×3 interactions.

All analyses were carried out in general linear mixed models, with time included as levels of a fixed factor and individuals as levels of a random factor. Our focus was not only on the detection of any overall effects of the

intervention, but also on the examination of whether the effects of the intervention were stronger for groups at greater risk for asthma morbidity. From the existing literature and our earlier research, race and SES were known to be factors of primary importance and were therefore the focus of preplanned hypotheses.[15–19] These questions were examined through tests of the interaction of treatment and time with a third variable such as race. The final model included, in addition to treatment and time, race (black vs white), family SES, and the child's age.

To adjust for baseline disease severity, we repeated the models adding the FEV_1 measure as a covariate (for all outcomes excepting, of course, the spirometry outcome itself). The results were not substantially altered, and the results of these analyses are not shown.

RESULTS

Morbidity Outcomes

There were no statistically significant differences among the treatment groups at baseline on the various outcome measures described below, although group 2 children tended to have somewhat increased morbidity.

Composite Severity Score

Table 3 gives the results for the composite asthma severity score for the three treatment groups by the three evaluation points. Looking at the entire sample (both black and white children), each of the treatment groups improved from baseline to 3 months postintervention. Improvement was greater for group 2 participants than for either group 1 ($P = 0.10$) or group 3 ($P = 0.002$). All groups were still improved at 1 year postexit; however, groups 1 and 2 experienced some decline in the improvement from 3 months postintervention to 1 year postexit, whereas group 3, which had the smallest initial improvement, continued to improve. Assessing the long-term impact of the various monitoring strategies by examining the improvement from baseline to 1 year postexit shows that group 2 continued to have greater improvement than group 1 ($P = 0.07$). At this point, however, there were no longer any significant differences in improvement between groups 2 and 3 ($P = 0.44$), nor were

Table 3. Group Comparisons for Treatment Impact on Asthma Severity Measures (Adjusted for SES and Age)

Measure	Baseline (time 1) mean (SE)	3 Months Postintervention (time 2) mean (SE)	1 Year Postexit (time 3) mean (SE)	Group comparisons for time 1 to time 2 change	Group comparisons for time 1 to time 3 change
Composite severity score (range = 1.3)*					
Whole sample				Groups *P* value	Groups *P* value
Group 1	1.70 (0.07)	1.44 (0.08)	1.56 (0.08)	1 vs 2 = 0.10	1 vs 2 = 0.07
Group 2	1.85 (0.07)	1.40 (0.07)	1.49 (0.08)	1 vs 3 = 0.13	1 vs 3 = 0.33
Group 3	1.76 (0.07)	1.66 (0.08)	1.50 (0.08)	2 vs 3 = 0.002	2 vs 3 = 0.44
White children					
Group 1	1.50 (0.07)	1.44 (0.07)	1.28 (0.08)	1 vs 2 = 0.11	1 vs 2 = 0.15
Group 2	1.50 (0.08)	1.26 (0.08)	1.44 (0.08)	1 vs 3 = 0.36	1 vs 3 = 0.12
Group 3	1.49 (0.07)	1.52 (0.07)	1.44 (0.08)	2 vs 3 = 0.01	2 vs 3 = 0.93
Black children					
Group 1	1.90 (0.13)	1.43 (0.13)	1.83 (0.13)	1 vs 2 = 0.34	1 vs 2 = 0.004
Group 2	2.19 (0.12)	1.55 (0.13)	1.55 (0.14)	1 vs 3 = 0.22	1 vs 3 = 0.05
Group 3	2.02 (0.13)	1.79 (0.14)	1.55 (0.15)	2 vs 3 = 0.03	2 vs 3 = 0.40
Spirometry (FEV_1% predicted)			Not measured @ Time 3		Not measured @ Time 3
Whole sample					
Group 1	88 (2.74)	90 (2.81)		1 vs 2 = 0.22	
Group 2	87 (2.64)	94 (2.72)		1 vs 3 = 0.44	
Group 3	83 (2.62)	88 (2.73)		2 vs 3 = 0.63	
White children					
Group 1	94 (2.67)	94 (2.69)		1 vs 2 = 0.91	
Group 2	95 (2.76)	96 (2.88)		1 vs 3 = 0.35	
Group 3	91 (2.62)	95 (2.61)		2 vs 3 = 0.44	
Black children					
Group 1	82 (4.85)	86 (4.99)		1 vs 2 = 0.18	
Group 2	79 (4.54)	91 (4.67)		1 vs 3 = 0.70	
Group 3	74 (4.62)	80 (4.87)		2 vs 3 = 0.31	

* Higher score = greater severity.
Group 1 = Subjective symptom monitoring.
Group 2 = PEFR monitoring when symptomatic.
Group 3 = PEFR monitoring twice daily and when symptomatic.

there any significant differences in groups 1 and 3 contrasts ($P = 0.33$). That is, at 1 year postexit there was some benefit to PFM use at symptomatic times over simply relying on subjective symptom recognition, but no additional benefit to more vigilant daily monitoring.

Black children in our sample at baseline had significantly greater illness severity than white children, with lower FEV_1 results ($P = 0.0001$) as well as higher composite asthma severity scores ($P = 0.0001$). Poor children also had significantly greater morbidity than those of higher SES. We focused our attention on these factors in examining for whom the intervention might have had its greatest impact. In evaluating differences based on race (adjusted for SES and age), the long-term impact of PFM monitoring on the composite asthma severity score in white children was quite lackluster (Fig 3 and Table 3). Although group 2 white children showed greater improvement from baseline to 3 months postintervention than group 1 children ($P = 0.11$), by 1 year postexit, these differences no longer existed. In fact, although not statistically significant, group 1 children had better scores. The picture was strikingly different for black children (Fig 3 and Table 3).

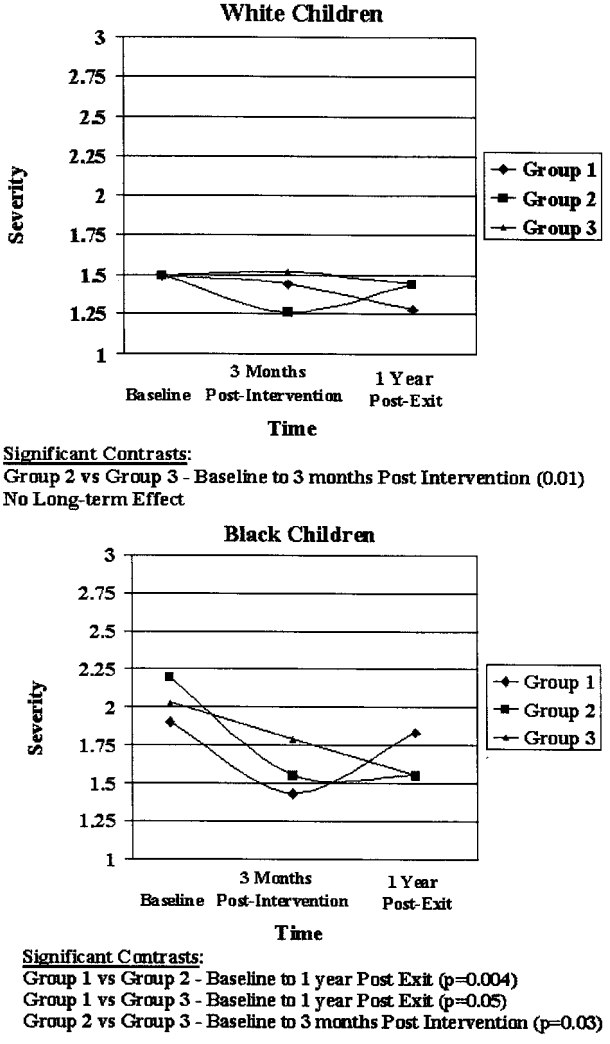

Figure 3. Subgroup comparisons of PFM impact on the composite severity score.

Both groups 1 and 2 children showed marked improvement from baseline to 3 months postintervention, and the difference between the two groups was not initially significant. Group 3 children showed much more modest improvement, and the contrast between groups 2 and 3 was significant. However, when the long-term impact of the intervention is examined, by 1 year postexit, both of the PFM groups (groups 2 and 3) sustained significantly greater improvement than the subjective symptom-monitoring group (group 1; $P = 0.004$ and $P = 0.05$, respectively). In fact, by 1 year postexit, the severity level in both PFM groups of black children is quite similar to that of the white children, whereas there had been a highly significant racial disparity at baseline. The initial disparity continued for group 1 children.

An important question at this point is whether the difference in the impact of the intervention by race is primarily attributable to differences in baseline morbidity. Do white children, by virtue of their lower illness severity, simply have less opportunity to improve? To examine this question, we adjusted for severity in an additional analysis on the composite asthma severity score using the baseline FEV_1 measure as a covariate. Despite this adjustment for baseline severity, there continued to be a significant long-term difference between groups 1 and 2 of black children ($P = 0.01$) that was not present (or present only as a trend) in white children ($P = 0.13$). That is, adjusting for underlying severity did not alter the patterns of treatment impact on the different ethnic groups.

Spirometry

In the entire sample, each of the treatment groups improved somewhat on the FEV_1 measure from baseline to 3 months postintervention. (Spirometry was not measured at the 1-year postexit evaluation). There were, however, no statistically significant differences by treatment group in the amount of improvement (Table 3). There was essentially no treatment impact on spi-

rometry scores for white children. The greatest improvement again was seen in group 2 black children, who raised their FEV_1 readings from a mean score of 79% predicted to 91% predicted ($P = 0.004$ comparing baseline with postintervention). Once again, for the group 2 children, the racial disparity on this measure postintervention was nearly eliminated, although it persisted for groups 1 and 3 children.

Symptom Days

In the entire sample, group 2 children had a significant improvement in the number of symptom days reported from the 3-month baseline period to 3 months postintervention when compared with group 1 ($P = 0.01$), with the greatest decline in symptom days once again in black children (Table 4). There was no significant difference in the improvement contrasting groups 2 and 3 ($P = 0.28$) and groups 1 and 3 ($P = 0.12$). Group 2 participants decreased their symptom days by almost 1 day per week; group 3 participants by 0.5 day per week; whereas group 1 participants remained essentially the same except for black children in that group who actually increased in the number of symptom days reported.

Health Care Utilization

There were no statistically significant differences among the treatment groups in the change in health care utilization pre- and postintervention. However, the pattern of improvement follows the other morbidity measures, with group 2 children generally having an almost twofold reduction in utilization (hospitalizations, ED visits, acute illness visits) compared with group 1 children (Fig 4). Although there were no statistically significant differences among the treatment groups in the decline in utilization, the comparatively larger decline postintervention in group 2 was of a magnitude to have considerable economic implications. A formal cost analysis is outside the scope of this paper. However, given the average charges for utilization in our region for ED and acute illness visits for asthma as indicated in Figure 4, the reduction translates into a decrease in annual health care charges of US$82 per child for group 1 children, $162 per child for group 2 children, and $61 per child for group 3 children. Hospitalization was a relatively rare event with 13 children hospitalized in the year preintervention and 7 children hospitalized in the year postintervention. This frequency of occurrence precludes between-group comparisons.

Adherence

At 3 months postintervention, when exiting from the study protocol, participants and their parents were interviewed regarding their likelihood of continuing their specific method of symptom monitoring. Ninety-three percent of parents, regardless of group assignment, planned to continue with the method learned. In contrast, when children were asked the same question, 81% of the symptom-monitoring group, and 73% of the symptom-time PFM group indicated they would continue their assigned method of symptom monitoring. However, only 61% of the daily PFM users indicated they were likely to continue daily monitoring ($P = 0.05$)

Looking at PFM use 1 year postexit in groups 2 and 3 children, parents of only 6% of the children reported daily PFM use, whereas 64% reported symptom-time use. Thirty percent of the families had discontinued PFM use entirely. The most common reason given for continuing use was that the objective data provided reassurance. There were no differences by race or SES in the likelihood to continue PFM use.[20] There was also no difference in the rate of complete discontinuation of the PFM between groups 2 and 3.

Exploratory Analyses Related to the Mechanism for PFM Effectiveness

The use of a PFM has no pharmacologic benefit in the treatment of asthma. Its only potential mechanism of action is if the information derived from PFM use somehow changes the patient's asthma management. In exploratory analyses we evaluated whether PFM use was related to the appropriateness of the child's medication regimen. We defined an inappropriate medication regimen as one where symptom report was consistent with National Heart, Lung, and Blood Institute recommendations for inhaled anti-inflammatory use and the family did not report an anti-inflammatory as part of the medication regimen. Looking at current symptom report and the medication regimen at 1 year postexit (n = 124), 13% of children who con-

Table 4. Group Comparisons for Treatment Impact on Symptom Report Baseline to Postintervention (Adjusted for SES and Age)

Measures	Baseline diary (time 1) mean (SE)	Postintervention diary (time 2) mean (SE)	Group comparisons for time 1 to time 2 change
# of days/week of symptoms			
Whole sample			Group comparison *P* value
Group 1	2.83 (0.33)	2.87 (0.34)	Group 1 vs Group 2 = 0.01
Group 2	2.87 (0.31)	2.00 (0.32)	Group 1 vs Group 3 = 0.12
Group 3	3.19 (0.32)	2.68 (0.32)	Group 2 vs Group 3 = 0.28
White children			
Group 1	2.80 (0.32)	2.47 (0.32)	Group 1 vs Group 2 = 0.14
Group 2	2.81 (0.33)	1.96 (0.34)	Group 1 vs Group 3 = 0.83
Group 3	3.13 (0.32)	2.72 (0.32)	Group 2 vs Group 3 = 0.21
Black children			
Group 1	2.85 (0.58)	3.27 (0.60)	Group 1 vs Group 2 = 0.03
Group 2	2.93 (0.53)	2.04 (0.54)	Group 1 vs Group 3 = 0.10
Group 3	3.25 (0.56)	2.64 (0.57)	Group 2 vs Group 3 = 0.62

Group 1 = Subjective symptom monitoring.
Group 2 = PEFR monitoring when symptomatic.
Group 3 = PEFR monitoring twice daily and when symptomatic.

tinued PFM use were on an inappropriate medication regimen. Nineteen percent of children who had discontinued use also reported an inappropriate regimen ($P = 0.59$ comparing PFM users with nonusers) However, 32% of the families in the subjective symptom-monitoring group reported an inappropriate regimen ($P = 0.05$ comparing PFM users with subjective symptom monitors).

DISCUSSION

Although National Heart, Lung, and Blood Institute guidelines recommend objective symptom monitoring for children with moderate to severe asthma, the scientific basis for these recommendations has been limited.[2] This research was designed to evaluate the potential contribution of PFM use to decreased asthma morbidity, over and above education related to symptom recognition and asthma management, and to address the question of which patients might benefit most from PFM monitoring. Our goal was to help define a rational place for PEFR monitoring in the management of pediatric asthma. PFM training and use involves effort on both the patient's and the health care provider's part. Time is required from the health care setting to train families and establish personal best PEFR readings and zones. Families are asked to deal with the extra burden of objective monitoring. It is important to evaluate whether PFMs are useful and for whom they have the greatest usefulness.

Although children with asthma may have waxing and waning of symptoms, there seems to be a benefit to good education related to symptom recognition and asthma management as shown by improvement in group 1 children in clinical status over most baseline measures. There was some additional benefit related to PFM use to inform symptomatic times, with the greatest benefit experienced by black children and their families. In this study population, these were generally also the sickest children. On several important outcome measures, group 2 black children achieved outcomes quite similar

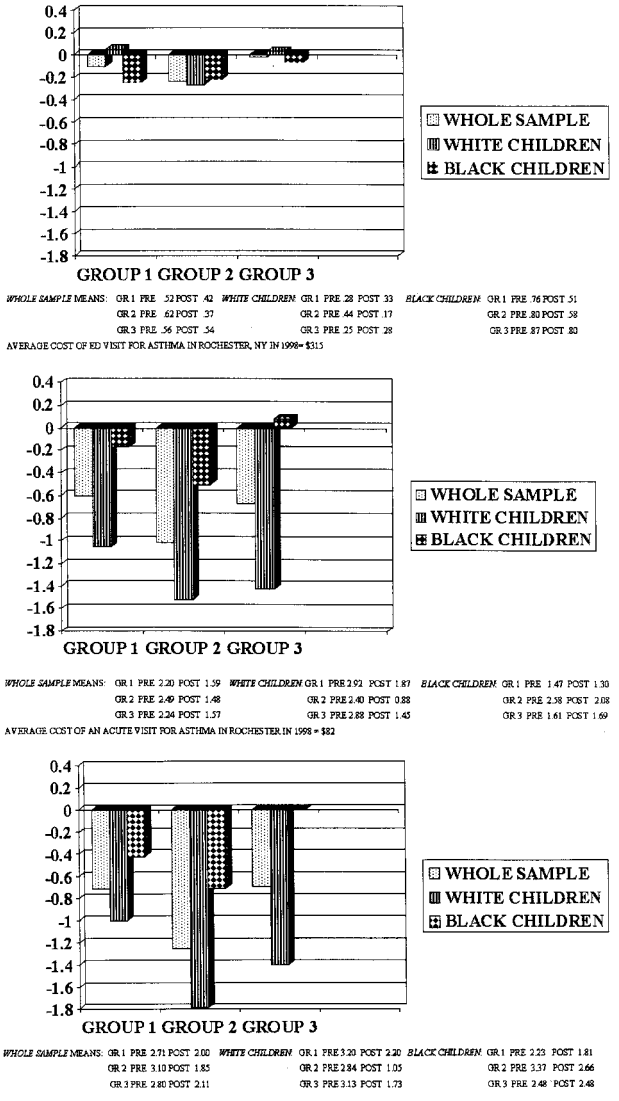

Figure 4. 1) Change in number of ED visits 1 year pre- to 1 year post- by treatment group and race. 2) Change in number of acute visits 1 year pre- to 1 year post- by treatment group and race. 3) Change in total number of illness visits 1 year pre- to 1 year post- by treatment group and race.

to white children postintervention, whereas there had been marked disparity at intake to the study. The disparity generally continued for group 1 children. There was no additional benefit to more vigilant daily monitoring (group 3). As anticipated, ongoing PFM monitoring was challenging for some families, with one-third of the families assigned PFMs discontinuing their use altogether and only a very small proportion continuing daily use.

The mechanism for the PFM's usefulness is, at this point, not totally clear. Understanding the mechanism seems especially important in black families. Whether the information provided by the PFM was used by families to help them make better decisions about self-management at home and appropriate health care seeking, or whether it made them better communicators with the health care system producing more appropriate medication regimens and treatment plans, deserves further exploration. Perhaps in health care situations characterized by less continuity of care (eg, EDs and

large clinics), having objective data to report increased the likelihood of a more standardized treatment plan.

It should be noted that 71% of white families continued to use PFMs at symptomatic times. Although their use of PFMs did not have the impressive impact on morbidity outcomes that was seen for black families, the PFM nevertheless served an important function in their lives by providing objective data. Outcomes such as confidence and a sense of mastery in the ability to manage asthma, although not measured in this study, may be important.

CONCLUSION

Who should use a PFM? Certainly not all children with asthma. Children and families facing extra challenges as a result of either illness severity, sociodemographic characteristics, or health care system characteristics clearly seemed to benefit most from PFM use. However, given that a significant proportion of all families reported ongoing PFM use (two-thirds of the PFM study population), it seems that many families found reassurance in the objective data the PFM provided during periods of asthma exacerbation. This is certainly a valid reason for use, whether or not it affects measured morbidity outcomes. There may be endpoints important to our participants that were not measured by the study, such as increased confidence in the ability to manage asthma or better communication with the health care provider. The option of monitoring symptoms using a PFM should probably be offered to all families with a child older than 5 years of age experiencing persistent symptoms, and strongly encouraged in families facing extra challenges because of illness severity and sociodemographic or health care characteristics.

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