

Individualized asthma self-management improves medication adherence and markers of asthma control

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Background: Adherence to inhaled anti-inflammatory therapy and self-management skills are essential parts of the asthma treatment plan to improve asthma control and prevent exacerbations. Whether self-management education improves long-term medication adherence is less clear.

Objective: A 24-week prospective, randomized controlled trial was performed to study the effect of self-management education on long-term adherence to inhaled corticosteroid (ICS) therapy and markers of asthma control.

Methods: After stabilization on ICS medication during a run-in phase, 95 adults with moderate-to-severe asthma were recruited from a large metropolitan community, and 84 were randomized to individualized self-management education, including self-monitoring of symptoms and peak flow or usual care with self-monitoring alone. The key components of the 30-minute intervention were asthma information, assessment, and correction of inhaler technique; an individualized action plan based on self-monitoring data; and environmental control strategies for relevant allergen and irritant exposures. The intervention was personalized based on pulmonary function, allergen skin test reactivity, and inhaler technique and reinforced at 2-week intervals.

Results: Participants randomized to the self-management intervention maintained consistently higher ICS adherence levels and showed a 9-fold greater odds of more than 60% adherence to the prescribed dose compared with control subjects at the end of the intervention ($P = .02$) and maintained a 3-fold greater odds of higher than 60% adherence at the end of the study. Perceived control of asthma improved ($P = .006$), nighttime awakenings decreased ($P = .03$), and inhaled β -agonist use decreased ($P = .01$) in intervention participants compared with control subjects.

Conclusion: Our results show that individualized asthma self-management education attenuates the usual decrease in medication adherence and improves clinical markers of asthma control. (J Allergy Clin Immunol 2009;123:840-6.)

Key words: Asthma, self-management, adherence, asthma control

Asthma affects approximately 21 million persons in the United States, causing more than 1.5 million emergency department visits.^{1,2} Daily self-management is necessary to prevent serious exacerbations. Effective self-management requires mastery of specific knowledge and skills.³⁻⁷ Research published over the last 2 decades shows that instruction in these skills improves asthma health outcomes.^{8,9}

Self-management education that incorporates behavioral strategies also can improve adherence to inhaled corticosteroids (ICSs),¹⁰⁻¹⁴ suggesting that adherence to treatment might be the mechanism by which self-management education improves asthma control. More recent evidence has shown that tailored educational interventions have greater efficacy than standardized interventions because patients believe the instruction is personally relevant.^{15,16} What remains unclear is which elements of self-management education account for improvement in adherence to treatment. It is thought that one important element is self-monitoring of symptoms, peak flow, or both. By heightening the patient's awareness of symptoms and airflow obstruction, monitoring alone might be sufficient to enhance adherence by showing the patient that asthma control deteriorates when treatment is ignored and improves when it is taken regularly. We undertook to determine whether instruction in self-management adds significantly to the effects of self-monitoring alone on adherence to ICS treatment.

METHODS

Participants

Adults with asthma ($n = 280$) were recruited from private and public community clinics in the San Francisco Bay Area by using posted flyers and advertisements. Patients telephoned to volunteer and were screened for eligibility. Participants included in the trial were 18 to 55 years of age with moderate-to-severe persistent asthma (ie, FEV₁ <80% of predicted value, daily symptoms, and ≥ 1 nighttime awakening per week),¹⁷ were nonsmokers with 5 or less pack-years of smoking history, and demonstrated spirometric evidence of reversible airflow obstruction or bronchial reactivity to inhaled methacholine.¹⁸ Those receiving systemic steroids within 4 weeks of study enrollment; with upper respiratory tract infection within 6 weeks of enrollment, pregnancy, or cardiac, gastrointestinal, psychiatric, or other lung disease; or with prior participation in a formal asthma education program were excluded. Of those screened, 100 were ineligible because of mild or intermittent asthma, current smoking status, or nonreversible airflow obstruction, and another 85 were not interested (Fig 1). Ninety-five participants provided written consent and were enrolled in the 6-month trial. During the run-in phase before randomization, 11 participants voluntarily withdrew, reporting inability to continue study visits because of time constraints. Participants were reimbursed for their time by hourly fee, received parking vouchers, and received fluticasone without cost.

Study design

The study was a randomized controlled trial with run-in, intervention, and observation phases. The 4-week run-in phase with biweekly visits was

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Abbreviations used

ECP: Eosinophil cationic protein
IBA: Inhaled β -agonist
ICS: Inhaled corticosteroid
OR: Odds ratio
T₀: End of run-in phase
T₁: End of intervention
T₂: End of study

used to stabilize ICS therapy (fluticasone) by adjusting the dose to the level recommended in the National Heart, Lung, and Blood Institute guidelines¹⁷ before introducing the intervention and to familiarize participants with self-monitoring. At the end of the run-in phase, participants (n = 84) were randomized using a computer-generated method to individualized asthma self-management education with self-monitoring of symptoms, peak flow, and nighttime awakenings (intervention group) or self-monitoring alone (control group). The 4-week intervention period of biweekly visits was followed by 14 weeks of observation, with visits held at 4-week intervals. Except for the study coordinator, who had no role in data management or assessment, the investigators were blinded to group assignment.

Protocol

During each phase of the trial, all participants measured morning peak flow with an electronic peak flowmeter (Airwatch; iMetrikus, Carlsbad, Calif) and also recorded their daily values in a diary. All participants were told that higher peak flow numbers meant their airways were more open and lower numbers meant their airways were more closed. An electronic medication monitor, which concealed readings from the subject (Doser CT; MediTrack, Hudson, Mass), was placed on each ICS inhaler. Participants also monitored daily symptoms, nighttime awakenings, and tabulated ICS and inhaled β -agonist (IBA) use in the diary. Data from the electronic monitors and diary pages were collected at each study visit.

The intervention was delivered in 3 identical 30-minute visits after randomization. Control participants attended the same number of visits, focusing on data collection only. Lung function, sputum markers, quality of life, and perceived control of asthma were measured at the end of the run-in phase, the end of the intervention, and the end of the study. At the last study visit, all participants were asked to report in writing what, if any, changes in asthma self-management they had made as a result of being in the study.

Individualized self-management educational intervention

The theoretically based self-management intervention used for this study was described and validated previously.^{10,11} Tailored individualized components were added to maximize relevance.¹⁹ The self-management intervention sessions were designed to be delivered in 30 minutes to simulate a clinical encounter. The first of the identical scripted sessions was delivered by a trained advanced practice nurse who was a certified asthma educator; the second and third were repeat reinforcements delivered by a respiratory therapist, also a certified asthma educator, who attended the first session. The education consisted of standardized components regarding asthma facts and medication actions, as well as individualized components. Personalized components included verbal and graphic interpretation of spirometric results, peak flow trends, metered dose inhaler technique errors, and results of allergen skin testing, along with specific strategies for control of personally relevant environmental exposures. This last component has been used previously in children²⁰ but not in adults. Lastly, the peak flow monitor of the intervention participants was adjusted to reveal how daily readings compared with individual personal best values. Zones based on a "traffic light" analogy were displayed on the monitor face and correlated to a simple written action plan. The action plan was not personalized to include increased doses of ICSs or individualized prednisone because subjects remained under the care of their own

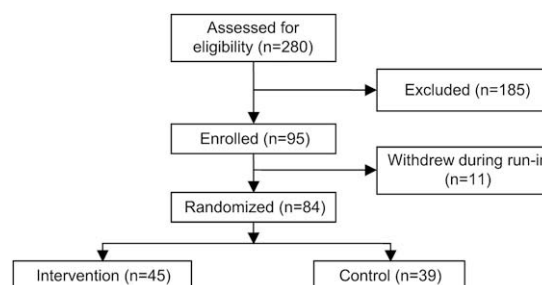


FIG 1. Enrollment flowchart.

personal physicians. No information about medication adherence was included in the intervention.

Outcomes

ICS adherence was calculated as the percentage of prescribed doses taken each week as measured by the electronic device validated for monitoring metered dose inhaler use.²¹ The numerator was capped at the prescribed doses per day to avoid overestimation of adherence to greater than 100% per day. Pulmonary function was assessed by means of spirometry before bronchodilator use and after withholding short-acting β -agonists for 6 or more hours and long-acting β -agonists for 24 or more hours. FEV₁ percent predicted was used as a proxy variable for overall lung function.²² Quality of life and perceived control of asthma were assessed by using validated and self-completed questionnaires.^{23,24} Peak flow was measured by using the electronic peak flowmeter.

Asthma symptoms were rated daily by participants on validated 10-point numeric rating scales, where 0 equaled "none" and 10 equaled "very severe" from subjects' diaries.²⁵⁻²⁸ Scores were averaged weekly for analysis. Symptom-free days (symptom score, 0), frequency of nighttime awakenings, and IBA use (number of puffs) were recorded daily and summed weekly for analysis.

Induced sputum samples were collected at the end of the run-in phase, the end of the intervention, and the end of the study to assess the degree of airway inflammation. Markers of inflammation included eosinophils, neutrophils, eosinophil cationic protein (ECP), and tryptase. Processing and analysis were performed as previously described.¹¹

Statistical analysis

The *a priori* power analysis showed a sample size of 80 was necessary to provide 80% power to detect a 10% change in adherence at an α value of .05; we enrolled 95 subjects and randomized 84 subjects. Intention-to-treat analyses included all participants randomized, 78 with complete data and 6 with incomplete data.

The effect of the intervention on adherence was analyzed as mean adherence and also by categorizing adherence dichotomously as 60% or greater or less than 60% adherence to the prescribed dose.¹² Research has shown that typical ICS adherence is no greater than 50% in adults with asthma.²⁹ We chose 60% as an important cutoff point to determine whether average ICS adherence could be improved to and sustained above this level (ie, 10% higher than reported norms). Effects of the intervention were assessed by using linear mixed-models analysis when variables were continuous; linear mixed models with a Poisson distribution were used with count variables. A mixed logistic model was used to assess binary variables (StataCorp, College Station, Tex). These analyses were chosen because they account for missing data in the calculation of outcome variables. Nonskewed data were reported as mean change over time. Skewed data were log-transformed and presented as odds ratios (ORs), as were binary data. Count data was presented as incidence rate ratios.

We compared within-group change rates from the end of the run-in phase (T₀) to the end of the intervention (T₁), the end of the intervention (T₁) to the end of the study (T₂), and the end of the run-in phase (T₀) to the end of the

TABLE I. Baseline sample characteristics

Characteristic	Intervention group (n = 45)	Control group (n = 39)	P value*
Age (y)	36.8 ± 9.4	39.7 ± 9.3	.17
Female sex	24 (53)	21 (54)	.96
Race			
Asian	10 (22)	6 (15)	.45
Black	1 (2)	4 (10)	
White	28 (62)	26 (67)	
Other	6 (14)	3 (8)	
Ethnicity (Hispanic)	3 (7)	10 (26)	.02
Education (y)	16.1 ± 2.1	15.2 ± 2.3	.06
Employed (yes)	41 (91)	36 (92)	.84
Health care			
Primary care	28 (62)	22 (56)	.16
Specialist	12 (27)	7 (18)	
Other	5 (11)	10 (26)	
Insured (yes)	37 (82)	27 (69)	.16
Asthma duration (y)	22.0 ± 13.1	25.3 ± 14.7	.29
Rhinitis (yes)	28 (62)	29 (74)	.24
Sinusitis (yes)	7 (16)	6 (15)	.98
Severity by FEV ₁ criteria			
Severe (≤60% predicted value)	22 (49)	18 (46)	.37
Moderate (61% to 79% predicted value)	21 (47)	21 (54)	
Mild (≥80% predicted value)	2 (4)	0	
FEV ₁ , after bronchodilator (% predicted)	82.7 ± 14.1	78.5 ± 12.8	.16
Perceived asthma control score (11-55)	41.8 ± 6.1	40.2 ± 4.2	.14
Asthma quality-of-life score (0-80)	16.0 ± 11.0	15.8 ± 11.1	.94
Adherence to ICS (%)	82 ± 18	81 ± 18	.71
Peak flow (morning only)	427.4 ± 91.1	381.8 ± 110.2	.04
Mean weekly puffs of β-agonist used	1.5 ± 1.9	1.7 ± 2.2	.71
Mean weekly symptom score	4.5 ± 4.4	5.1 ± 5.1	.55
Mean % symptom-free days per week	34.1 ± 37.1	31.0 ± 37.2	.70
Mean weekly number of nighttime awakenings	0.29 ± 0.69	0.35 ± 0.97	.75

Values are presented as number (percentage) or mean ± SD.

study (T₂) to assess the within-group effects for the intervention and control groups. We then compared the change rates between the groups during those same time intervals to assess the effect of the individualized self-management intervention.

RESULTS

Table I shows the baseline characteristics for subjects randomized. There were no significant differences between groups, except in peak flow. We adjusted the analysis of lung function for peak flow, and there were no differences between the adjusted and unadjusted analyses. There were no significant differences between the participants who were randomized and those who were not (n = 11, data not shown). Electronic and diary adherence and peak flow data were compared to look for concurrence, but only the electronic data for both were used in the analysis. Retrospective analysis showed that adherence to diary keeping and peak flow measuring over time decreased by 0.02% for intervention subjects and 0.12% for control subjects (P = .10).

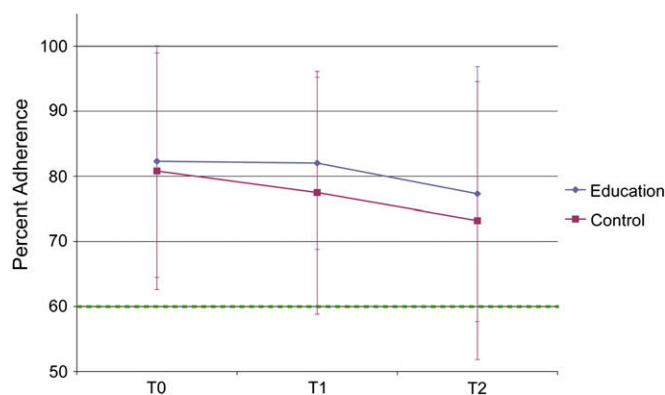
Mean ± SD adherence for the intervention and control groups was 82% versus 80% at T₀, 82% versus 77% at T₁, and 77% versus 73% at T₂, respectively (Fig 2). Mean adherence did not differ significantly between groups but stayed consistently higher over time in the intervention group compared with that seen in the control group. At the end of the study, median adherence was 86% for the intervention group and 76% for the control group. Mean change in adherence decreased in both groups over time, although

less so in the intervention group, but the differences were not statistically significant (Table II). The odds of maintaining greater than 60% adherence over the intervention period increased 9-fold for the intervention group, and there was no change in the control group (OR, 9.2 vs 0.4; P = .02; Table III). At T₂ the intervention group maintained 3-fold greater odds of greater than 60% adherence.

The odds of being symptom free were significantly higher during the intervention and at the end of the study for the intervention group (T₀-T₁ OR, 2.2; P = .01; T₀-T₂ OR, 5.9; P = .02), but the change rates were not significantly different between groups (Table III). The mean change in symptom scores also decreased significantly for both groups over time, and the change rates were not significantly different between groups (Table II).

The odds of nighttime awakenings decreased significantly over time in the intervention group (T₀-T₁ OR, 0.24; P = .001; T₀-T₂ OR, 0.17; P < .001) compared with no significant change in the control group (Table III). The odds of experiencing nighttime awakenings caused by asthma over the entire study period decreased significantly in the intervention group versus that seen in the control group (T₀-T₂ OR, 0.17 vs 0.77; P = .03).

The incidence of rescue β-agonist use decreased significantly during the intervention period in intervention versus control subjects (T₀-T₁ incidence rate ratio, 0.56; P < .001; Table III). Both groups decreased β-agonist use over time, with no significant differences between groups by T₂.

**FIG 2.** Mean adherence to ICS use over 6 months.

Prebronchodilator FEV₁ percent predicted improved in both groups during the intervention period and over the period of the entire study, with no significant differences between groups (Table II). Postbronchodilator FEV₁ percent predicted improved in the intervention group at all time points and decreased in the control group, with no significant differences between groups. Morning peak flow improved significantly for the intervention group compared with the control group during the intervention period (T₀-T₁, 20.9 L/min [$P < .001$] vs 11.5 L/min [$P = .052$]), and both groups improved by the end of the study (T₀-T₂, 29.6 L/min [$P < .001$] vs 24.5 L/min [$P = .004$]), with no significant differences in the change rates between groups (Table II).

In the intervention group perceived control of asthma improved significantly during the intervention period (T₀-T₁, 1.89 [$P < .001$] vs 0.53 [$P = .37$]) and during the entire study (T₀-T₂, 2.87 [$P < .001$] vs 0.68 [$P = .25$]; between-group difference, $P = .006$; Table II). Quality-of-life scores improved significantly in the intervention group from T₀ to T₁ (-2.71, $P = .01$) and T₀ to T₂ (-3.82, $P < .001$) compared with no change in the control group; the between-group difference for T₀ to T₂ showed a trend favoring the intervention ($P = .07$).

Eosinophil counts (as a percentage) and tryptase levels (in micrograms per liter) were highly skewed and converted to binary variables: positive for eosinophil count if the total cell count was greater than the lower limit of detection (positive >1/500 cells) and positive for tryptase level if the total concentration was above the lower limit of detection (positive >1 µg/L). Neutrophil counts (as a percentage) and ECP levels (in nanograms per milliliter) were reported as means. There were no significant differences in the odds of eosinophil counts being positive within groups or between groups. Likewise, there were no significant differences within or between groups in ECP levels. There was a significant decrease in the odds of tryptase levels being positive for the intervention group from T₀ to T₁ (OR, 0.06; $P = .02$) and an overall decrease from T₀ to T₂ (OR, 0.003; $P = .03$) but no significant differences between groups (Table III). There were no significant within-group changes in neutrophil counts in either group. However, over the entire study period, there was an increase in mean neutrophil count of 5.3% for the intervention group and a decrease in neutrophil count of -6.7% for the control group, with a significant between-group difference ($P = .04$).

Intervention subjects reported significantly more changes in self-management behavior in the study group than in the control group (mean per-person changes, 1.82 vs 0.87; $P < .0005$). Overall, 98% of intervention subjects reported 1 or more changes

TABLE II. Mean changes in outcomes

Outcome	Time interval	Group	Mean change	Within-group significance	Between-group significance
Adherence (%)	T ₀ -T ₁	I	-0.18	.94	.72
		C	-1.40	.58	
	T ₁ -T ₂	I	-4.28	.06	.97
		C	-4.41	.09	
	T ₀ -T ₂	I	-4.46	.13	.79
		C	-5.81	.08	
FEV ₁ % predicted (before bronchodilator)	T ₀ -T ₁	I	1.47	.08	.32
		C	2.72	.003	
	T ₁ -T ₂	I	1.13	.19	.25
		C	-0.37	.70	
	T ₀ -T ₂	I	2.60	.003	.85
		C	2.35	.02	
Morning peak flow	T ₀ -T ₁	I	20.9	<.0005	.24
		C	11.5	.05	
	T ₁ -T ₂	I	8.7	.13	.62
		C	13.0	.05	
	T ₀ -T ₂	I	29.6	<.0005	.65
		C	24.5	.004	
Perceived control of asthma	T ₀ -T ₁	I	1.89	<.0005	.07
		C	0.53	.33	
	T ₁ -T ₂	I	0.98	.06	.28
		C	0.14	.80	
	T ₀ -T ₂	I	2.87	<.0005	.006
		C	0.68	.25	
Quality of life*	T ₀ -T ₁	I	-2.71	.01	.36
		C	-1.39	.20	
	T ₁ -T ₂	I	-1.11	.28	.27
		C	0.58	.61	
	T ₀ -T ₂	I	-3.82	<.0005	.06
		C	-0.80	.49	
Symptom score	T ₀ -T ₁	I	-1.28	.003	.84
		C	-1.41	.002	
	T ₁ -T ₂	I	-0.97	.01	.06
		C	0.11	.80	
	T ₀ -T ₂	I	-2.25	<.0005	.19
		C	-1.30	.02	
Neutrophils	T ₀ -T ₁	I	2.7	.46	.41
		C	-1.7	.67	
	T ₁ -T ₂	I	2.6	.50	.18
		C	-5.2	.23	
	T ₀ -T ₂	I	5.3	.18	.04
		C	-6.7	.13	
ECP	T ₀ -T ₁	I	0.88	.53	.55
		C	1.05	.82	
	T ₁ -T ₂	I	0.88	.52	.44
		C	1.11	.65	
	T ₀ -T ₂	I	0.77	.21	.18
		C	1.17	.49	

T₀, End of the run-in phase; T₁, end of the intervention phase; T₂, end of the observation phase; I, intervention; C, control.

*Lower scores mean higher quality of life.

TABLE III. Odds ratios for outcomes

Outcome	Time interval	Group	Odds ratio	Within-group significance	Between-group significance
Adherence (≥60%)	T ₀ –T ₁	I	9.2	.02	.02
		C	0.4	.37	
	T ₁ –T ₂	I	0.3	.32	.31
		C	1.1	.90	
	T ₀ –T ₂	I	3.0	.38	.22
		C	0.5	.58	
Symptom-free days	T ₀ –T ₁	I	2.2	.01	.48
		C	1.6	.23	
	T ₁ –T ₂	I	2.7	.07	.63
		C	1.8	.36	
	T ₀ –T ₂	I	5.9	.02	.51
		C	2.8	.23	
Nighttime awakenings	T ₀ –T ₁	I	0.2	.001	.13
		C	0.7	.37	
	T ₁ –T ₂	I	0.7	.49	.45
		C	1.2	.71	
	T ₀ –T ₂	I	0.2	<.0005	.03
		C	0.8	.59	
β-Agonist use*	T ₀ –T ₁	I	0.6	<.0005	.01
		C	0.8	.057	
	T ₁ –T ₂	I	0.5	.001	.98
		C	0.5	.002	
	T ₀ –T ₂	I	0.3	<.0005	.30
		C	0.4	.004	
Eosinophils (>0%)	T ₀ –T ₁	I	0.5	.24	.40
		C	1.0	.97	
	T ₁ –T ₂	I	3.1	.12	.09
		C	0.6	.38	
	T ₀ –T ₂	I	1.7	.49	.29
		C	0.6	.41	
Tryptase (>0)	T ₀ –T ₁	I	0.1	.02	.29
		C	0.2	.22	
	T ₁ –T ₂	I	0.1	.10	.24
		C	0.4	.54	
	T ₀ –T ₂	I	0.0	.03	.08
		C	0.1	.27	

T₀, End of the run-in phase; T₁, end of the intervention phase; T₂, end of the observation phase; I, intervention; C, control.

*Reported values are in incidence rate ratios.

versus 64% of control subjects. Intervention subjects reported improving inhaler technique ($P = .03$), reducing outdoor allergen exposure ($P = .02$), and reducing indoor dust exposure ($P < .0005$) significantly more frequently than control subjects, as shown in Table IV.

DISCUSSION

Meta-analysis of published randomized trials of asthma self-management has shown improved health outcomes, especially reduction in emergency department visits and hospitalizations.⁸

TABLE IV. Self-described changes in self-management behavior after study participation

Change	Intervention group	Control group	P value
Improved adherence	21 (47)	17 (44)	.78
Changed medication	2 (4)	2 (5)	.88
Improved inhaler technique	10 (22)	2 (5)	.03
Increased peak flowmeter use	8 (18)	6 (15)	.77
Started using spacer	4 (9)	0	.06
Reduced dust exposure	19 (42)	2 (5)	<.0005
Reduced pet exposure	4 (9)	0	.06
Mold remediation	1 (2)	0	.35
Increased in-home ventilation	2 (4)	1 (3)	.64
Avoided outdoor air pollution	1 (2)	2 (5)	.47
Reduced household chemical exposure	2 (4)	0	.18
Reduced occupational trigger exposure	0	1 (3)	.28
Avoided food triggers	1 (2)	1 (3)	.92
Avoided alcohol triggers	1 (2)	0	.35
Avoided outdoor allergens	6 (7)	0	.02
Average number of changes per person	1.82 ± 0.91	0.87 ± 0.89	<.0005

Values are presented as number (percentage) or mean ± SD.

Fewer trials have evaluated the effect of self-management education on adherence to ICS treatment, with mixed results.^{12,30} In our study individualized asthma self-management training that incorporated behavioral strategies and self-monitoring was more effective in maintaining adherence to ICS use, decreasing nighttime awakenings and rescue IBA use, and increasing perceived control of asthma than self-monitoring alone. Although participants in the control group self-monitored and had research visits as often as the intervention group, they did not maintain ICS adherence, decrease nighttime awakenings or IBA use, or improve their perception of asthma control. Mean ICS adherence in the control group decreased over the study to levels similar to those reported in usual care.³¹ Rates of adherence for the control group were higher than those reported by other published adherence studies,³² but this finding was consistent with our expectation of the influence of continuous monitoring and free ICS medication (fluticasone). The effect of the intervention was more pronounced during the intervention period, producing a 9-fold increase in the odds of 60% or greater adherence to ICS use in the intervention group compared with that seen in control subjects ($P = .02$). The odds of 60% or greater adherence were preserved in the intervention group at a ratio of 3:1 to the end of the 24-week trial. There was waning of adherence over time in both groups but less so in those who had been trained in asthma self-management.

Key indicators of clinical asthma control improved over time in the intervention group compared with the control group, with the odds of experiencing nighttime awakenings decreasing significantly by the end of the intervention and by the end of the study. Rescue IBA use also decreased significantly in the intervention group compared with the control group during the intervention period. Eventually during the observation period, the incidence of IBA use decreased significantly in the control group as well, suggesting that personalized self-management has a more

immediate effect but that self-monitoring alone also decreases IBA use over time. Perceived control of asthma also improved significantly among intervention participants compared with control subjects, showing a parallel change with other clinical markers of asthma control. Symptoms decreased in both groups, suggesting this outcome is sensitive to the placebo effect of being enrolled in a research trial. The intervention had little effect on pulmonary function, as others have found,⁸ and a small statistically significant effect on mean peak flow of 30 L/min in the intervention group.

Self-management education had mixed effects on sputum markers of inflammation, with no effects on eosinophil counts or their primary constituent, ECP. Intervention participants had a significant decrease in tryptase levels. A possible explanation is the significant reduction in allergen exposures made by the intervention participants (Table IV). A pattern emerged with respect to neutrophilic changes between the 2 groups. Although neutrophil levels decreased 6.7% in the control group, they increased 5.7% in the intervention group, possibly reflecting the neutrophilic effects of greater cumulative corticosteroid inhalation as a function of greater adherence. These findings were inconsistent with those found previously¹¹ and difficult to assess for true significance because of the highly dispersed nature of the data. The role of monitoring inflammatory biologic markers in asthma remains unclear.

Although our adherence results are strengthened by the use and analysis of electronic monitoring, no device is infallible. The Doser CT has a date stamp that tallied the number of puffs for each day. Data were capped at prescribed dose/frequency to avoid overestimation of adherence to greater than 100% per day. The phenomenon of "data dumping" just before a research visit could not be ruled out up to the prescribed daily dose. Loss of data can occur if the device is lost or the battery fails between research visits. We used analytic methods that allowed for missing data. Diary forms were necessary to collect information about symptoms and nighttime awakenings, and these were subject to the limitations of self-report, which include forgetting to record information, loss of diary booklets, recording incorrect information, and nonadherence with recording data overtime. Similarly, changes in self-management behavior during the trial were also subject to the limitations of self-report. Additionally, our findings might not be generalizable to populations with low levels of education and high levels of unemployment, given the relatively high level of employment and education in our study population.

Notably, self-monitoring alone did not prevent a decrease in medication adherence. These results are similar to results reported by others who found self-monitoring did not improve medication adherence.³³⁻³⁵ Our results show that self-management education coupled with self-monitoring attenuated the often observed decrease in medication adherence and improved asthma clinical outcomes. With the modest time and resources required to achieve these outcomes, it appears to be worth the effort to include self-management education with self-monitoring in clinical practice settings in which adults with asthma are seen. Our study was not designed to analyze the cost-effectiveness of the intervention. However, a trained and certified asthma educator might be cost-effective if the goal is to improve asthma control and reduce urgent care visits. Alternatively, if the clinical goal is to reduce overuse of IBA, then self-monitoring of symptoms and peak flow might be an adequate and cost-effective approach.

Including the novel feature of personalizing allergen exposure control based on skin test results in adult asthma self-management education is unique to this study. It is now recommended by Expert Panel Report 3 asthma guidelines³⁶ and likely increased the power of our intervention. The improvements observed indicate the positive value of personalizing asthma self-management training.

Clinical implications: Individualized self-management education coupled with self-monitoring of asthma symptoms, nighttime awakenings, and peak flow confers additional benefits in adults with asthma beyond self-monitoring alone and should be considered in clinical settings in which adults with asthma are seen.

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