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Quality-of-Life and Cost–Benefit Analysis of a Home Environmental Assessment Program in Connecticut

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Background. The National Asthma Education Prevention Program's (NAEPP) Expert Panel Report 3 (EPR3) guidelines have stressed the need for environmental control measures for asthma, but there is limited evidence of their efficacy. *Objective.* To examine the effectiveness of an in-home asthma intervention program for children and adults in Connecticut, we conducted a panel study to analyze quality-of-life indicators for asthmatic patients and the cost–benefit relationship in preventive care versus acute care. *Methods.* The Asthma Indoor Reduction Strategies (AIRS) program was developed to reduce acute asthma episodes and improve asthma control through patient education and a home environmental assessment. Follow-up was conducted at 2-week, 3-month, and 6-month intervals. Measured quality-of-life indicators included number of unscheduled acute care visits, days absent from school/work due to asthma, times rescue inhaler used, and number of symptom-free days. Repeated measures analysis of variance (ANOVA) was used to determine whether significant differences exist in quality-of-life indicators at follow-up compared to that at the initial visit. Cost–benefit analysis was conducted by tabulating costs associated with physician office visits and emergency department (ED) visits due to asthma for children and adults separately. *Results.* Twenty percent of participants in the program met the criteria for well-controlled asthma, 16% for not well-controlled asthma, and 64% for very poorly controlled asthma. At 6 months follow-up, the mean number of unscheduled acute care visits, days absent from school/work due to asthma, and times rescue inhaler used in the past week decreased by 87%, 82%, and 74%, respectively, whereas the mean number of symptom-free days increased by 27% compared to the initial visit. Furthermore, the percent of participants with very poorly controlled asthma decreased from 64% at initial visit to 13% at 6 months follow-up. All changes were statistically significant at $p < 0.05$. A net savings of $26,720 per 100 participants was estimated at 6 months follow-up due to decreases in unscheduled acute care visits for adults and children. *Conclusion.* Significant improvement in quality-of-life and decreases in healthcare resource utilization and costs were found after implementation of the AIRS program in Connecticut.

Keywords asthma, cost–benefit analysis, environmental exposure, intervention studies, quality-of-life

INTRODUCTION

Patients with asthma may be exposed to multiple indoor allergens and environmental tobacco smoke (ETS) in their homes, which may contribute to increased asthma-related exacerbations (1, 2). Many patients with asthma, particularly those who live in poverty and rely on emergency departments (EDs) as their primary source of healthcare, may not be receiving adequate education about asthma self-management and how to avoid environmental exposures to asthma triggers. According to the most recent asthma surveillance report, the prevalence of asthma among adults is higher in Connecticut than in the United States as a whole and appears to be increasing, 9.3% in 2006, up from 7.8% in 2000 (3). Approximately 248,000 adults (9.3%) and 86,000 children (10.5%) in Connecticut reported that they had asthma in 2006, with the majority of individuals with asthma living in the poorest urban areas of Connecticut (4, 5).

The National Asthma Education Prevention Programs EPR3 (NAEPP) guidelines have stressed the need for environmental control measures, but there is limited evidence in previous studies of their efficacy. Numerous studies of asthma patient education and intervention programs have been conducted in the United States, United Kingdom, and elsewhere. However, results of the programs have been mixed—many have shown distinct benefits but others have not. A meta-analysis of 32 trials involving 3706 patients by Guevara et al. concluded that education programs are effective in improving self-management of asthma in young people and should be included as part of routine care (6). The ELECTRA study in Britain (7), an educational intervention in a Yale study (8), and a home-based environmental intervention study in seven major cities across the United States (9) have shown positive improvements in children and adults. However, several studies failed to achieve statistically significant results (10, 11). One potential limitation of all these intervention strategies is their focus on decreasing exposure to a single allergen, rather than improving the indoor environment as a whole. In addition, previous studies did not combine both an educational and home assessment component that focuses on changing behavior as well as environment for managing asthma outcomes.

To examine the effectiveness of an in-home asthma intervention program for children and adults in Connecticut, we analyzed quality-of-life indicators for asthmatic patients and the cost–benefit of prevention versus acute care treatment. The Putting on AIRS (Asthma Indoor Reduction Strategies) program was developed to reduce acute asthma episodes and improve asthma control through increased patient understanding on how to manage their asthma and recognition and elimination/reduction of environmental and other

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asthma triggers. The AIRS program provides the patient/family/caregiver with one or more one-on-one, interactive, health education sessions focusing on patient education and asthma self-management. This program follows the National Heart, Lung, and Blood Institute (NHLBI) NAEPP EPR3 Guidelines for the Diagnosis and Management of Asthma. Funding was provided by the Centers for Disease Control and Prevention (CDC) and the Environmental Protection Agency (EPA) to the Connecticut Department of Public Health to support implementation by six local health department contractors. The program grew out of a pilot project developed and evaluated by Connecticut's Ledge Light Health District that illustrated the need for formalized documentation and procedures/protocols (12, 13). The objective of this evaluation is to assess quality-of-life indicators and cost–benefit of implementing the AIRS program within the State of Connecticut.

METHODS

AIRS Program

The AIRS program serves diverse populations in six funded asthma regions in Connecticut. Participants may be children, adults, or families who are referred from the ED, healthcare providers, school health services, or self-referral. Although children are the primary target, the AIRS program is open to people with asthma of all ages. For the remainder of this document "participant" will be used to identify children and their caregivers, adults, or families who are referred to the program. The program is free to anyone regardless of income or insurance status. One local health department in each region takes the lead to expand the program through other health departments within their respective region. Local health department staff provides patient education and a home environmental assessment.

A nurse, health educator, or respiratory therapist who each may also be a Certified Asthma Educator conducts the education session, reviews medications and administration technique, and provides phone support and follow-up after the initial visit. For the remainder of this document "nurse" will be used to identify this role. The nurse conducts follow-up with the participant at 2-week, 3-month, and 6-month intervals. A Registered Environmental Health Specialist/Registered Sanitarian (REHS/RS) is someone who is certified by the National Environmental Health Association (NEHA) and shows competency in environmental health issues, directs and trains personnel to respond to routine or emergency environmental situations, and frequently provides education to their communities on environmental health concerns (14). The registered sanitarian conducts an environmental assessment of the home and/or caregiver location, identifies asthma triggers, and makes recommendations to reduce or eliminate exposure.

Prior to the initial visit, the nurse administers an intake questionnaire with the participant via telephone and schedules a home visit. On the first home visit, the asthma project nurse and environmental specialist both participate in the initial home visit. The nurse administers a home assessment questionnaire that captures baseline data on knowledge of common asthma triggers, such as cockroaches, furred or furry pets, dust mites, ETS, and mold/mildew. The nurse collects additional baseline data regarding missed school days, ED visits due to asthma, asthma-related physician visits in the previous month, medication usage and technique, and current asthma action plan and begins a dialog with the participant about issues and questions. All baseline data are self-reported.

Both the nurse and the environmental specialist conduct a walk-through of the home, assessing and recording sources of environmental triggers for asthma. These triggers include household characteristics, such as the presence of sanitation tools (i.e., vacuum, broom, or mop), self-reported weekly household cleaning, presence of scented aerosolized products (i.e., cleaning chemicals, scented candles, perfumes), self-reported evidence of cockroaches and rodents, pets currently in home, stuffed animals or extra pillows on bed, carpeting in bedroom or living room, gas stoves, mold/mildew on walls or ceilings, water damage in any room or surface, water in basement or crawl spaces, and exposure to ETS.

Results from the home assessment inform an environmental summary care plan which outlines low or no-cost options to reduce or eliminate the trigger sources. The environmental summary care plan is discussed with the participant. At the end of the visit, the participant/caregiver retakes the home assessment questionnaire regarding knowledge of asthma triggers for the purpose of post-assessment evaluation. Staff reviews post-assessment results with the patient to reinforce knowledge of asthma triggers. Staff leaves a folder of educational information with the participant containing various brochures/fact sheets including "Helping Your Child Manage Asthma: A Parent Handbook," "What Everyone Should Know About Asthma," and "Controlling Asthma and Allergies in Your Home," as well as an asthma action plan and fact sheets on medications specific to the participant. Patient-specific materials for reducing exposure to ETS or smoking cessation would be offered when there are smokers in the home. General information regarding recognizing asthma symptoms, when to take medications, and when to call the doctor are provided, along with information on identifying indoor asthma triggers and ways to reduce or eliminate exposure to those triggers.

The program may also provide pillow/mattress covers, spacers, and peak flow meters, if available. A spacer is provided if the medication order from the doctor specifies it and/or the patient verbalizes they use one but lost it. Bed covers are provided for all patients based on availability of funds. In the past 2 years they have been available and provided. Peak flow meters are only provided if the doctor ordered it and if the patient currently does not have one.

Informed consent to participate in the in-home assessment was given at the time of referral. Because data were de-identified upon analysis, the study was exempt from IRB review at the Connecticut Department of Public Health.

Follow-Up Home Evaluations

Subsequent to the visit, an in-home evaluation summary with recommended action items is completed and sent to the participant and the participant's medical providers (i.e., primary care physician, school nurse, asthma specialist, school health services, school-based health center). At 2 weeks after the initial visit, the nurse follows up with the participant either in-person or by telephone. The nature of the follow-up is to evaluate the participant's progress in implementing the recommendations suggested on the In-Home Evaluation Summary and to answer any questions regarding their asthma management.

At 3 months follow-up, the asthma project nurse contacts the participant to review the progress in implementing the care plan recommendations. The nurse offers recommendations and answers questions and concerns. If progress is not occurring, another visit is encouraged. Otherwise, the nurse collects data regarding self-reported missed days from school or work due to asthma, rescue inhaler use, symptom frequency, and asthma-related emergency room visits and physician visits.

At 6 months follow-up, the nurse attempts to make a final follow-up call to determine if any additional support or answers to questions are needed. Then, the nurse collects final data regarding self-reported missed days from school or work due to asthma, rescue inhaler use, symptom frequencies, and asthma-related emergency room visits and physician visits. A program evaluation form is provided to the patient with a self-addressed stamped envelope to gather feedback about the program following the final 6 months follow-up.

Statistical Analysis

Quality-of-life indicators included asthma-related visits to the ED, visits to a physician, missed days of school or work due to asthma, rescue inhaler use, and symptom-free days. Indicators were collected on day of initial visit and at 3 months and 6 months follow-up. Asthma control was categorized as "well controlled," "not well controlled," and "very poorly controlled" and defined based in part on the NAEPP EPR3 Guidelines control parameters (15), according to events at the initial visit (Table 1). Participants who reported no unscheduled acute care visits (i.e., physician office visits and ED visits) in the past 3 months, no days absent from school or work due to asthma in the past 3 months, less than or equal to two times rescue inhaler used in the past 1 week, and greater than or equal to 10 symptom-free days in the past 2 weeks were categorized as "well controlled." Those who reported one unscheduled acute care visit in the past 3 months, 1–3 days absent from school or work due to asthma in the past 3 months, three to six times rescue inhaler used in the past 1 week, or 2–9 symptom-free days in the past 2 weeks were categorized as "not well controlled." Finally, those who reported two or more unscheduled acute care visits in the past 3 months, 4 or more days absent from school or work due to asthma in the past 3 months, one or more times of rescue inhaler use per day in the past 1 week, or 1 or less symptom-free days in the past 2 weeks were categorized as "very poorly controlled."

TABLE 1.—Classification of asthma control at initial visit.

	Well controlled	Not well controlled	Very poorly controlled
Average number of unscheduled acute care visits[a] in the past 3 months	0	1	2 or more
Average number of days absent from school/work due to asthma in the past 3 months	0	1–3	4 or more
Average number of times rescue inhaler used in the past 1 week	≤2	3–6	7 or more
Average number of symptom-free days in the past 2 weeks	10–14	2–9	≤1

[a]Defined as physician's office visits or emergency room visits for worsening asthma symptoms in the past 3 months.

Medications corresponded to self-reported prescribed medications. They were categorized as "controller" or "rescue" based on the NAEPP EPR3 Guidelines. The categories were determined based on the medication used and not on the delivery method (i.e., nebulized albuterol was included in counting the use of rescue inhaler).

To measure hygienic quality of the home, several variables were created to determine whether the participant had any sanitation tools in the home or reported cleaning on a weekly basis. A participant was categorized as having sanitation tools if they reported having either a vacuum, broom, or mop. A participant who reported either changing the sheets, dusting, sweeping, or vacuuming at least once a week was categorized as having cleaned on a weekly basis. Scented aerosolized products are defined as using any cleaning chemicals, scented candles, or perfumes. ETS is defined as reporting a person(s) in household who smokes or having any visible ashtray or tobacco products in the home.

For examining bivariate associations, we used chi-square tests to evaluate any differences in demographic and household characteristics by level of asthma control. We used repeated measures analysis of variance (ANOVA) to examine whether significant differences exist in the mean number of unscheduled acute care visits, days absent from school/work due to asthma, times rescue inhaler used, and number of symptom-free days at 3 months and 6 months follow-up compared to these responses at the initial visit. In addition, ANOVA was used to examine differences in level of asthma control at 3 months and 6 months follow-up compared to the initial visit.

Cost–benefit analysis was conducted by tabulating costs associated with physician office visits and ED visits due to asthma for children and adults separately. The estimated cost was $525 per ED visit for children with a primary diagnosis of asthma, $652 per ED visit for adults with a primary diagnosis of asthma, and $98 per patient

office visit, for children and adults, which includes history and exam (3, 16).

RESULTS

Study Population

From 2005 to 2009, there were 454 participants with home visits, out of 592 referrals to the AIRS program (Table 2). The majority (79%) of the participants were under 18 years of age and 52% were female. Approximately half (49%) of the participants were non-Hispanic White, 13% were non-Hispanic Black, 33% were Hispanic, and 5% were categorized as other.

At the initial visit, 84% of the participants reported understanding at least one asthma self-management education component (i.e., asthma pathophysiology, medications, correct inhaler administration technique and when to use, peak flow meter use, recognizing symptoms of exacerbations and responding appropriately to reduce them) or having a written asthma action plan (Table 2). However, only 17% were able to use a peak flow meter correctly and only 20% had a written asthma action plan. Among participants, 83% were prescribed at least one controller or rescue medication. Sixty-seven percent were prescribed controller medications, 76% were prescribed rescue medications, and 61% were prescribed both. Sixteen percent were prescribed rescue medications only.

Seventy percent reported having any one of the following sanitation tools: broom, mop, or vacuum (Table 3). Sixty percent reported cleaning on a weekly basis, which includes changing bedding, dusting, sweeping, or vacuuming. Almost half (46%) reported using scented aerosolized products (i.e., scented candles, perfumes, or cleaning chemicals). Twenty-one percent reported evidence of rodents or cockroaches in the home and 40% reported having pets in the bedroom. Twenty-eight percent of participants had mold/mildew on walls or ceilings, water damage in any room or surface inside or outside, or water in basement or crawl spaces. A quarter of participants had a gas stove, and 45% reported being exposed to ETS in the home.

Based on the classification developed by the Asthma Program for asthma control (Table 1), 20% met the criteria for well-controlled asthma, 16% for not well-controlled asthma, and 64% for very poorly controlled asthma (Table 2).

Bivariate Analyses

The level of asthma control was significantly associated with prescribed controller and rescue medications, presence of any sanitation tools (e.g., vacuum, broom, mop), frequency of cleaning, use of scented aerosolized products, the presence of mold/moisture in the home, and presence of a gas stove (Table 3). Participants who were prescribed controller or rescue medications or both had a significantly lower level of asthma control compared to those who were not prescribed controller or rescue medications. Participants who were prescribed rescue medications only had significantly higher levels of asthma control compared to those prescribed both controller and rescue medications. Those who reported having no sanitation tools (i.e., vacuum, broom, mop) had significantly higher levels of asthma control. In addition, those who reported cleaning on a weekly basis (i.e., changed bedding, dusted, or vacuumed), having scented aerosolized products, having mold/moisture in the home, or having gas stoves had significantly lower level of asthma control.

Differences in Quality-of-Life Indicators at 3 and 6 Months Follow-Up

The mean number of unscheduled acute care visits in the past 3 months decreased significantly by 77% at 3 months and 87% at 6 months follow-up compared to the initial visit (Table 4). The mean number of days absent from school/work due to asthma in the past 3 months was significantly reduced by 75% at 3 months and 82% at 6 months after visit compared to the initial visit. The mean number of times rescue inhaler was used in the past week decreased significantly by 74% at 6 months compared to the initial visit. In addition, the mean number of symptom-free days in the past 2 weeks significantly increased by 23% at 3 months and by 27% at 6 months compared to the initial visit.

Differences in Levels of Asthma Control at 3 and 6 Months Follow-Up

The percent of participants with well-controlled asthma increased significantly from 20% at the initial visit to 63% at 3 months and 76% at 6 months follow-up (Table 5). Likewise, the percent of participants with not well-controlled asthma decreased significantly to 10% at 6 months compared to 16% at initial visit ($p < 0.01$). Finally, the percent of participants with very poorly controlled asthma decreased significantly from 64% at initial visit to 21% and 13% at 3 and 6 months follow-up, respectively.

Cost–Benefit Analysis

A net savings of $19,507 per 100 participants and $26,720 per 100 participants was estimated at 3 months and 6 months follow-up, respectively, due to decreases in number of total unscheduled acute care visits for adults and children in the previous 3 months. Costs for unscheduled acute care visits were estimated at $38,865 per 100 participants for children and adults at initial visit (Table 6). At 3 months, the estimated total cost associated with unscheduled acute care visits was $19,358 per 100 participants, for a net savings of $19,507 compared to that at initial visit. At 6 months, the estimated total cost associated with unscheduled acute care visits was $12,145 per 100 participants, for a net savings of $26,720 compared to that at 3 months prior to visit.

TABLE 2.—Demographic characteristics by level of asthma control (AIRS, 2009).

Respondent characteristics	Number	Percent[a]	Level of asthma control		
			Well controlled	Not well controlled	Very poorly controlled
Number referred	592	100.0	—	—	—
Number with home visits	454	76.7	20.4	16.0	63.6
Age					
<18	353	78.8	73.4	81.0	77.2
≥18	95	21.2	26.6	19.0	22.8
Sex					
Male	230	48.0	47.5	50.8	52.3
Female	212	52.0	52.5	49.2	47.7
Race/ethnicity					
Non-Hispanic White	141	49.0	59.7	47.1	46.6
Non-Hispanic Black	40	13.2	8.8	13.7	12.1
Hispanic	100	32.9	28.1	27.5	38.5
Other	15	4.9	3.5	11.8	2.9
Patient education					
Understands asthma pathophysiology					
Yes	361	79.5	83.8	87.3	89.6
No	93	20.5	16.2	12.7	10.4
Understands medications					
Yes	336	74.0	81.3	77.8	83.6
No	118	26.0	18.7	22.2	16.4
Uses inhaler correctly					
Yes	239	52.6	58.8	54.0	60.8
No	215	47.4	41.2	46.0	39.2
Uses peak flow meter correctly					
Yes	77	17.0	21.3	7.4	20.8
No	376	83.0	78.7	92.6	79.2
Understands asthma management					
Yes	260	57.3	61.3	65.1	66.0
No	194	42.7	38.7	34.9	34.0
Has written asthma action plan					
Yes	93	20.5	15.0	19.1	25.2
No	361	79.5	85.0	80.9	74.8
Prescribed medication					
Controller medication***					
Yes	305	67.2	48.8	66.7	85.6
No	149	32.8	51.2	33.3	14.4
Rescue medication*					
Yes	346	76.2	76.3	82.5	87.6
No	108	23.8	23.7	17.5	12.4
Rescue medication alone***					
Yes	71	15.6	36.3	23.8	9.5
No	383	84.4	63.7	76.2	90.5
Controller and rescue medication***					
Yes	275	60.6	41.3	57.1	78.2
No	179	39.4	58.7	42.9	21.8
Controller or rescue medication**					
Yes	376	82.8	86.3	87.3	95.2
No	78	17.2	13.7	12.7	4.8

[a]Percent based on participants with home visits only.
*$p < .05$;
**$p < .01$;
***$p < .0001$.
Note. Percentages may not add to 100 because of rounding.

DISCUSSION

We found that a home-based intervention, focusing on patient self-management education and reducing exposure to multiple indoor allergens or irritants and ETS, significantly decreased unscheduled acute care visits, missed school/work days, rescue inhaler use, and symptoms among patients with asthma. Use of controller and/or rescue medications was found to be significantly associated with level of asthma control. Household characteristics such as the lack of any sanitation tools (i.e., vacuum, broom, mop), scented aerosolized products, mold/moisture, and gas stoves were also found to be significantly associated with level of asthma control.

Unscheduled acute care visits for asthma in the past 3 months decreased significantly by 87% at 6 months follow-up compared to the initial visit. We observed a

TABLE 3.—Household characteristics by level of asthma control (AIRS, 2009).

Household characteristics[a]	Number	Percent[b]	Level of asthma control: Well controlled	Not well controlled	Very poorly controlled
Any sanitation tools (i.e., vacuum, broom, mop)*					
Yes	316	69.6	69.7	74.6	82.0
No	138	30.4	31.3	25.4	18.0
Weekly cleaning**					
Yes	274	60.4	53.8	66.7	72.4
No	180	39.6	46.2	33.3	27.6
Scented aerosolized products*					
Yes	206	45.4	40.0	42.9	56.4
No	248	54.6	60.0	57.1	43.6
Pests					
Yes	97	21.4	18.8	20.6	26.8
No	356	78.6	81.2	79.4	73.2
Pest management					
Yes	20	4.4	7.5	6.4	4.0
No	434	95.6	92.5	93.6	96.0
Pets					
Yes	182	40.1	42.5	46.0	46.4
No	272	59.9	57.5	64.0	53.6
Dust mites					
Yes	263	57.9	57.5	66.7	66.0
No	191	42.1	42.5	33.3	34.0
Mold/moisture*					
Yes	127	28.0	21.3	28.6	36.0
No	327	72.0	78.7	71.4	64.0
Gas stove*					
Yes	113	24.9	25.0	15.9	32.4
No	341	75.1	75.0	84.1	67.6
Environmental tobacco smoke (ETS)					
Yes	145	44.6	38.5	56.8	45.3
No	180	55.4	61.5	43.2	54.7

[a]Lack of sanitary tools is defined as absence of a vacuum, broom, and mop. Weekly cleaning is defined as whether one changed bedding, dusted, swept, or vacuumed at least once per week. Scented aerosolized products are defined as using any cleaning chemicals, scented candles, or perfumes. Pests are defined as having any cockroach or rodent exposure. Cockroach is defined as having any evidence of cockroaches or seeing any cockroaches in the past month. Rodent is defined as having any evidence of rodents or seeing any rodents in the past month. Pest management is defined as using aerosols, insecticide bombs, or organic pesticides. Pets are defined as having any pets in the home. Dust mites are defined as having any stuffed animals or extra pillows on bed or any carpeting in the bedroom or living room. Mold/moisture is defined as having any mold/mildew on walls or ceilings, water damage in any room or surface inside or outside, or water in basement or crawl spaces in the past 12 months. Gas stove is defined as having a gas stove in the home. ETS is defined as reporting a person(s) in household who smokes or having any visible ashtray or tobacco products in the home.
[b]Percent based on participants with home visits only.
*$p < .05$;
**$p < .01$;

reduction in the number of days absent from school/work due to asthma in the past 3 months by 82% at 6 months compared to the initial visit. The mean number of times rescue inhaler was used in the past week decreased significantly by 74% at 6 months compared to the initial visit. In addition, the mean number of symptom-free days in the past 2 weeks significantly increased by 23% at 3 months and by 27% at 6 months compared to the initial visit. These events led to improvements in quality-of-life and savings in healthcare costs.

The quality-of-life for participants in the AIRS program significantly improved at 6 months follow-up. The percent of participants with well-controlled asthma increased from 20% at the initial visit to 76% at 6 months follow-up. Likewise, the percent of participants with very poorly controlled asthma decreased significantly from 64% at initial visit to 13% at 6 months follow-up. Improvements in quality-of-life have been shown to lead to lower morbidity and mortality in patients with asthma.

Direct medical costs saved from reduced unscheduled acute care visits are substantial. The AIRS program has been shown to decrease the number of unscheduled acute care visits by 87% at 6 months for a net savings of $26,720 per 100 participants. Although the cost-effectiveness of the intervention has not been measured, preliminary analyses suggest that the reduction in healthcare costs and improvements in quality-of-life alone far outweigh the costs of implementation. Other unmeasured benefits include improved school and workplace productivity due to a decrease in absenteeism and presenteeism. More symptom-free days and a decrease in need of rescue inhaler use may translate to a large

TABLE 4.—Characteristics associated with asthma control at initial visit and 3 and 6 months follow-up (AIRS, 2009).

Asthma control characteristics	Initial visit	3 months follow-up (%)	% change[a]	6 months follow-up (%)	% change[a]
Number of unscheduled acute care visits[b] in the past 3 months (mean ± SE)	3.0 ± 0.3	0.7 ± 0.1	76.7***	0.4 ± 0.1	a. 86.7*** b. 42.9
Number of days absent from school/work due to asthma in the past 3 months (mean ± SE)	2.7 ± 0.4	0.7 ± 0.1	74.7***	0.5 ± 0.1	a. 82.3*** b. 26.8
Number of times rescue inhaler used in the past week (mean ± SE)	3.2 ± 0.4	1.8 ± 0.4	43.9**	0.9 ± 0.2	a. 73.5** b. 50.0
Number of symptom-free days in the past 2 weeks (mean ± SE)	8.9 ± 0.3	11.6 ± 0.3	23.0***	12.2 ± 0.4	a. 27.1*** b. 5.2

[a]Repeated measures ANOVA.
[b]Defined as physician's office visits or emergency room visits for worsening asthma symptoms in the past 3 months.
a. Percent change from initial visit.
b. Percent change from 3 months follow-up.
**$p < .01$;
***$p < .0001$.

TABLE 5.—Level of asthma control at initial visit and 3 and 6 months follow-up (AIRS, 2009).

Level of asthma control	Initial visit	3 months follow-up (%)	% difference[a]	6 months follow-up (%)	% difference[a]
Well-controlled asthma	20.4	62.5	42.5***	76.4	a. 55.8*** b. 13.3***
Not well-controlled asthma	16.0	16.2	0.1	10.4	a. 5.2 b. 5.3
Very poorly controlled asthma	63.6	21.2	42.6***	13.2	a. 50.7*** b. 8.0***

[a]Repeated measures ANOVA.
a. Percent change from initial visit.
b. Percent change from 3 months follow-up.
***$p < .0001$.

reduction in healthcare resource utilization and a reduction in school/work absenteeism that could increase productivity. The overall improvements in terms of societal benefits and the quality-of-life of children and adults with asthma demonstrate a significant positive outcome of the intervention.

Our study corroborates the report of a crossover study of educational and environmental intervention by Bryant-Stephens et al. (17). In that study, the authors found a reduction in certain triggers, nighttime symptoms, and inpatient and ED visits among urban children with asthma and a history of poor symptom control who had a home-based educational and environmental intervention. Additional reports have documented the value of in-home environmental programs to reduce environmental triggers of asthma and to show significant cost savings and improved quality-of-life. The Inner-City Asthma Study, which cost $1469 per family, led to statistically significant reductions in symptom days, unscheduled clinic visits, and use of β-agonist inhalers which resulted in an intervention cost of only $27.57 per additional symptom-free day following a year of implementation (18). The Minnesota Department of Health released a report on 28 February 2008, showing that an investment of $468 per child would yield savings of almost $2000 through avoidance of expensive care in emergency rooms, inpatient hospitals, and doctors' offices (19). This suggests that in-home environmental programs are cost-effective in reducing healthcare costs while improving quality-of-life for patients with asthma.

One limitation of our study is that it was not designed to allow for control of confounding variables. We cannot conclude with certainty, therefore, that the positive effects we observed were due to the interventions and not some other variables. We also cannot determine whether participants modified their behavior or environment in response to the in-home assessment or which behaviors they modified. Based on qualitative analysis, the program has undergone numerous additions to improve the intervention without, however, compromising the initial components. Substantial improvements in quality-of-life among patients with asthma and savings in healthcare resources and costs following the intervention strongly suggest that the AIRS program has a large impact among children and adults with asthma. In addition, because risk factors and level of asthma control were reported at

TABLE 6.—Cost–benefit analysis (AIRS, 2009).

	Initial visit	3 months follow-up	6 months follow-up
Mean number of physician's office visits among children in the past 3 months per 100 participants	73.6	37.8	23.7
Mean number of ED visits among children in the past 3 months per 100 participants	17.9	8.7	7.1
Mean number of physician's office visits among adults in the past 3 months per 100 participants	64.2	52.5	40.0
Mean number of ED visits among adults in the past 3 months per 100 participants	24.4	9.1	3.3
Cost[a] associated with unscheduled acute care visits per 100 participants	$38,865	$19,358	$12,145
Net savings in cost per 100 participants	0	$19,507	$26,720

[a]For adults and children, estimated cost at $525 per ED visit for children with a primary diagnosis of asthma, $652 per ED visit for adults with a primary diagnosis of asthma, and $98 per patient office visit, including history and exam.

the same point in time, causality cannot be inferred. For example, we found that participants who were prescribed controller or rescue medications or both had significantly worse asthma control compared to those who were not prescribed controller or rescue medications. This may be because participants who have uncontrolled asthma are more likely to be prescribed medication. In addition, the finding that those who reported cleaning on a weekly basis (i.e., changed bedding, dusted, or vacuumed) were more likely to have uncontrolled asthma may be due to the fact that these participants are cleaning more often in response to their worse asthma control. Thus, only associations can be derived from the analyses and cause-and-effect relationships cannot be determined. Future studies will include analyses of cost-effectiveness, inclusion of a comparison group, and behavior and/or environmental modifications following the in-home assessment.

However, one of the major strengths of the study is the longitudinal design. Participants were measured at the initial visit and then measured again at 2 weeks, 3 months, and 6 months. This type of study, called a panel study, measures subjects at different points in time and is useful in predicting long-term or cumulative effects (20). If participants are again measured on the same environmental factors and quality-of-life indicators at follow-up and compared with those at the initial visit, cause–effect relationships may be predicted. In addition, because this is a real-life program and not a carefully constructed clinical trial, these findings are more likely to be seen in the general public.

The AIRS program is the first of its kind in the state that links healthcare providers who treat asthma patients with school nurses and the local health department so that the patient receives comprehensive medical and environmental management of asthma. Although it is difficult to generalize our results to all patients with asthma, it seems likely that participants who receive asthma self-management education and are able to identify and reduce exposure to environmental allergens and irritants similar to those present in the homes of our participants may derive a similar benefit from this intervention and avoid asthma exacerbations which could lead to an ED visit. The substantial improvements in quality-of-life among patients with asthma and savings in healthcare resources and costs following the intervention suggest that the AIRS program has a large impact among children and adults with asthma.

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DECLARATION OF INTEREST

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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