Home and Allergic Characteristics of Children with Asthma in Seven U.S. Urban Communities and Design of an Environmental Intervention: The Inner-City Asthma Study

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Most published environmental remediation interventions have been directed at single allergens and have employed demanding strategies; few have been performed in the homes of inner-city children disproportionately burdened by asthma. Our objective was *a*) to describe the allergen sensitivities, environmental tobacco smoke (ETS) exposure, and home environmental characteristics of a national sample of inner-city children with moderate to severe asthma and *b*) to develop and implement a multifaceted, home-based comprehensive intervention to reduce home allergens and ETS, tailored to the specific sensitization and exposure profiles of those children. Allergen skin testing and a home evaluation were performed to determine the presence of ETS and factors known to be associated with increased indoor allergen levels. Based on published remediation techniques, a home environmental intervention, organized into modules, each addressing one of five specific allergen groups or ETS, was designed. Of 994 allergic children from seven U.S. urban communities, 937 successfully completed baseline interviews and home allergen surveys and were enrolled. More than 50% of children had positive skin tests to three or more allergen groups. Cockroaches were reported in 58% of homes, wall-to-wall carpeting in the child's bedroom in 55%, a smoker in 48%, mice or rats in 40%, and furry pets in 28%. More than 60% of enrolled families received four or more modules, and between 94% and 98% of all modules were completed. We conclude that most inner-city children with moderate to severe asthma are sensitized to multiple indoor allergens and that environmental factors known to be associated with asthma severity are commonly present in their homes. The intervention developed for the Inner-City Asthma Study employs accepted methods to address an array of allergens and ETS exposure while ensuring that the intervention is tailored to the specific sensitization profiles and home characteristics of these children. *Key words:* environmental intervention, home environmental characteristics, inner-city children, pediatric asthma. *Environ Health Perspect* 110:939–945 (2002). [Online 13 August 2002]

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The burden of asthma is rising across the United States and is disproportionately high among inner-city residents, especially children (*1*). Although many factors have been associated with this phenomenon, there is growing evidence that exposure to allergens and irritants in the home is particularly important (*2*). Cat, cockroach, and house dust mite exposures have been associated with asthma exacerbations in sensitized individuals with asthma (*3–6*), and studies suggest that children exposed to smoking in the household have greater disease severity than those not exposed (*7–9*). Recently, levels of mouse allergen in the home have been related to skin test sensitivity and asthma morbidity (*10*); in the National Cooperative Inner-City Asthma Study (NCICAS), 19% of children with moderate to severe asthma were sensitized to rat allergen and 15% to mouse (*11*).

The 1997 national asthma education guidelines published by the National Institutes of Health (*12*) as well as more recent reports (*13*) state that the first and most important step in controlling allergen-induced asthma is to reduce exposure to relevant allergens. Skin testing in patients with persistent asthma should be used to focus remediation efforts on allergens to which the patient is sensitized. Although the guidelines recommend a long list of allergen reduction measures, few data exist to characterize the allergen risks in the homes of inner-city children. The NCICAS documented the association between cockroach allergen exposure and symptoms in sensitized children (*6*), and data from the NCICAS and elsewhere (*6,9,14,15*) suggest that most inner-city children with asthma are sensitized and exposed to multiple indoor allergens (*16*) and highly exposed to environmental tobacco smoke (ETS). However, most published environmental remediation interventions have been directed at single allergens and have employed demanding strategies. Few have been delivered in the homes of inner-city children, who are disproportionately burdened by asthma and underserved with respect to asthma care (*17*). This article describes the allergen sensitivities, ETS exposure, and home environmental characteristics of a national sample of 937 children with moderate to severe asthma from seven major inner-city U.S. communities enrolled in the Inner-City Asthma Study, and the development and implementation of a multifaceted, home-based, comprehensive environmental

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intervention that is tailored to the specific sensitization and exposure profiles of those children.

Methods

Inclusion criteria. Children and their families were eligible if the child had at least one overnight hospitalization or two visits to the emergency department for asthma during the 6 months before screening and had a positive skin test (wheal size at least 2 mm greater than glycerin control) (*18*) to at least one of 11 common indoor allergens: *Dermatophagoides farinae* and *D. pteronyssinus* (dust mite), German and American cockroach mix, rat, mouse, *Alternaria*, *Cladosporium*, *Aspergillus* mix (*A. flavus, fumigatus, glaucus, nidulans, niger*), *Penicillium*, cat (standardized to 10,000 BAU/mL), and dog (mixed breeds). Cockroach (German and American mix) extract was ordered from Bayer Corporation (Spokane, WA), and all other extracts were ordered from Greer Laboratories (Lenoir, NC). All extracts of each type were ordered from the same lot number. The specific allergens that were chosen were based on findings from the NCICAS (*6,11*) as well as other studies (*2,19*). In addition, the children had to live in a census tract in which at least 20% of households had a household income below the federal poverty line, and they had to sleep in the intervention home at least 5 nights out of every week.

Baseline data used to guide the design of the intervention. After obtaining informed consent, trained bilingual interviewers administered a baseline clinical interview to the child's primary caretaker that included demographics, asthma morbidity, characteristics of the home environment, and the child's exposure to ETS. Morbidity was measured by asking the caretaker to report on the number of days in the past 2 weeks that the child experienced wheezing, tightness in the chest, or cough; that the child's sleep was disturbed because of asthma; and the number of days that the child had to slow down or discontinue play because of asthma. In addition, the caretaker was asked to report on the number of hospitalizations, scheduled and unscheduled clinic visits due to asthma, and emergency department visits for asthma. Total unscheduled visits were calculated as a sum of unscheduled clinic visits and emergency department visits. The summary variable, maximum number of days of symptoms in the previous 2 weeks, was measured as the largest value among the number of days that the child experienced wheezing, tightness in the chest or cough, sleep disturbance, or slowing or discontinuation of play because of asthma. During the baseline clinical interview, children underwent skin testing (MultiTest II; Lincoln Diagnostics, Decatur, IL) (*20*) to the 11 allergens listed above plus three aeroallergens that varied according to the geographic region of the participating site.

Approximately 1–3 weeks after the baseline clinical evaluation, an evaluation was performed in the home of each child. Two trained home evaluators performed a visual assessment of the child's home that included general information such as type of dwelling and presence of animals and information about the family/TV room, the kitchen, the child's sleeping area, and the bathroom. Each room was assessed for cockroaches and cockroach stains, moisture or leaks, mold, musty smell, ashtrays, tobacco smell, type of floor covering, and condition of the floors, walls, and ceilings. In the child's bedroom, the evaluators determined the size and type of mattress and box spring, the presence or absence of impermeable mattress covers, the type of bedding and stuffed animals, and the presence and type of any air filtration devices.

Conceptual underpinnings of the intervention. Building on NCICAS, our primary goal was to provide the child's caretaker with the knowledge, skills, and motivation necessary to perform home environmental remediation activities. To enhance acceptance, the intervention was delivered by an environmental counselor, a culturally sensitive, bilingual resident of the community from which the participating families were recruited. The intervention was organized around concepts from several models of behavior change, particularly social cognitive theory (*21–24*), which emphasizes the interdependence of cognitions (attitudes, expectations) and behaviors. For each mitigation behavior in the intervention, we attempted to provide information to the caretaker on the efficacy of the behavior, model the targeted behavior, have the caretaker rehearse the behavior with feedback, establish that the caretaker had mastered the behavior, and increase the caretaker's outcome expectancies and self-efficacy for the behavior (*25*). These principles guided the development of the content and delivery of the intervention; at each step, the intervention included both education and demonstration of remediation techniques and required the participation of the child's primary caretaker.

Organization and tailoring of the intervention. The intervention had to address a number of allergens and be easily tailored to the specific exposures of each child. We targeted five allergen groups, furry pets (dog, cat), cockroach, dust mites, rodents (rat, mouse), and mold, as well as ETS, all found to be common in inner-city homes of children with asthma. The intervention was organized into modules so that the full complement of educational, skill development, and remediation activities required for any particular allergen group or ETS exposure could be delivered consistently to the child's caretaker. Moreover, an intervention organized as distinct modules could be easily tailored to the multiple and varied allergen sensitivities and exposures of each child. We culled allergen and ETS remediation techniques reported in the literature to be successful or proposed in current asthma management guidelines (*12,13*). These techniques were modified when necessary to increase acceptability and adoption of the recommended environmental control behaviors required by each module (Appendix 1).

So that the intervention could be quickly tailored to the needs of individual participants, the specific modules that a family received were determined by the child's allergen sensitivities and exposure profile. The child was considered to be exposed if either the caretaker reported evidence of the allergen or ETS in the home (e.g., seeing cockroaches, having a furry pet presently or within the previous 6 months, reporting that someone smokes in the home) or the home evaluator saw evidence of the allergen or ETS (e.g., cockroach stains, ashtrays, mouse droppings). These items were combined into an environmental risk assessment tool (ERAT) that organized and summarized the child's home characteristics, related those characteristics to the child's skin test results, and determined which modules and the intensity of the modules that the family would receive.

The first module, the safe sleeping zone, was organized around reducing all allergen levels and ETS in the bedroom and was delivered to every family. Because children spend most of their time indoors in their bedrooms, we focused allergen and ETS reduction activities there. Well-established dust mite remediation activities (Appendix 1) were essential components of this module. Although not all children were sensitized to dust mites, these activities reduce the overall dust burden in the room, thereby reducing exposure to all allergens found in dust. The other modules (cockroach, furry pets, rodents, ETS, and mold) each began with a review of allergen and ETS reduction activities in the child's bedroom and then addressed one specific allergen or allergen group or ETS in rooms other than the child's bedroom. Every family received the basic education component of the ETS module. The child's skin test sensitivities determined whether or not the family received the cockroach, rodent, furry pet, and mold modules. Families with children exposed to ETS or pets in the home received a more intensive version of the ETS or furry pets module (Appendix 1).

A team consisting of two individuals, an environmental counselor and an environmental interventionist, delivered the intervention. Two individuals were used to keep the visits within a 2-hr time limit to minimize participant fatigue. Only the cockroach module could take more than a single visit because it required several intensive activities. To ensure that the intervention would be delivered in a culturally sensitive manner, environmental intervention team members were bilingual residents of the communities in which the intervention families lived. At two centralized training sessions, team members were taught basic information about asthma, airway inflammation, and the role of allergens and irritants and were trained to follow a standardized protocol, to ensure uniform delivery of the intervention across families and across sites.

For each module, the counselor introduced the allergen to the caretaker and explained how it could make the child's asthma worse. Then the counselor educated the caretaker about ways to decrease the child's exposure to the allergen. The interventionist demonstrated remediation activities and helped motivate the primary caretaker by performing some remediation activities that the primary caretaker might have had difficulty doing alone, such as washing mold off a wall or cleaning heavy cockroach stains. The caretaker practiced remediation activities and received feedback and encouragement from the counselor, and together they made a plan for implementing the allergen reduction goals they established together. At the beginning of each visit after the first, the counselor reviewed with the caretaker the progress the family had made in implementing the goals and the status of any barriers previously identified. The counselor also worked with the caretaker to develop strategies to overcome those barriers. After the last intervention visit, the counselor reported on how well the caretaker implemented the intervention, barriers the caretaker experienced in implementing the intervention, and how interested the caretaker was in the intervention.

We ensured that the caretaker had the necessary tools and resources needed to mitigate allergens and ETS. All children in the intervention received impermeable mattress, box spring, and pillow covers (Allergy Control Products, Ridgefield, CT). Each family also received cleaning supplies as well as handout materials that included the family-specific goals they had agreed to try to accomplish for each module they received.

Because wall-to-wall carpeting is known to be a major allergen reservoir (*26*), we would have preferred to remove it from the child's bedroom. However, expense and apartment rental contracts prevented us from relying on this approach. All caretakers were given and instructed in the use of a vacuum cleaner with a high-efficiency particulate air (HEPA) filter (*27,28*). Intervention homes that had carpets covering 50% or more of the child's bedroom or the family/TV room received a HEPA vacuum cleaner with a power brush (model S434-I; Miele Co., Somerset, NJ) (*29*). If carpets covered less than 50% of both of these rooms, the family received a HEPA vacuum cleaner with a bare floor brush (model S312-I; Miele Co.).

A HEPA air purifier (model 293; Holmes Products Corp., Milford, MA) was placed in the child's bedroom if the child had allergic sensitivity to mold, mouse, or rat, had a smoker in the home, or demonstrated sensitivity to dog or cat and had an indoor pet presently or within the previous 6 months (*30,31*). The carbon prefilter was replaced every 3 months. The intervention team instructed the caretaker in the use and maintenance of the HEPA air purifier. Families were reimbursed for the estimated cost of the electricity required to run the HEPA air purifier continuously during the intervention year. In homes with forced air heat, filters were applied to the vent grilles in the child's bedroom (Vent-Pro; Allergy Control Products).

Intervention time line. The intervention schedule included five mandatory visits and two optional visits during a 12-month period. The first three mandatory visits occurred within 2–3 months after enrollment. All modules were delivered during these visits. The two optional visits occurred between months 3 and 6 if the counselor did not feel that the caretaker was successfully performing the remediation strategies of previously implemented modules or if one or more of the first three visits had been missed. The last two mandatory visits occurred during months 7 and 12 and were reserved for summarizing and reviewing the goals and mitigation techniques that had been addressed in the previous visits as well as for addressing any remaining barriers. Each visit except the last was followed by a telephone call to determine whether the caretaker was able to accomplish the goals that had been established during the visit. The call was also used to identify and address any remaining barriers and to reinforce the goals from the previous visit(s). If an optional visit was not made or if a mandatory visit was missed, the counselor called the caretaker to check on the implementation of the goals established at previous visits.

Results

From seven U.S. urban communities, 1,059 children who met study eligibility criteria for asthma severity and residence attended a baseline clinical evaluation. Of these, only 65 (6.1%) had no skin test reactions to any indoor allergens and were therefore not eligible for enrollment. For another 57 children (5.4%), the caretaker did not complete the baseline home evaluation. Nine hundred thirty-seven children were enrolled in the study; 469 were randomized to receive the environmental intervention. The demographic characteristics and baseline asthma morbidity of the 937 enrolled children are noted in Table 1. Reflecting our efforts to enroll children from low-income census tracts, 60% of households reported an annual income less than $15,000. Caretakers reported that their children experienced an average of 6 asthma symptom days in the 14 days before the baseline interview.

The skin test results for the 937 children are noted in Table 2. Most children were sensitized to cockroach followed by dust mites and mold. Sensitization to each group of allergens except rodent was approximately

Table 1. Demographic characteristics and baseline asthma morbidity (n = 937).

Characteristic	Result
Age of child (mean ± SD)	7.7 ± 2.0
Male (%)	61.7
Ethnicity (%)	
African American	39.7
Latino	40.3
Other	20.0
Caretaker completed high school (%)	69.4
At least one household member employed (%)	75.9
Household income < $15, 000[a] (%)	60.3
Asthma morbidity (mean ± SD)	
In the 2 weeks before baseline	
Days of wheeze, chest tightness, or cough	4.31 ± 4.20
Nights the child woke up due to asthma	2.73 ± 3.71
Days the child slowed down or stopped play	3.96 ± 4.63
Maximum symptom days	5.99 ± 4.96
In the 2 months before baseline	
Hospitalizations due to asthma	0.16 ± 0.42
Unscheduled visits for asthma	0.92 ± 1.21

[a]Responses provided by 887 of 937 caretakers.

50% or higher. Moreover, more than half of the children enrolled were sensitized to three or more allergens.

The home characteristics of the 937 children are noted in Table 3. More than half the families live in apartments, and the average number of people living in the home was nearly twice the 2000 U.S. census average of 2.59 (*32*). Nearly all caretakers reported use of sweeping to clean the floor. More than half of the caretakers reported that the child's bedroom has wall-to-wall carpeting or large rugs, and approximately 30% reported that the child has a humidifier in the room and stuffed animals on the bed. The home evaluator noted plastic covers on the mattress in fewer than 17% of the children's bedrooms. There was a significant relationship between observing mildew in the child's bedroom and the caretaker's report of using a humidifier in the child's room during the previous year ($p < 0.03$).

Appendix 2 illustrates the items from the caretaker's interview at baseline and the home evaluator's observations, which were combined with the skin tests results into the ERAT. The ERAT was used to determine the modules and the intensity of the modules that each family would receive. Data on the home environmental exposures of the 937 children are noted in Table 4. Exposures are based on the caretaker's report. Additional exposures, not reported by the caretaker but determined by the home evaluator's inspection, are noted below the results from the caretaker's report. The caretaker's report appears fairly accurate for exposure to ETS and furry pets, but there was a greater than 15% increase in the number of homes with cockroach exposure and a nearly 25% increase in the number of homes with dampness or water leaks when the home evaluator's observations were added to the caretaker's report.

Table 5 displays the relationship between exposure to an allergen group reported by either the caretaker or the home evaluator and sensitization to that allergen group. For cockroach and rodent, children were significantly more likely to be sensitized if they were exposed, whereas this was not the case for mold and furry pets.

Table 6 shows the mean number of maximum symptom days reported for the 2 weeks before baseline by the number of modules required for a household by the ERAT. There was a significant relationship between the number of modules required by the ERAT and some measures of asthma morbidity, but not health service use.

Ninety-two percent of the 469 intervention families completed the number of modules required by the ERAT; 52.2% received an extra visit at week 13 and/or 17 to complete delivery of the modules; for 78% of these, the extra visit was needed because of a missed visit during week 2, 5, or 9. Table 7 describes aspects of the delivery of the intervention, including the percentage of households that were assigned by the ERAT to receive each module, the percentage of households that completed each module, and the number of modules delivered per household. Table 8 displays the environmental counselors' ratings of families' interest and success in implementing the intervention as well as the counselors' assessments of whether the family experienced any barriers to implementing the intervention. The counselors' assessments were made at the end of the intervention

Table 2. Allergy skin test results ($n = 937$).

Allergen sensitivities	Positive (%)
Dust mites	
D. farinae	47.6
D. pteronyssinus	57.1
Either dust mite	61.8
Cockroach mix (American and German)	68.6
Rodent	
Rat epithelia	18.9
Mouse epithelia	28.2
Either rodent	33.3
Mold	
Alternaria tenuis	35.9
Cladosporium herbarum	18.1
Aspergillus mix	27.0
Penicillium notatum	13.0
Any mold	50.1
Furry pets	
Cat standardized (10,000 BAU/mL)	44.1
Dog epithelia (mixed breeds)	21.1
Either pet	49.4
No. positive skin test groups per child	
1	20.9
2	28.2
3	26.7
4	15.2
5	9.0

Table 3. Home environment characteristics ($n = 937$).

Home characteristics	Percent
Type of dwelling	
Detached house	29.1
Duplex/triplex	9.2
Row house	2.3
Low-rise apartment (1–3 floors)	29.8
High-rise apartment (> 3 floors)	27.5
Mobile home/trailer	2.0
Mean no. people in home	4.7
Mean no. rooms in home	4.9
Reported methods of floor cleaning	
Vacuuming	54.1
Dust mopping or dry mopping	28.8
Damp mopping	93.6
Sweeping	95.1
Child's bedroom characteristics	
Location where child usually sleeps	
Own bedroom	81.5
Parent's bedroom	15.2
Family/TV room	3.1
Other	0.2
Wall-to-wall carpeting or large rugs	54.6
Room or central air conditioning	33.5
Humidifier	29.9
Any stuffed animals on bed	32.8
Plastic mattress cover observed on child's bed	16.9

Table 4. Home environment exposures ($n = 937$).

Exposure	Percent
Smoking exposure	
Caretaker currently smokes (R)	32.1
Homes with at least one current smoker (R)	48.2
Percent observed by evaluator but not reported by caretaker	5.7
Dampness/mold exposure	
Water, dampness or water leaks in past 12 months (R)	45.4
Percent observed by evaluator but not reported by caretaker	24.8
Cockroach exposure	
Problems with cockroaches in past 12 months (R)	57.8
Percent observed by evaluator but not reported by caretaker	15.3
Rodent exposure	
Problems with mice or rats in past 12 months (R)	39.5
Percent observed by evaluator but not reported by caretaker	9.0
Furry pet exposure	
Furry pets currently in home (R)	27.9
Cat	13.0
Dog	16.6
Other furry pet	4.7
Percent observed by evaluator but not reported by caretaker	2.2

R, reported by caretaker.

Table 5. Relationship between exposure by caretakers' report or evaluators' observation and sensitization ($n = 937$).

Allergen	Percent sensitized among unexposed	Percent sensitized among exposed	*p*-Value
Cockroach	52.6	74.6	< 0.01
Rodent	28.9	38.0	< 0.01
Mold	52.5	49.0	NS
Pets (dog or cat)	50.4	47.7	NS
Dog	21.6	19.4	NS
Cat	44.2	43.4	NS

NS, not significant.

year and were available for 421 (89.8%) of the 469 intervention families.

Discussion

The children in our national sample represent the population of inner-city children with moderate to severe asthma. We developed a comprehensive, multifaceted, home-based, environmental intervention. The intervention emphasized providing information about allergens and ETS and successful remediation strategies, modeling and rehearsing behaviors, ensuring mastery of behaviors, and increasing the caretaker's outcome expectancy and self-efficacy for the behaviors. Organized into modules, the intervention could be delivered in manageable doses and easily tailored to the specific sensitization and exposure profiles of inner-city children with moderate to severe asthma.

Our data confirm previous reports that a large proportion of urban children with asthma are exposed to ETS and to indoor allergens to which they are sensitized. Phase I of NCICAS (*11*) reported high rates of sensitization to cockroach among inner-city children, and sensitization to dust mite, mold, cat, dog, and rodent allergen was also common. The rates of sensitization and of multiple sensitizations in our population, however, are even higher than those found in NCICAS and other studies. Kattan et al. (*11*) found that 15% of children in phase I of the NCICAS were sensitized to mouse allergen, whereas this rate was nearly twice as high in our sample. Cockroach sensitivity was found in 68% of our sample compared with 36% of the children enrolled in phase I of the NCICAS (*11*). Compared with the present study, phase I of the NCICAS enrolled children with less severe asthma; approximately 10% had undiagnosed asthma. In ICAS, children had to have moderate to severe asthma and demonstrate cutaneous hypersensitivity to at least one indoor allergen. Only 6.1% of the children with moderate to severe asthma who were screened were disqualified by lack of sensitization to at least one indoor allergen, suggesting that children with more severe asthma have an especially high prevalence of allergy to indoor allergens.

The home environmental characteristics of our population reflect the presence of many factors believed to be detrimental to asthma. Nearly two-thirds of the children in this study live in apartments and in overcrowded conditions. Most caretakers use sweeping to clean the floors, which is not recommended for allergic individuals. More than half of the children's bedrooms have wall-to-wall carpeting or large rugs, and more than 30% have at least one stuffed animal on the bed. Nearly 30% have humidifiers. Few have allergen-impermeable mattress covers. Because ETS aggravates asthma (*33,34*), the finding that nearly 50% of households had at least one smoker suggests that this is an important target for environmental remediation activity. In addition, the high rates of characteristics associated with dust mite proliferation, dampness and leaks, cockroaches, mice and rats, and furry pets in the homes of these children suggest that a remediation program must be able to address all of these issues and that there is considerable opportunity for home environmental remediation activities recommended by the National Asthma Education and Prevention Program guidelines (*12*) to reduce asthma morbidity. The association between the number of modules required by the ERAT and some measures of asthma morbidity reported by the caretaker also supports the need for a comprehensive intervention.

For any recommendations to be effective, they need to be translated into specific actions that caretakers can understand and perform. Families have to be given opportunities to master the requisite allergen reduction behaviors through modeling, practice, and feedback. Delivering allergen reduction

Table 6. Baseline asthma morbidity (mean ± SD) by number of modules required by the ERAT (n = 469).

Morbidity measure	2 (n = 24)	3 (n = 154)	4 (n = 144)	5 (n = 92)	6 (n = 55)	p-Value
In the past 2 weeks						
Maximum symptom days	5.25 (5.18)	5.42 (4.60)	6.43 (5.02)	5.80 (5.02)	7.53 (5.10)	< 0.05
Days of wheeze, chest tightness, cough	3.54 (3.95)	4.08 (3.96)	4.65 (4.11)	4.84 (4.74)	5.45 (4.94)	< 0.04
Days child slowed, stopped play	3.79 (5.13)	3.78 (4.23)	4.08 (4.92)	3.31 (4.25)	5.30 (5.16)	NS
Nights child woke due to asthma	2.17 (2.87)	2.69 (3.36)	2.99 (4.00)	3.01 (3.91)	3.49 (3.91)	NS
In the past 2 months						
Hospitalizations due to asthma	0.42 (0.93)	0.14 (0.36)	0.18 (0.47)	0.15 (0.49)	0.25 (0.48)	NS
Unscheduled visits due to asthma	0.96 (1.37)	0.88 (1.13)	0.83 (1.18)	0.90 (1.20)	0.98 (1.30)	NS

NS, not significant.

Table 7. Delivery of the environmental intervention (n = 469).

Module	Assigned (%)	Completed (%)
Safe sleeping zone	100.0	98.1
ETS	100.0	95.3
Cockroach	67.6	98.1
Rodent	33.5	94.9
Pets	47.8	96.9
Mold	51.2	94.7
Modules delivered per household (%)		
0		1.7
1		1.5
2		4.9
3		31.8
4		29.9
5		19.2
6		11.1
Mean length in minutes of each visit (± SD)		73.6 ± 27.59
Mean number of visits per household (± SD)		4.7 ±1.09

Table 8. Counselor's report of caretaker's participation (n = 421).

Variable	Percent
Caretaker's interest in environmental intervention	
Very interested	38.3
Somewhat interested	60.5
Not interested	1.2
Caretaker's success in implementing the intervention	
Well	67.4
Not well	32.6
Barriers to implementation experienced by caretakers	
Any	59.5
Housing (structural problems)	29.9
Caretaker's work or job	28.0
Too little space in apartment/house	25.6
Financial problems	24.6
Caretaker's physical health	9.3
No interest in intervention	5.3

strategies by a culturally sensitive environmental counselor using modules built on the tenets of behavior change theory will maximize the likelihood of persistent behavior change.

The ERAT enabled us to combine the skin test results for each child with exposure data gathered from the child's caretaker and a trained observer to quickly identify the modules and module intensity required for each family. Without the ERAT, we would have had to base delivery of exposure reduction procedures solely on the child's skin test results. This approach would have wasted resources and likely disinterested the caretakers. The tailored approach allowed us to focus on the meaningful exposures in the child's home and help the caretaker learn techniques to reduce those exposures.

Little is known about whether families can identify environmental problems as well as a trained home observer. Table 4 compares the ERAT exposure findings based on the caretaker's report with the observations of the home evaluator. Overall, it appears that the caretaker is as good at reporting exposures to furry pets as is a trained evaluator and nearly as good at reporting exposure to ETS. Caretakers were less accurate in reporting problems with mice or rats and cockroaches, and 25% of homes with dampness or water leaks would have been missed if evaluation were based solely on the caretaker's report.

Social desirability bias may have played a role in the underreporting by caretakers of problems with mice and rats or cockroaches. It is also possible that some caretakers may not recognize evidence of cockroach or rodent infestation. The difficulty that caretakers appear to have reporting problems with water or dampness is concerning. Dampness is the single strongest predictor of respiratory disease, and dampness is a risk factor for wheezing (*35*–*37*). It might be difficult for caretakers to notice a musty smell that is constantly present in their homes or evidence of dampness or leaks (*38*). The home evaluators were taught to identify evidence of water leaks or dampness. Our data suggest that for certain types of exposures, the caretaker may be able to provide a reliable report that can be used to guide and tailor environmental remediation activities;

Appendix 2. Environmental exposure components of the ERAT.[a]

Module	Caretaker's report items	Evaluator's observation items
Safe sleeping zone	Location of child's sleeping area Type of window treatments Type of floor covering Frequency and method of floor cleaning Frequency bedding is washed Type of heating and cooling Use of humidifier/dehumidifier Presence of stuffed animals Presence of forced air vents Presence of plastic/vinyl bedding covers	Type of floor covering Presence of mattress covers
Cockroaches	Report of cockroach problems Report of leaks/dampness Use of extermination products/services	Evidence of cockroaches Location of leaks/moisture/mildew Problem areas that attract roaches
Rodents	Report of rodent problems Report of leaks/dampness	Evidence of rodents Location of leaks/moisture/mildew Problem areas that attract rodents
Mold	Report of leaks/dampness Type of flooring Type of heating and cooling Use of humidifiers/dehumidifiers Presence of forced air vents	Evidence of leaks/moisture/mildew Type of floor covering Musty smell
Environmental tobacco smoke	Number of smokers in home Frequency child is around smoke Caretaker's smoking habits	Evidence of ashtrays Smell of smoke
Furry pets	Report of pets in home Access of pets to child's bedroom	Evidence of pets in home

[a]Responses to the items from the caretaker's report at baseline and the evaluator's observation at the baseline home visit were part of the printed ERAT used by the counselor to direct the module activities to the specific risks of each child.

Appendix 1. Essential teaching/action points of the basic and intensive versions of the modules.

Safe sleeping zone
- Provide overview of intervention in context of relationship of asthma to allergens and ETS
- Describe how child's skin tests and exposures from parental report/evaluators observations will guide intervention activities
- Purpose of module: Make child's bedroom as allergen free and smoke free as possible
  - Apply mattress and pillow covers
  - Install air vent filtration covers where applicable; check for mold
  - Demonstrate vacuuming/damp mopping/damp dusting all surfaces
  - Encourage caretaker to adopt allergen reduction activities
    - Wash bedding in hot water at least every 2 weeks
    - Remove or vacuum carpets, damp dust every week
    - Freeze/wash stuffed toys
- Develop activity goals with caretaker to continue safe sleeping zone activities

Cockroach module
- Provide caretaker education about cockroach behavior and integrated pest management
- Demonstrate cleaning strategies such as shelf cleaning, sealing of nonrefrigerated food, countertop cleaning, mopping of kitchen, garbage and trash removal
- ✦ Remove visible cockroach stain and droppings
- ✦ Provide professional extermination services involving sealing of cracks and crevices, application of hydramethylnon gel baits and bait stations, hydoprene growth retardant

Rodent module
- Provide caretaker education about rodent behavior
- Identify entry points with caretaker and seal them with copper mesh
- Review and demonstrate cleaning and food storage methods as for cockroach module
- Give family a HEPA air purifier for child's room and instructions in its use

ETS module
- Provide caretaker education about importance of avoiding ETS at home and in public places
- Give all families "No Smoking/Lungs at Work" signs for home and child's bedroom
- ✦ Develop strategies with caretaker to eliminate or reduce child's exposure at home, primarily to keep ETS out of the child's bedroom
- ✦ Provide list of local smoking cessation programs if caretaker assessed as ready to change
- ✦ Give family a HEPA air purifier for child's room and instructions in its use

Furry pet module
- Provide caretaker education on pet allergens and their relationship to asthma
- Provide caretaker education on avoidance of pets outside home
- ✦ If pet in home presently or within past 6 months, give HEPA air purifier and instructions in use
- ✦ If pet in home presently, discuss strategies for pet removal or pet avoidance. Pet removal is the goal; secondary goal is banning pet from child's room, operating HEPA air purifier daily, encouraging child to wash hands after touching pet

Mold module
- Provide caretaker education on sources of mold/moisture in the home (e.g., leaking windows, damp mops, plumbing leaks, humidity in child's bedroom, number of houseplants, moldy smells, visible mold on walls/woodwork)
- Wash moldy surfaces with 10% bleach solution and instruct caretaker in preparation and use of solution
- Discuss importance and methods of providing ventilation and not using home humidifiers
- Give family a HEPA air purifier for child's room and instructions in its use

✦Denotes component added to basic module to comprise intensive version.

however, assessments for cockroach and water problems and, to a lesser extent, rodents may require trained individuals.

The relationship between allergen exposure and sensitization is complex. In our sample of children with moderate to severe asthma, children were significantly more likely to be sensitized to cockroach and rodent if they were exposed, by caretaker report or home evaluator observation. However, as noted by Arshad et al. (*18*) and Platts-Mills et al. (*39*), there was little difference in rates of sensitization to furry pets by whether the child was exposed to a cat or dog in the home. We also found little difference in sensitization to mold by exposure to dampness, water leaks, or mold.

The intervention was designed to address an array of exposures in a population sensitized and exposed to multiple indoor allergens and ETS. Despite its complexity, the ERAT enabled the intervention to be tailored to the needs of the recipients. Although more than 60% of the families completed four or more modules, the length of each visit was not excessive, and more than 91% of families completed exactly the number of modules that the ERAT determined they should receive. At the end of the intervention year, the counselors thought that nearly 60% of families had at least one barrier to implementing the intervention, but for only 5% of families was lack of interest reported as a barrier.

Although our sample was not population based or random, every effort was made to enroll a broadly representative sample of children with moderate to severe asthma from seven U.S. urban areas. It is possible that caretakers whose homes required more environmental remediation might have been more likely to enroll in the study leading to an overrepresentation of home environmental characteristics detrimental to asthma. However, this was not a volunteer sample, and the high consent rate among eligible children who were contacted from hospital and emergency department visit logs and invited to participate suggests that this was not the case.

Conclusion

These data demonstrate in a national sample that inner-city children with moderate to severe asthma tend to be sensitized to multiple allergens and to live in homes with many conditions associated with allergen and ETS exposure. These findings suggest that an environmental remediation intervention targeted to inner-city children needs to address multiple allergens and ETS, to be flexible, and to be easily tailored to the sensitizations and exposures of individual children. These were our goals in designing a modular, education-based intervention, firmly grounded in principles of behavior change that focused initially and repeatedly on remediation activities in the child's bedroom and expanded from there to address other exposures.

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