A single intervention for cockroach control reduces cockroach exposure and asthma morbidity in children

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Background: Exposure to cockroaches is an important asthma trigger, particularly for children with asthma living in inner cities. Integrated pest management is the recommended approach to cockroach abatement; however, it is costly and difficult to implement. The impact of reducing cockroach exposure on asthma outcomes is not known.

Objective: We sought to test the use of a single intervention, insecticidal bait, to reduce cockroach exposure in the home of children with asthma in New Orleans and to examine the impact of cockroach reduction on asthma outcomes.

Methods: One hundred two children aged 5 to 17 years with moderate to severe asthma were enrolled in a 12-month randomized controlled trial testing the use of insecticidal bait on cockroach counts and asthma morbidity. Homes were visited 6 times and asthma symptoms were assessed every 2 months.

Results: After adjustment, intervention homes had significantly fewer cockroaches than did control homes (mean change in cockroaches trapped, 13.14; 95% CI, 6.88-19.39; $P < .01$). Children in control homes had more asthma symptoms and unscheduled health care utilization in the previous 2 weeks (1.82, 95% CI, 0.14-3.50, $P = .03$; 1.17, 95% CI, 0.11-2.24, $P = .03$, respectively) and a higher proportion of children with FEV_1 of less than 80% predicted (odds ratio, 5.74; 95% CI, 1.60-20.57; $P = .01$) compared with children living in intervention homes.

Conclusions: Previous research has demonstrated improvement in asthma health outcomes using multifaceted interventions. The strategic placement of insecticidal bait, which is inexpensive, has low toxicity, and is widely available, resulted in sustained cockroach elimination over 12 months and was associated with improved asthma outcomes. This single intervention may be an alternative to multifaceted interventions currently recommended to improve asthma morbidity. (J Allergy Clin Immunol 2017;140:565-70.)

Key words: *Asthma, cockroach, integrated pest management, indoor allergens, intervention studies, FEV_1, FENO*

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Asthma exacerbation is mediated by exposure to indoor allergens.[1] There is evidence that not all allergen exposure affects children equally.[2] Cockroach exposure results in severe asthma outcomes and is a major contributor to asthma morbidity.[3-7] Although the mechanism by which cockroach allergen leads to morbidity is not well understood,[8] exposure has been shown to increase proliferative T-cell responses and to be highly potent, inducing an IgE response at considerably lower levels of exposure than dust mite and cat allergen.[9-11]

Allergen avoidance is one of the principles of asthma management. The National Asthma Education and Prevention Program Expert Panel recommends reducing cockroach exposure as a strategy to reduce asthma morbidity.[12] Integrated pest management (IPM) is the recommended approach for cockroach extermination.[13] The efficacy of IPM has been shown; however, IPM is costly and difficult to implement without special training,[14-16] making it unfeasible for low-income families.[17] A series of controlled studies demonstrated that cockroach elimination can be achieved by using insecticidal baits alone.[18-20] Baiting is a component of IPM in which baits are placed in out-of-the-way locations to lure cockroaches into consuming the insecticide. Use of baits alone is a promising alternative to multicomponent IPM approaches.

Whether reducing cockroaches improves health is unknown. Previous studies that assessed cockroach reduction evaluated interventions that reduced multiple allergens; therefore, improvements in asthma outcomes cannot be attributed to the reduction of cockroaches.[21-23] A systematic review of asthma intervention trials emphasized this point, citing the need to investigate the individual components of asthma intervention studies.[24]

To address this data gap, we conducted a single-intervention trial of insecticidal baits in the homes of children with asthma. The goals of the study were to determine whether baiting reduces cockroach infestation and whether reducing cockroaches results in reduced asthma morbidity, improved biomarkers of inflammation, and reduced health care utilization.

METHODS

Study population

Children residing in Greater New Orleans were recruited. Eligibility criteria included age 5 to 17 years, moderate to severe doctor-diagnosed

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Abbreviations used
ED: Emergency department
FENO: Fractional exhaled nitric oxide
GEE: General estimating equation
IPM: Integrated pest management

asthma, and being exposed to cockroaches. The child must have slept in the target home at least 4 nights per week, on average, in the preceding year. Children were ineligible if they had other serious medical or chronic illnesses including chronic respiratory infections, if the caregiver was not fluent in English, Spanish, or Vietnamese, or if the family had plans to move in the coming year.

Study design

The New Orleans Roach Elimination Study (NO-Roach) was a 2-group randomized controlled trial. Block randomization was used to keep the size and seasonality similar between treatment groups. The project received Institutional Review Board approval from Tulane University. Informed consent of the caregiver and assent of children 7 years and older was obtained before data collection.

Children were screened for moderate to severe asthma via telephone interview of the primary caregiver using a structured questionnaire. *Moderate to severe asthma* was defined as the child being hospitalized for asthma within the past 6 months or 2 unscheduled clinic or emergency department (ED) visits for asthma within the past year. To determine eligibility, families received a home visit to confirm household exposure to cockroaches. Field technicians placed 6 pheromone sticky traps (Victor Roach Pheromone Traps, Woodstream, Lititz, Pa) in the kitchen, living room, and child's bedroom (18 total) and conducted a visual inspection of the home for evidence of cockroach infestation (excrement, dead roaches, cockroach stains) to guide the placement of traps. The traps were retrieved 3 days later and transported to the laboratory for enumeration. Homes in which cockroaches were trapped were eligible for inclusion. The number of cockroaches counted was used as the baseline data. A venous blood sample was drawn by the study phlebotomist and analyzed by the National Institute for Environmental Health Sciences Clinical Research Unit Specimen Processing Laboratory for total IgE and a panel of allergen-specific IgE via Phadia Immunocap assay. *Cockroach sensitization* was defined as an allergen-specific IgE level of more than 0.35 Ku/L to either German cockroach (*Blattella germanica*) or American cockroach (*Periplaneta americana*). Children with moderate to severe asthma, who were exposed to cockroaches, were randomized to the treatment group.

Data collection and description of the intervention

Follow-up was 12 months and included home visits at baseline, 1, 3, 6, 9, and 12 months, and telephone interviews for outcome ascertainment (symptom days, health care utilization, and economic measures) at 2, 4, 6, 8, 10, and 12 months. At the baseline home visit, insecticide bait was placed in intervention homes according to package instructions by field staff using trapping data and evidence of infestation to guide placement. The bait used was either Maxforce FC Magnum (Bayer Environmental Science, Research Triangle Park, NC; fipronil 0.05%) or Advion (DuPont, Wilmington, Del; indoxcarb 0.6%). Bait was placed in areas with evidence of active cockroach infestation, typically in the back corners of kitchen cabinets, behind kitchen appliances, and inside bathroom vanities. During subsequent home visits, trapping was repeated. If cockroaches were trapped in intervention homes, bait was reapplied. For homes having less than 90% reduction in trapped cockroaches, alternate insecticide bait would have been used; however, there was no evidence of insecticide resistance to either product. No other intervention was given to either group. The impact of the insecticidal baiting was assessed by the number of cockroaches trapped.

The primary health outcome was the mean of the maximum number of symptom days over the previous 2 weeks defined as the largest value among the following: days with wheezing, tightness in the chest, or cough; days experienced disrupted sleep due to asthma; and days child had to slow down or discontinue physical activity because of asthma. Secondary health outcomes included health care utilization (hospitalizations, ED visits, asthma clinic visits), economic measures (number of school days missed because of asthma, number of workdays missed, and medication use), asthma control, pulmonary function, and fraction of exhaled nitric oxide (FENO). Symptom, health care utilization, and economic data were collected via a Computer-Assisted Telephone Interview system. Data were entered directly into the Computer-Assisted Telephone Interview system programmed to follow predetermined skip patterns and response fields. Pulmonary function (FEV_1) (EasyOn, ndd Medical Technologies, Inc, Andover, Me) was measured using standard techniques and reference values.[25] Spirometry was attempted on all children. If unsuccessful after 8 tries, no further attempts were made. Children with an FEV_1 value of less than 80% were considered to have airway obstruction. The NIOX MINO was used to measure FENO following standard procedures.[26] Results were categorized by the likelihood of eosinophilic inflammation based on cutoff points recommended by the American Thoracic Society; levels of 20 ppb or more were considered an indication of eosinophilic inflammation.[27] An asthma control test was administered at each home visit. Spirometry and FENO were measured at baseline and 12 months.

Statistical analysis

To characterize the study population, descriptive statistics, means, and SDs for continuous variables and frequencies (%) for categorical variables were assessed. Before conducting regression analysis, treatment and control groups were compared on baseline variables by *t* test, Wilcoxon rank test, or χ^2 test depending on the distribution of the variables. Variables not equally distributed at baseline ($P < .05$) were included in regression models.

Regression models were used to examine intervention effects. Outcome variables were considered as the mean of the change score from baseline to 12 months between groups or the score assessed at the 12-month visit. For binary outcome variables, a logistic regression model was applied. For continuous outcome variables, a semiparametric model was applied because of the lack of normality of the outcome. The semiparametric model relaxes the normality assumption and provides a robust estimate of the treatment effect.

Longitudinal analysis was performed for repeated measures. Generalized estimating equations (GEEs) were applied to model the marginal mean responses over follow-up. Unlike the linear mixed effects model, which explicitly models the between-subject and within-subject variations using random effects, the semiparametric GEE approach ignores between-subject variability by treating subjects as independent units and basing model estimation and inference on the marginal distribution of the response of such units. GEE provides robust estimates because it requires no distribution assumptions. The study had a high retention rate (96%), and missing data were kept to a minimum. At the 12-month visit, 6 participants were missing either spirometry or FENO because of the child's inability to perform a valid measure. Only subjects with complete data were included in the analyses.

Potential confounders identified in bivariate analysis were included as covariates in multivariable models. For all analyses, 2-sided tests were assumed and *P* values of less than .05 were considered significant. Data analyses were conducted with SAS statistical software version 9.4 (SAS Institute, Inc, Cary, NC).

RESULTS

Overall, 65% of participants were male, 62% were black, and the mean age was 9.3 years (Table I). Most caregivers had at least a high school education (77%) with a household income of less than $25,000 (92%). Sixty-four percent of participants had atopic asthma and 58% were sensitized to multiple allergens. Twenty-seven percent had allergen-specific IgE level of 0.35 KU/L or more to cockroach. Of these, virtually all were sensitized to at least 1 additional allergen (data not shown). The median number of cockroaches trapped was 35 (interquartile range, 6-48) and

TABLE I. Characteristics of the study population (n = 102)

Characteristic	N	Intervention (n = 53)	Control (n = 49)	*P* value
Demographic characteristics, n (%)				
Age (y), mean ± SD	102	9.46 ± 3.26	9.19 ± 3.87	.70
Sex: female	102	18 (33.96)	18 (36.73)	.77
Race	102			.09
Black		38 (71.70)	25 (51.02)	
Hispanic		11 (20.4)	20 (40.81)	
Other		4 (7.4)	4 (8.16)	
Annual household income ≤$25,000	74	35 (94.59)	33 (89.19)	.40
Medicaid	101	48 (90.57)	43 (89.58)	.87
Sensitized (sIgE ≥0.35 KU/L), n (%)				
Cockroach	89	13 (27.66)	11 (26.19)	.88
House dust mite	91	20 (40.82)	25 (59.52)	.08
Mouse	88	5 (10.87)	6 (14.29)	.63
At least 1 allergen	91	29 (59.18)	29 (69.05)	.33
≥2 allergens	91	27 (55.10)	26 (61.90)	.51
Type of dwelling, n (%)	78			.01
Multifamily		10 (25.64)	21 (53.85)	
Detached home		29 (74.36)	18 (46.15)	
Parental education level, n (%)	77			.31
Less than HS		7 (18.42)	11 (28.21)	
HS and higher		31 (81.58)	28 (71.79)	
Environmental data, n (%)				
Smoker in home	77	15 (39.47)	12 (30.77)	.43
Households with ≥30 cockroaches trapped	77	29 (74.35)	24 (63.16)	.27
Cockroaches trapped, median (IQR)	77	42 (30.0-71.0)	32.5 (2.0-37.0)	.01
Used pesticides in the past 12 mo	73	35 (92.11)	30 (85.71)	.38

HS, High school; *IQR*, interquartile range; sIgE, allergen-specific IgE.

TABLE II. Clinical characteristics

Characteristics	N	Intervention (n = 53)	Control (n = 49)	*P* value
Asthma-related symptoms, past 14 d, mean ± SD				
Maximum days with symptoms	101	4.32 ± 4.56	3.48 ± 4.00	.33
Child woke up	101	2.37 ± 2.96	1.67 ± 2.45	.21
Child slowed down	101	2.33 ± 3.43	1.65 ± 3.06	.30
Missed school days, n (%)	97	9 ± 18.00	11 ± 23.40	.51
Wheeze, n (%)	101	42 ± 80.77	37 ± 75.51	.52
Health care utilization, past 12 mo				
Asthma hospitalization, n (%)	101	6 (11.54)	9 (18.37)	.29
ED or unscheduled clinic visits, mean ± SD	95	1.92 ± 1.35	1.55 ± 1.27	.18
Uncontrolled asthma, ACT score ≤19, n (%)	83	32 (71.11)	27 (71.05)	.96
Symptom medication use, past 14 d, n (%)	102	35 (66.04)	33 (67.35)	.89
FENO ≥20 ppb, n (%)*	79	21 (48.84)	16 (44.44)	.70
FEV_1 % predicted <80%, n (%)	100	22 (43.14)	24 (48.98)	.56

ACT, Asthma Control Test.
*Average of 3 measurements.

68% of households had cockroach infestation (≥30). Children had a high degree of morbidity; 71% had uncontrolled asthma and 78% wheezed in the past 2 weeks. At baseline, children had, on average, 3.9 days with symptoms in the previous 2 weeks and 1.7 unscheduled health care visits due to asthma in the previous year. Forty-six percent had FEV_1% predicted less than 80% and 47% had signs of eosinophilic inflammation (Table II). For most variables, randomization resulted in comparable groups.

Longitudinal results of median cockroach counts by group are presented in Fig 1. Results of GEE found that at each time point, controlling for the number of cockroaches at baseline, sex, age, and race, median cockroach levels in control homes were significantly higher than in intervention homes (data not shown). By 3 months, median cockroach count was 0 in intervention homes. At 12 months, no intervention home had cockroach infestation compared with 22% of control homes. Comparing the mean change in cockroach counts from baseline to 12 months and controlling for baseline levels of cockroach and dwelling type, control group homes had a significantly higher number of cockroaches ($P < .01$) (Table III). Finally, control homes were much more likely to have cockroaches trapped at any time point (adjusted odds ratio, 21.76; 95% CI, 5.40-87.75; $P < .01$). Bait was reapplied as follows: month 1, 21 homes; month 3, 9 homes; month 6, 10 homes; month 9, 3 homes; month 12, 5 homes. All but 1 of the homes where bait was reapplied had an infestation (≥30 cockroaches trapped) at baseline.

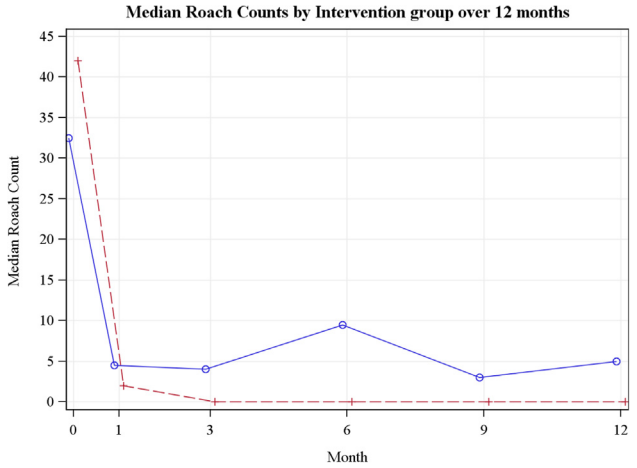

FIG 1. Median roach counts by intervention group over 12 months. *Blue,* Control; *red,* intervention.

TABLE III. Effect of insecticidal baiting on cockroach counts and asthma morbidity

Variable	Estimate (control vs intervention)		
	β coefficient	95% CI	*P* value
Cockroaches trapped*,†	13.14	6.88 to 19.39	<.01
Mean maximum symptom days*,‡	1.82	0.14 to 3.50	.03
Number of ED/unscheduled clinic visits‡	1.17	0.11 to 2.24	.03
Number of missed school days‡	0.24	−.09 to 0.56	.15
Number of nights caregiver lost sleep‡	−0.01	−0.73 to 0.72	.99

	Odds ratio	95% CI	*P* value
Households trapped ≥30†,§	21.90	1.04 to 462.81	.05
Households trapped ≥1†	25.23	6.27 to 101.50	<.01
Hospitalized‡,§	1.89	0.41 to 8.80	.42
Uncontrolled asthma (ACT score <19)‡	2.50	0.88 to 7.06	.08
FEV_1 <80% predicted‡	5.74	1.60 to 20.57	.01
FENO ≥20 ppb‡	1.38	0.44 to 4.35	.59

ACT, Asthma Control Test.
*Mean change from baseline to month 12.
†Adjusted for dwelling type and baseline roach count.
‡Adjusted for sex, race, age, and baseline value.
§Firth correction used.

Children in intervention homes had significantly fewer days with asthma symptoms (Table III). In adjusted linear regression models, children in control homes were found to have 1.82 (95% CI, 0.14-3.50; $P = .03$) additional symptom days in the previous 2 weeks. In the GEE analysis, over the 12 month follow-up, at each time point, control group children had 0.46 more days with asthma symptoms. Overall, there was no time by treatment interaction (data not shown).

Children in the control group had a greater number of unscheduled clinic or ED visits ($\beta = 1.17$; 95% CI, 0.11-2.24; $P = .03$) in adjusted models. The proportion of children hospitalized was higher in the control group; however, the difference did not reach statistical significance (adjusted odds ratio, 1.89; 95% CI, 0.41-8.80). Airway obstruction was more common in the control group (adjusted odds ratio, 5.74; 95% CI, 1.60-20.6). There were no significant differences in FENO, asthma control, the number of school days missed or days caregivers lost sleep because of their child's asthma. The intervention's effect was more pronounced in children sensitized to cockroach (Table IV). In sensitized children, mean maximum symptom days, number of missed school days, and unscheduled asthma clinic or ED visits were significantly higher in the control group. A strong, but nonsignificant effect of % FEV_1 of less than 80% was also confined to the sensitized group. Positive treatment effects were found in nonsensitized children; however, none reached statistical significance.

DISCUSSION

IPM is a successful approach to cockroach abatement,[28,29] but it is not clear which component(s) are responsible for the effects. This study found that the strategic placement of insecticidal bait appeared to eliminate cockroaches, even from homes with high-intensity infestation. Cockroach elimination was achieved rapidly, and was sustained over the course of a year. The insecticidal baits used are readily available, inexpensive, and easily applied. Study staff had no experience in insecticidal baiting; therefore, it is our belief that with minimal instruction, targeted placement can be performed by homeowners, although this should be tested. Insecticidal bait is a viable alternative to multifaceted IPM for cockroach control.

Asthma outcome disparities are well documented.[30] Disparities are driven by many factors, with disproportionately high exposure to cockroach being one cause.[4,5,31] Cockroach exposure is inversely related to socioeconomic status.[32] Up to 85% of homes of children with asthma in the inner city have detectible levels of cockroach allergen in the dust and roughly half have very high levels (>8 U/g).[4,33] In contrast, cockroach allergen was detected in only 44% of homes in a general population survey, with 9.5% having levels of more than 8 U/g.[34] Children exposed to cockroaches have severe asthma and high rates of hospitalizations and ED visits[3-5,35] and early exposure is associated with allergic sensitization and wheeze.[6,7,36,37] Therefore, cockroach exposure is an important contributor to asthma disparities that, despite an overall trend for stabilization in prevalence, continues to rise among the poor.[38] Identifying interventions that result in clinical benefits and that are affordable and feasible for low-income families are urgently needed.

Many intervention studies report environmental results but do not include health outcomes.[19,20] Failure to include health outcomes in allergen avoidance studies on house dust mite resulted in clinical recommendations for house dust mite avoidance despite evidence that there is no improvement in health.[39-42] To our knowledge, this is the first study to assess whether insecticidal bait alone works to reduce cockroach exposure in homes with any subsequent benefit in asthma outcomes.

Children residing in homes receiving insecticide bait had significantly reduced asthma morbidity. Improvement was seen in symptoms, health care utilization, and lung function despite a relatively small sample size. Asthma symptom days decreased 1.8 days per 2-week period corresponding to 47 fewer days with symptoms over the course of a year. The number of unscheduled clinic and ED visits was 17% lower in the intervention group, and the percentage of children with suboptimal lung function was 32.8 compared with 26.7 in the homes where cockroaches were eliminated. The effects on all children were driven by the effects in children sensitized to cockroaches. Assessing for cockroach

TABLE IV. Effect of insecticidal baiting on asthma outcomes by cockroach sensitization status*

Variable	Nonsensitized, sIGE <0.35 (N = 65)				Sensitized, sIGE ≥0.35 (N = 24)			
	N	β coefficient†	95% CI	P value	N	β coefficient †	95% CI	P value
Mean maximum symptom days‡	62	1.46	−0.46 to 3.47	.16	20	4.13	0.25 to 8.01	.04
No. of ED/unscheduled clinic visits	61	0.77	−0.33 to 1.87	.17	23	2.67	0.35 to 4.99	.02
No. of missed school days	52	0.05	−0.33 to 0.43	.79	17	0.35	0.28 to 1.64	.01
No. of nights caregiver lost sleep	62	0.31	−0.23 to 0.85	.26	20	−0.76	−2.84 to 1.31	.47
	N	Odds ratio†	95% CI	P value	N	Odds ratio†	95% CI	P value
Hospitalized§	64	1.9	0.26 to 13.85	.52	24	1.24	0.09 to 16.74	.87
Uncontrolled asthma (ACT score <19)§	53	2.62	0.79 to 8.77	.12	17	2.65	0.29 to 24.14	.39
FEV_1 <80% predicted§	61	2.48	0.53 to 11.67	.25	22	13.09	0.79 to 217.47	.07
F_{ENO} ≥20 ppb	49	1.43	0.32 to 6.35	.64	20	1.57	0.23 to 10.87	.65

ACT, Asthma Control Test.
*All models adjusted for sex, race, age, and baseline value.
†Control vs intervention.
‡Mean change from baseline to month 12.
§Firth correction used.

allergy in clinics will help identify the children most likely to benefit from cockroach baiting. Although the effect was more pronounced in children with cockroach allergy, benefit was present in those in whom allergy was not detected, consistent with previous observations of the importance of cockroach exposure independent of sensitization status.[5,7] In nonsensitized children, the mechanism is thought to be through irritant effects or other non–IgE-mediated mechanisms. The differential effects based on sensitization warrant further investigation in studies with larger sample sizes. The unique contribution of cockroach to severe asthma outcomes may be due to increased potency. Studies have found that an allergic response occurs at exposure levels 10 to 100 times lower than responses to other aeroallergens.[11] Notably, we saw reductions in cockroach in control homes. We suspect that cockroach levels declined in the control group because of study effects. We believe this took several forms. First, there is a natural tendency to clean before home visits. Also, despite being equal at baseline, reported spraying for cockroaches in the previous 2 weeks was significantly higher in the control group at each time point (eg, at 10 months, 85% of control vs 6% of intervention homes). Therefore, we conclude that the reduction in cockroaches in control homes as due to study effects and increased pesticide use by control families. Interestingly, intermittent insecticidal baiting still resulted in greater pest control compared with routine spraying with the added benefit of lower exposure to pesticides. Baiting is low cost, easily applied, and has low toxicity. In conventional use of insecticides (eg, spraying and fogging), large amounts of insecticide are used to ensure the cockroaches will encounter the insecticide. By baiting, a small fraction of insecticide is used, drawing the cockroach to the insecticide with the bait. The bait is applied in areas in which cockroaches are common (under the sink, behind the refrigerator). Direct contact with humans is less probable in these locations.

This study adds important insight into the role that allergen avoidance plays in managing asthma. Current recommendations call for multifaceted interventions that reduce numerous asthma triggers (house dust mites, cockroaches, rodents, mold, and moisture).[23,24,43] To our knowledge, this is the first study to empirically test the impact of reducing cockroach exposure on asthma outcomes using a single-component intervention. We found health improvement despite children's sensitivity to multiple allergens. If these findings are replicated, perhaps it is time to reconsider the need for multifaceted interventions for prevention of asthma exacerbation in homes with cockroaches.

This study had numerous strengths including the randomized design, control for seasonality, repeated and objective measurements of cockroach and asthma outcomes, low loss to follow-up, limited missing data, and the use of patient-centered outcomes. We used patient-centered outcomes because disseminating research findings into clinical practice has proven difficult, in part because outcomes that are important to researchers are often unimportant to patients. For example, we included cockroach counts rather than cockroach antigen because eliminating cockroaches in the home is important to participants. In theoretical models of health behavior change, self-efficacy is a construct often overlooked in allergen avoidance strategies. It is reasonable to expect behavior change in response to something a resident cares about (eg, cockroaches), but it is another to expect them to change something they cannot see (submicroscopic allergens). The primary limitations were sample size, which prevented the thorough assessment of effect modification by sensitization status, and lack of blinding of the field staff to group assignment. Considerable effort went into standardizing outcome assessment to limit bias. First, to limit interviewer bias, we had highly experienced field staff trained in asthma survey data collection. Second, all outcome data were collected using Computer-Assisted Telephone Interview, forcing the interviewer to follow a predetermined script. To reduce social-desirability bias, participants were told that the purpose of the study was to reduce cockroaches (an objectively measured variable), but were not told that the purpose was to relate this to asthma improvement. However, future studies should include blinded treatment and unblinded assessment personnel. Although we did not encounter insecticide resistance, local resistance patterns will be important in attempts to replicate the findings in other cities.

Conclusions

Cockroaches in the homes of children with asthma with substantial asthma morbidity were eliminated and led to fewer asthma symptom days, improved lung function, and less health care use. Insecticidal bait is inexpensive, has low mammalian toxicity, is easily implemented, and is an alternative to comprehensive IPM and to multifaceted interventions to reduce asthma triggers. Additional research is needed to replicate these findings

and to determine ways in which this strategy for cockroach abatement may achieve widespread use.

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Key message

- **In homes of children sensitized and exposed to cockroaches, a single intervention—the strategic placement of insecticidal bait—results in eradication of cockroaches and improved asthma outcomes for children.**

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